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For consistency and clarity, a space (when absent) has been placed between the number and the unit of weight lb. and lbs. giving for example '21 lbs.' in place of '21lbs.'

Fractions, usually in the form '14 3-4' in the original text, have been converted to the form '14$^3/_4$' in this etext.

Also, in a few larger tables with italic styling on some text, this italic styling has been removed, for consistency with the .txt version. In a few cases a word has been abbreviated to conserve table space: cal. = caliber; diam. = diameter.

Some instances of *Tome* in French citations have been changed to Tome (no italic), for consistency.

Some accents and spelling in French citations have been corrected.

For consistency, instances of 'fireworks' and 'fire works' have been changed to the predominant form 'fire-works'.

Obvious typographical errors and punctuation errors have been corrected after careful comparison with other occurrences within the text and consultation of external sources.

More detail can be found at the end of the book.

A

SYSTEM OF PYROTECHNY,

COMPREHENDING THE THEORY AND PRACTICE, WITH THE APPLICATION OF CHEMISTRY;

DESIGNED FOR EXHIBITION AND FOR WAR.

***IN FOUR PARTS*:**

CONTAINING AN ACCOUNT OF THE SUBSTANCES USED IN FIRE-WORKS; THE INSTRUMENTS, UTENSILS, AND MANIPULATIONS; FIRE-WORKS FOR EXHIBITION; AND MILITARY PYROTECHNY.

ADAPTED TO THE

MILITARY AND NAVAL OFFICER, THE MAN OF SCIENCE AND ARTIFICER.

BY JAMES CUTBUSH, A.S.U.S.A.

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PHILADELPHIA:

PUBLISHED BY CLARA F. CUTBUSH.

1825.

To the Corps of Cadets, of the United States' Military Academy, West Point;

Gentlemen,

To you, a scientific and distinguished Corps, this work on Pyrotechny is respectfully dedicated. Your liberal subscription first encouraged me to undertake its publication; for which, accept my grateful thanks.

CLARA F. CUTBUSH.

ADVERTISEMENT.

In submitting the present work to the public, it may be proper to state some of the difficulties, under which it has been published, and to bespeak an indulgent allowance for any imperfections, which may be observed in the style or arrangement. As a posthumous work, it has been deprived of those final improvements and emendations, which are generally made by Authors, while their works are in progress of publication. While, however, the work has laboured under these disadvantages, the publisher has felt it her duty to make every arrangement, to supply, as far as possible, the want of the author's personal superintendence of the publication. This course was due to the scientific reputation of her late husband, as well as to the numerous and generous patrons of the work.

Philadelphia, April, 1825.

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INTRODUCTION. [xv]

In presenting this work to the public as a system of Pyrotechny, which, we have reason to believe, is the only full and connected system that has appeared, we may be permitted to remark, that, in our arrangement of the subject, we have appropriated separate heads for each article.

This plan, of the subject being considered in chapters and sections, and forming with the divisions of the work, a connected system of arrangement, enables the reader to have a full view of the whole, and, at the same time, all the facts in detail belonging to the chapter, or section under consideration. By referring to the Table of Contents, this plan will be seen without further comment. The arrangement of the different articles in this manner, necessarily comprehends in the onset all the substances, which are employed in various preparations. In considering this part of our subject, we have given the chemical characters, or peculiar properties of each substance respectively; by which a rationale of pyrotechnical effects may be the better understood, and, consequently, the action of bodies on each other better illustrated.

In this part we also comprehend the General Theory of Fire-works, which it may be proper to remark, we have drawn from the known effects of chemical action; so far, at least, as the laws, of affinity, which govern such action, are applicable to the subject. The importance of this inquiry, although having no relation to the mere manipulations of the artificer, can not be doubted; since a knowledge of chemistry has already improved the preparation of gunpowder, and its effects are now known to be owing to the formation of sundry elastic aeriform fluids. On this head, that of the application of chemistry to Pyrotechny, we claim so much originality, as, so far as we know, to have been the first, who applied the principles of chemistry.

It is not to be expected in every instance, that a rationale of the decomposition as it occurs, or the order in which it takes place, [xvi] can be given with certainty; because, where a variety of substances enter into the same preparation, which is frequently the case, the affinities become complicated, and the laws of action for that reason indeterminate, and frequently anomalous. But, on the contrary, in a variety of primary operating causes, by which effects analogous in their nature result, decomposition of course being the same, the causes are well understood, and the effects are thereby known, and duly appreciated.

This, for instance, is the case with a mixture of nitrate of potassa, charcoal, and sulphur, in the proportion necessary to form gunpowder; for, it is known, that the explosive effects of powder are owing to the sudden production of a number of gases, which suffer dilatation by the immense quantity of caloric liberated at the moment of combustion. Although the production of caloric by the inflammation of gunpowder is a case, which cannot be explained by the present received theory of combustion, as we have noticed in that article; yet we know that it is a fact, and that caloric is generated by the decomposition of the powder.

If we consider the primary cause of this decomposition, we naturally inquire into the products of the combustion, and endeavour to account for the production of the elastic aeriform fluids. We know that carbon has the property of decomposing nitric acid, and also nitrate of potassa; for, when it is brought in contact in the state of ignition with nitre, a deflagration will ensue, and carbonic acid be formed. The quantity of this acid is in the direct *ratio* to the quantity of oxygen required to *saturate* a given quantity of carbon; and therefore, by employing certain proportions of nitre and charcoal, the latter will decompose the former, and by abstracting its oxygen, on the same principle form carbonic acid, while the azote, the other constituent of nitric acid, will be set at liberty. Nor is this all, if we consider the action of sulphur. The sulphur must unite with one portion of the oxygen to produce sulphurous acid gas, and also with the potassa of the nitre, and form a sulphuret, a compound necessary to be formed, before we can explain the production of sulphuretted hydrogen gas, which results from the decomposition of water contained in the nitre. There also results, as a product, sulphate of potassa. In considering these products at large, it would be necessary to go into detail; and, as we have descanted largely on its combustion in gunpowder, we accordingly refer the reader to the article on [xvii] *Gunpowder*. It will be sufficient, however, to remark, that the *agent*, and consequently the cause, which produces the decomposition of nitrate of potassa, is carbon or charcoal. This, by uniting with the greater part of the oxygen of the nitre, produces, in a determinate proportion, carbonic acid gas. This gas, therefore, in conjunction with other gases, formed at the same time, all of which being expanded, causes what is denominated the *explosive effect* of gunpowder.

We have then a primary cause of the decomposition, and most of the effective force of gunpowder is owing to the carbonic acid; and it is found, that gunpowder made without sulphur is equally powerful as that with, since it adds nothing to its power.

Causes, therefore, chemically speaking, operate alike under similar circumstances. The materials made use of being equally pure, and used in the same proportion, the effect must necessarily be the same.

It is not only in the instance we have mentioned, but in every other, in which chemical action ensues, that this doctrine is tenable. We might, indeed, notice a number of cases of a similar kind; as, for instance, in the combustion of many incendiary preparations, as fire-stone, fire-rain, composition for carcasses, light-balls, and a variety of fire-works of the same kind. If we mix pitch, tar, tallow, &c. with nitrate of potassa, and burn the mixture, we have the combined action of two elementary substances, which enter into the composition of these bodies, namely, carbon and hydrogen. The products would be carbonic acid gas, and water; because the oxygen of the nitre would unite with the hydrogen, as well as the carbon. If we employ sulphur at the same time, another product would be sulphurous acid gas, and probably sulphuric acid; and if gunpowder be used, as in the *fire-stone* composition, then, besides these products, we would have those of the gunpowder.

As this subject, however interesting to the theoretical pyrotechnist, cannot be understood without a knowledge of chemistry, it is obvious, that that science is a powerful aid to pyrotechny. It is unnecessary to dwell on this head. We may add, nevertheless that, in order to understand the effect of all mixtures, or compositions made use of, it is necessary to consider the nature of the [xviii] substances employed, and the manner in which chemical action takes place, and consequently the products, which determine in fact the characteristic property of each species of fire-work, and the phenomena on which it is predicated. All products of combustion depend on the substances thus decomposed, and by knowing the effects, we may readily refer them to their proper causes.

With respect to *caloric*, it may not be improper to offer some remarks.[1] The hypothetical element of phlogiston having given way to the antiphlogistic theory at present received, our ideas respecting caloric are predicated on facts. Caloric is a term, which expresses heat, or matter of heat. In pyrotechny, we have merely to consider it in a free, or uncombined state; but as the subject is interesting, we purpose to notice it very briefly under the following heads: viz. its nature; the manner it is set in motion; its tendency to a state of rest; the changes it produces on bodies; and the instruments for measuring its intensity.

As to the nature of caloric, different opinions are entertained. We know the effect of heat: if we touch a substance of a higher temperature than our bodies, we call it hot, and *vice versa*. The one is evidently the accession, and the other the abstraction, of caloric. The latter is merely relative as respects ourselves; for the effect depends on our feelings, and the sensation of hot or cold is therefore governed by them.[2] Caloric, however, is considered to be a substance, composed of inconceivably small particles; but [xix] count Rumford and sir H. Davy are of a contrary opinion, namely, that it depends upon a peculiar motion and not on a subtle fluid.

As the effect of caloric, according to their view, depends on motion, the agencies by which this is effected are of the first importance. That it exists in all bodies in a state of rest, and in a greater or smaller quantity, and consequently in a relative proportion, is well known, and on this, the capacities of bodies for caloric is founded. The capacities of bodies for heat are changed by various means, and caloric is put in motion; and, according to its quantity, the bodies may be either cold or hot. When the surrounding bodies become heated, they receive this caloric thus set free, and, in this view, the absolute quantity of their heat is increased. This state of rest, to which caloric is subject, may be destroyed either by an increase or a diminution of the capacity of a body. If caloric be put in motion by causes of any kind, which influence the capacities of different bodies, a theory maintained by Davy, then as the capacity for heat is changed so is free heat produced. Diminish the capacity of a body, its excess will of course be given out, and distribute itself among the surrounding bodies, which become heated; but increase the capacity, and a different effect ensues. The body absorbs caloric, by which its capacity is increased, and cold is produced. Caloric, whether considered a substance, or an attribute, possesses, nevertheless, this property, that when it is given out, as in the mixture of sulphuric acid and water, which occupies a less space than both in a separate state, the sensation of heat follows; and when it is absorbed, as in the various freezing mixtures, or in a mixture of snow and common salt, the sensation of cold is excited. The causes, however, which [xx] set caloric in motion, or that produce heat, are such as combustion, condensation, friction, chemical mixture, and the like. It is remarkable, that these effects are invariably the same, and are affected by corresponding affinities. When a piece of iron is struck with a hammer, the percussion produces a condensation of the iron, its specific gravity is increased, and the iron finally becomes ignited. The condensation of air, in the condensing syringe, will set fire to tinder. The flint and steel produce a condensation; for the metal, although small, is sent off in scintillations in the state of ignition. That caloric is contained in bodies in the state of absolute rest, and is evolved by condensation, there is no doubt. Gunpowder, by percussion, in contact with pulverized glass, is inflamed; and it appears very probable, that it also contains caloric in a state of rest. The experiments of Lavoisier and Laplace, on the quantity of caloric actually absorbed in nitric acid, and in a latent state, (noticed in the article on *gunpowder*), are satisfactory. If caloric is not in that state in nitre, how are we to explain the sudden transmission or evolution of caloric in fired gunpowder, where no external agent in any manner can influence the formation, or disengagement of caloric? Friction or attrition produces heat; and the distributable excess of caloric, as it is called, although not satisfactorily accounted for, may arise from a condensation; which, however, is denied.

The Esquimaux Indians kindle a fire, very expeditiously, in the following manner: They prepare two pieces of dry wood, and making a small hole in each, fit into them a little cylindrical piece of wood, round which a thong is put. Then, by pulling the ends of this thong, they whirl the cylindrical piece about with such velocity, that the motion sets the wood on fire, when lighting a little dry moss, which serves for tinder, they make as large a fire as they please; but as the little timber they have is drift wood, this fails them in the winter, and they are then obliged to make use of their lamps for the supply of their family occasions. *Ellis's Voyage for the Discovery of a North-West Passage*.

Friction is, therefore, one means of producing distributable heat, which is also exemplified very frequently in the axis of a carriage wheel; of mill work; in the rubbing of wood, when turned on its axis in a lathe, by which turners ornament their work with black rings; rubbing a cord very swiftly backwards and forwards against a post or tree, or letting it run over a boat, &c. as in the [xxi] whale fishery; the motion of two iron plates against each other, pressing them at the same time, &c. The great object in the construction of machines is to avoid, or lessen the degree of friction. See Hatchette, Vince, and Gregory. Count Rumford (Nicholson's Journal, 4th edit. ii, 106), and professor Pictet (*Essai sur le Feu*, chap. ix.) have made some valuable experiments on heat evolved by friction.

The sun is one great source of caloric. In whatever mode it produces it, whether by giving it out from its own substance, by the action of light on the air that surrounds the globe; by the concentration of calorific rays by means of the atmosphere, acting as a lens; or by putting caloric in the distributable state, always pre-existing in some other, as in a state of rest, are questions, which, in our present state of knowledge, we are unable to solve. We know the fact, and that the caloric is of the same nature as that obtained by combustion.[3]

Combustion is a process by which caloric is put in a distributable state. The opinion of Stahl and others, that all combustible [xxii] bodies contained a certain principle called phlogiston, to which they owed their combustibility, and that combustion was nothing [xxiii] more than a separation of this principle, gave rise to the phlogistic or Stahlian theory, which was afterwards modified by Dr. [xxiv] Priestley. But his theory is equally untenable. Kirwan's opinion was no less vague, although he substituted hydrogen for phlogiston.

The Lavoiserian, or antiphlogistic theory overturned the Stahlian. According to this theory, a combustible in burning unites with oxygen, and heat and light are given out by the gas, and not from the combustible. According to a modified theory of the above, by Dr. Thomson, caloric is evolved by the gas, and light from the burning body. Without noticing the instances, in which this theory, as a general one, is insufficient to explain the cause of combustion, or of the production of heat and light, we will merely remark, that bodies which support combustion are called supporters, as oxygen gas, chlorine gas, &c. and those, that undergo this change, are named combustible bodies.

The products of combustion may be fixed or gaseous, and either alkalies, oxides, or acids; or, when chlorine is the supporter, chlorides, &c. A few examples will be sufficient. By the combustion of metals, iron for instance, we obtain a fixed product, and in [xxv] the present case an oxide of iron; by the combustion of antimony and arsenic, the antimonic and arsenic acids; by the combustion of charcoal, we have carbonic acid gas, a gaseous product; by the combustion of potassium or sodium, we obtain a fixed alkali, depending however on the quantity of oxygen; by the combustion of sulphur, phosphorus, &c. acids; and when metals are burnt in chlorine gas, chlorides are produced.

It is evident from facts, that, whatever theory may be assumed, combustion occasions the production of *free* caloric, or changes the *condition* of caloric, from quiescent to distributable heat. The conclusions drawn by Mr. Davy and others, appear to have been predicated on the absorption of the base, and development of caloric, as in oxygen gas, and the peculiar alteration in bodies implying a decrease in their capacity; and hence, as regards the products of combustion, they must necessarily possess a less capacity for heat than the mean capacity of their constituents.

Whether we regard heat as latent, in the acceptation of the term, as applied or used by Dr. Black, or quiescent, or in a state of rest, it is certainly evident, that combustion is a chemical change, and by it caloric passes from a combined to an uncombined state, and is thus made sensible, free, or thermometrical heat. Combustion may, as it certainly does, put quiescent heat in a distributable state; but this quiescent heat is the same in the present case, of which there can be no doubt, as latent caloric. The thermometer will only indicate as much caloric in the air as is in a distributable, or free state; but, if the same air be employed to supply, or support combustion, the heat, rendered appreciable by the senses and the thermometer, will be in the ratio of the decomposition of the oxygen gas of the atmosphere, and, of course, to the development of free caloric.

Chemical combination, such as occurs by the mixture of fluids, as alcohol and water, sulphuric acid and water, some of the gases, as muriatic acid gas with water, &c. evolves heat, and sometimes sufficient to boil water. In cases of spontaneous combustion, it would seem, that quiescent heat passes to the state of distributable heat; for if nitric acid, for instance, contains so large a quantity of quiescent heat, or fixed heat, as the experiments of Mr. Lavoisier make it appear, we may readily explain why [xxvi] spontaneous combustion ensues, when that acid is brought in contact with spirits of turpentine; because the chemical action of the acid on the carbon and hydrogen of the turpentine, which takes place, produces at the same time a corresponding change in the caloric itself, from a quiescent to a distributable state. If the same data be admissible with regard to the combination of the nitric acid with potassa, which we may judge to be the case by the experiments of Lavoisier and Laplace, (quoted in our article on *Gunpowder*), then, indeed, its mechanical union with charcoal, and sulphur, although in a common temperature no combustion ensues, will, at the temperature required to inflame the mixture, (about 700 degrees according to some), produce a decomposition altogether chemical; and while new products are formed, the caloric, necessary also for their generation, passes from a quiescent to a distributable state; and a portion of it goes into a new state of combination, also quiescent. We mean that portion which is necessary for the constitution of gaseous fluids. This fact is remarkable. By referring to the original state or condition of the caloric, if we admit that state in the present instance, (which appears the only mode of accounting for the emanation of free caloric by the combustion of gunpowder), it is easily perceived, that chemical changes, besides the usual supporters of combustion being concerned, as in ordinary cases of combustion, must produce a similar change in the state of combined or quiescent heat.

Predicating this opinion on the results of the experiments of MM. Lavoisier and Laplace, and seeing that gunpowder inflames *per se*, or without the aid of a gaseous supporter, we have no hesitation in risking it, in the present state of our knowledge concerning heat as our present belief and conviction. Although there is no satisfactory theory offered to explain all the instances of spontaneous combustion, yet it seems reasonable to conclude, that in many cases at least, that effect may take place by some chemical action, which, like the instances already quoted, may change quiescent into distributable heat. We have stated (See *Gunpowder*) some instances of spontaneous combustion, which have taken place merely in consequence of the charcoal. Some have attributed the effect to pyrophorus, and others to the presence of hydrogen in the coal, which, by absorbing and combining [xxvii] with oxygen and forming water, sets the caloric of the oxygen gas at liberty, and thus produces combustion. However this may be, there are other instances, that of cotton and oil, some kinds of wood, wood-ashes and oils, &c. which have produced spontaneous combustion.

We will only add, however, that until we can give a better theory, the effect in these instances may be attributed to chemical action, and *with it*, the change of caloric in the manner already mentioned. Chemical action in such cases appears necessary, although mechanical means, as percussion will produce heat.

Quiescent heat is also put in motion by electricity; but in what manner it acts, so as to produce that effect, is unknown. It is a powerful agent in nature, and calculated for important ends, of which we are ignorant. It is unnecessary to notice opinions concerning it. All electrics will yield it, such as glass, rosin, &c. and it may be collected in the usual manner by the prime conductor and Leyden jar. Galvanism, called also Galvanic electricity, produced by an arrangement of zinc, and copper plates in a pile, or trough, and placed in contact with some oxygenizing fluid, has the same effect of causing quiescent heat to become distributable, and is undoubtedly the result of chemical action. The peculiar character of this fluid, the nature of the two opposite poles, &c. have been, and continue to be, a subject of interest to the philosopher. The *deflagrator* of professor Hare of Philadelphia is an apparatus well calculated for many interesting experiments on galvanism. To that gentleman, we are also indebted for the compound blowpipe, which produces a very intense heat by the combustion of hydrogen in contact with oxygen gas. Notwithstanding professor Clark of England has laid claim to the apparatus, and the use of hydrogen gas in this way, the merit of the discovery is due to our learned and ingenious countryman.

Since heat is put in motion as a consequence of the increased capacity of a body, and, by combining with a substance whose capacity has been increased, becomes by degrees quiescent, according to the respective capacities of bodies; cold is an effect,

which is occasioned by this change from a free to a combined or quiescent state. The absorption of heat, necessary for the generation of cold, if so we may consider it, takes place in every instance, where that effect is observed. The heat of surrounding [xxviii]
bodies, in a distributable state, is now no longer characterised as such; and the consequence is, therefore, that that particular sensation, or effect follows.

Cold may be produced by saline mixtures, the salts for which having their full quantum of the water of crystallization; and by the evaporation of fluids, as water, alcohol and ether. In the one case, that of the freezing mixtures, we have seen, that the effect is produced by the *absorption* of heat; and with regard to the cold produced by fluids, even in *vacuo*, (where the effect is more instantaneous), the cause is attributable to evaporation; for the fluid changes from a liquid to an aeriform state, and during this transition robs the body, with which it was in contact, of a part of its caloric, and thereby reduces its temperature. Artificial ice is made on this principle.

The next subject with regard to heat, is the different modes in which it tends to a state of rest. There are some facts in relation to this subject worthy of notice; and particularly, that, in the tendency of caloric to become quiescent, after having been put in motion, bodies often increase in temperature. This tendency to a state of rest is effected either by the conducting power of bodies, or radiation. Heat radiates in all directions, and in quantities, according to the experiments of Leslie, more or less variable, which depend on the nature of the radiating surface. Hence that power, which bodies possess, called the radiating power, varies in different substances. Thus, the radiating power of lampblack is 100, while gold, silver, copper, and tin plate are 12, from which it appears that the metals distribute less heat by radiation. That caloric obeys the same laws as light, is obvious from Pictet's experiments with concave mirrors, where the calorific rays move in the same order, the angle of incidence being equal to the angle of reflection. It is also refracted; hence the concentration of the solar rays in a focus by the burning glass. Various experiments have been made with mirrors, and concave reflectors. The effect of the former in destroying the fleet before Syracuse, an experiment made by Archimedes, is a fact well authenticated in history. Concave reflectors have inflamed gunpowder. This subject, however, is noticed at large, when speaking of mirrors as an incendiary in war. [xxix]

That bodies conduct heat, and with different degrees of power, so that some are called good and others bad conductors, is well known. This property depends on the quantity of caloric, which a body receives, before it changes its state. Metals are considered good conductors, and glass, charcoal, feathers, &c. bad conductors. Hence bad conductors, as wool, &c. preserve the temperature of the body, or keep it *warm* in winter; and snow, for the same reason, prevents the action of intense cold on the ground. Liquids also conduct heat. Whether we consider caloric in this case carried, or transported, as it is more properly defined, the fact may be shown by several experiments. Ebullition, or boiling, is a phenomenon, which depends on the increment of temperature; for as water, for instance, receives caloric, until the thermometer indicates 212 degrees, the boiling point, mere evaporation ensues; but that temperature, under the usual pressure of the atmosphere, causes the formation of bubbles at the bottom of the vessel, as that part receives the degree of heat necessary for ebullition before any other; and these bubbles, as they form, rise in succession, and pass off in the state of steam, while the circumjacent fluid takes its place, and the process continues till all is boiled away. Water, when it passes off in the state of steam, which requires a degree of heat equal to 212 degrees of Fahrenheit, receives also 1000 degrees of non-distributable caloric, or latent heat; and however singular the fact may appear, the wise Author of Nature, it seems, has reserved a *store of caloric*, in this form, ready to be put in requisition, when necessity demands it, in a distributable shape.

Caloric, when in a state of rest, exists in different proportions, and although the actual temperature may be the same, yet the quantity of caloric in a quiescent state may be variable. There are several experiments, which are adduced to illustrate this fact. It results from experiment, that bodies receive heat according to their several capacities for it; hence, when any number of bodies are differently heated, the caloric, which becomes latent, does not distribute itself in equal quantities, but in various proportions, according, as we remarked, to their several capacities. Caloric, therefore, in a state of rest, is in relative quantities; and as the [xxx]
capacity of bodies for heat is variable, and relative as to each other, the term *specific caloric* has been applied. From these conclusions, we may readily perceive what is implied by an equality of temperature. That it merely depends on the state of rest, which caloric necessarily comes to, and which is relative as respects the capacity of bodies, and nothing more, is a deduction very plain and obvious. Heat, in a state of motion, may be said to be progressing to a quiescent state; and equalization of temperature, although differently understood, may be considered an equalization of fixed caloric, according to the relative capacity of bodies, without regarding the equalization, which takes place of uncombined caloric, as is manifested by thermometrical instruments. In a word, by considering caloric in this view, that of tending to a state of rest, and uniting with bodies according to their respective capacities, we may account for many phenomena; as, for instance, the quantity of caloric which enters into ice, and becomes latent, during liquefaction. The quantity of caloric, in this respect, may be learnt by adding a pound of ice at 32 degrees to a pound of water at 172 degrees. The temperature will be much below 102 degrees, the arithmetical mean, viz. 32 degrees. It is evident that the excess of caloric has disappeared; and by deducting 32 degrees from 172 degrees, 140 degrees remain, which is the quantity of caloric that enters into a pound of ice during liquefaction, or the quantity required to raise a pound of water from 32 degrees to 172 degrees. This change of capacity appears to be absolutely essential to the well being of the universe, as affording a constant modification of the action of heat and cold, the effects of which would otherwise be inordinate. If this did not take place, the whole of a mass of water, which was exposed to a temperature above the boiling point, would be instantly dissipated in vapour with explosion. The polar ice, would all instantly dissolve, whenever the temperature of the circumambient air was above 32 degrees, if it were not that each particle absorbs a quantity of caloric in its solution, and thereby generates a degree of cold which arrests and regulates the progress of the thaw; and the converse of this takes place in congelation, which is in its turn moderated by the heat developed in consequence of the diminution of capacity, which takes place in the water during its transition to a solid [xxxi]
state. The reason why boiling water in the open air never reaches a higher temperature than 212 degrees is evident, if we consider, that the capacity of those portions of liquid, which are successively resolved into a vapour, becomes thereby sufficiently augmented to enable them to absorb the superabundant caloric as fast as it is communicated.

The most obvious effect of caloric on bodies, is the change, which they undergo when exposed to its action.

That it acts constantly in opposition to the attraction of cohesion or of aggregation, by which bodies pass from a solid to a fluid, and from a fluid to an aeriform state, and produces also different changes in bodies,—are facts that come under our daily observation.

It occasions changes in the bulk of bodies; hence solids, liquids, and gases are expanded. The expansion, and subsequent contraction of atmospheric air, give rise to various winds, which are currents of air rushing from one point of the compass to another to maintain an equilibrium. The theory of the winds is predicated on this fact, although some have asserted, that they depend greatly on the diurnal motion of the earth. The air thermometer of Sanctorius, and the differential thermometer of Leslie, are founded on this principle, of the expansion of air. Fluids expand until they arrive at the boiling point, as is the case with water, alcohol, &c. The expansion of mercury, in a glass tube, furnished with a graduated scale, forms the mercurial thermometer, by the rise and fall of which, the different variations of temperature are marked.

Notwithstanding caloric has the property of expanding bodies, there are some exceptions to this law, which may be proper to notice. Water, for instance, at the temperature below 40° contracts at every increment of temperature until it reaches 40°, which is its maximum of density. Above 40° it expands, until it arrives at the boiling point. Alumina, or pure argillaceous earth, also contracts by heat; hence it is used in the pyrometer of Wedgwood, to measure by its contraction intense degrees of heat. Various saline substances, in the act of crystallization, also expand. Several of the metals, when previously melted, on cooling exhibit the same character; and water, in the act of freezing, exerts a powerful force by its expansion, competent to the bursting of shells, and [xxxii]
the splitting of rocks.

The changes in bodies, produced by caloric, we have already noticed. We will only add, that fluids require different temperatures, called the boiling point, to make them boil, under the same atmospheric pressure. Water boils at 212°. Many observations have been made with respect to water, both in the state of ice, and the state of vapour. Besides the accession of 212 degrees of caloric, appreciable by the thermometer, in water in the state of steam, there is also an accession of non-distributable caloric, called *latent heat*, which is calculated at 1000°. In consequence of this circumstance, steam has been judiciously applied to various useful purposes, and particularly in a certain manner for the drying of gunpowder.

That chemical changes are produced by the agency of caloric, is a fact well known. It is supposed to occasion decompositions, according to the laws of affinity, by changing previous affinities, and causing new affinities to take place. Hence the operations by fire, whether the substances themselves are exposed in a dry state to the action of heat, or otherwise, produce new results, or compounds, which could not be made without it. This truth has long been obvious. In consequence of a knowledge of this fact, Dr. Black (*Lectures* vol. i, p. 12,) defined "chemistry to be the study of the effects of heat and mixture, with the view of discovering their general and subordinate laws, and of improving the useful arts."

Caloric as a powerful auxiliary, performing as it does an innumerable multitude of changes and effects, an agent by which the operations of the universe are maintained in order and harmony for universal good, exerts the same effect in the furnace of the chemist, as in the great laboratory of nature; and regulates, and determines all the consequences, which follow a succession of fixed, and appointed changes.[4]

We have thus, in this brief and hasty outline of the nature, principal effects, and properties of caloric, detailed the leading facts on this subject; from which it will be seen, that caloric, so far as respects its generation by the combustion of different pyro-mixtures, and effects, generally, should form a part of Pyrotechny, and claim the attention of those, who are connected with the preparation of Fire-Works. [xxxiii]

Respiration is also a process which puts quiescent heat in motion.[5]

In the second part of the work, we embrace the furniture of a laboratory, for the use of fire-workers, consisting of various tools and utensils.

Under this head, we also embrace sundry manipulations, such as the preparation of substances for use, the manner of forming mixtures, and various anterior operations. The formation of pasteboard for cases, the mode of forming as well as charging cases, [xxxiv] different modes of charging rockets, the dimensions of rammers, mallets &c. This preliminary ought to be well understood; as the successful practice of the art depends greatly on these operations. We may observe, however, that we have had occasion to repeat some of these manipulations in certain instances, to make them more intelligible; or rather to present, more in connection with the subject, a detail of minutiæ.

In the different compositions, the reader will bear in mind, that the copious collection of formulæ, both old and new, embraces all the facts, with which we are acquainted, concerning pyrotechnical preparations.

In most instances, where the importance of the subject required it, we designated, or set apart from the rest, formulæ, which have been *approved*, and particularly in France.

This is more particularly the case as it respects the fourth and last part, which appertains exclusively to Military Fire-Works. On this subject, permit me to remark, that fire-works, intended for the purposes of war, should be depended on; and for that reason, in order to produce a certain effect, the materials of which they are composed should be pure, weighed with accuracy in the proportions required, and carefully mixed according to the rules laid down. It is true, however, that while this nicety is required in particular cases, it is unnecessary in the formation of all fire-works. The composition for carcass and light-ball, for tourteaux, links, and fascines, and some others, do not require that precision; whereas the composition for fuses for bombs, howitzes, and grenades should be in every respect accurately made; for on the accuracy of the composition, must depend the time a fuse will burn, which is afterwards regulated by using more or less of the fuse, according to the time it will take for the shell to reach its destination, on which depends the skill of the bombardier. Accuracy, however, in making of preparations should be a general rule.

Viewing Pyrotechny either as a science or an art, there is undoubtedly required in its prosecution much skill and practice. A knowledge of the theory of fire-works may be readily acquired. The mere artificer or fire-worker, by constant habit and experience, may understand it is true how to mix materials, prepare compositions, charge cases, and perform all other mechanical operations; [xxxv] but it is equally certain, that, without a knowledge of chemistry, he cannot understand the theory. We would not say, that the workman should be a chemist, but that he should know enough to determine the purity of the substances he employs, and their respective qualities and effects; for if that principle were admitted, we might go further and say, that every person, who practices a chemical art, as the tanner, gluemaker, brazier, &c. should be a chemist, or that the art could not be conducted without a previous knowledge of chemistry, which we know is contrary to fact. This, however, may be said, that in *all* arts which are decidedly chemical, as that of *dying* for instance, chemical knowledge will enable the artist or operator to conduct his processes with better advantage, and correct any *old* routine, which is too often pursued, because it was handed down from generation to generation. Mr. Seguin in France facilitated the preparation of tanned leather, by adopting a new process altogether chemical. In a word, so far as chemistry is connected with the arts, and by which we explain the operations that take place, it is undoubtedly important; and with regard to Pyrotechny, it appears, in the way we have mentioned, to be indispensable. Chaptal (*Elements de Chimie*) observes, that the works of artificers frequently miscarry in consequence of their being unacquainted with the art.

In noticing this subject, we may be permitted to digress, while we state, that, being fully convinced of this truth, we have directed our labours in the Chemical Department of the United States' Military Academy to two distinct objects; *viz.* to theoretical and experimental chemistry, forming the first year's course, and chemistry in its application to the arts, manufactures, and domestic economy, constituting, along with mineralogy, the course of the second year. In addition to the usual applications, Pyrotechny, in the manner we have stated, and especially that branch which treats of military fire-works, has claimed our attention; and we have reason to believe, that this addition, to the usual course of chemical instruction, has considerably advanced the utility, especially to gentlemen designed for the army, of the application of chemistry.

The system of instruction adopted throughout the academy, in the different departments, (the plan of which may be seen in the new *Army Regulations*, article Military Academy), which, we have no hesitation in believing, is the most complete of any in the [xxxvi] United States, and by far the most extensive,[6] is so regulated, that each section of a class regularly recite, and are interrogated on each subject of instruction, so that, while an emulation to excel is thus excited, the comparative merit or standing of the cadets is thereby determined. Adopting the same system in the Chemical department, that of interrogation on the subject of the preceding lecture, has many peculiar advantages; so that, while the mind and memory of the pupil are thus exercised, a comparative estimate of the progress of each one is obtained during each week, by which we are enabled, as in other departments, to present a Weekly Class Report of their progress.

While we are indebted to the talents and industry of the professors and teachers of the Academy, for the flourishing condition it is now in, and the progress of the cadets in every branch there taught; it is but justice to remark, that for the present organization of the academy, as relates to the studies, which is obviously preferable to the old system, and also for the improvements in instruction, we are indebted to the present superintendent, Col. S. Thayer, of the U. S. corps of engineers.

Considering pyrotechny, abstract from the questions usually given, and forming a distinct branch, it may be proper to remark, that the interrogatories on this head have been minutely and satisfactorily answered. The following outline will exhibit the order in which such questions were put, observing, however, that they are merely in connection with this subject:

What is saltpetre? What is nitric acid? What is potash? What are the sources of saltpetre, and how is it obtained? How is it formed in nitre beds, extracted, and refined? What circumstances are necessary to produce nitre, and how does animal matter act in its production? What is the difference between the old and new process for refining saltpetre? What reagents are used to discover the presence of foreign substances in nitre? What are nitre caves? Where do they exist? What are the nitre caves of the [xxxvii] Western country, and how is nitre extracted from the earth? What proportion of nitre does the saltpetre earth of the nitre caves afford? What is the theory of the process for extracting saltpetre from nitrous earth, or nitrate of lime? What is sulphur? How is it obtained, and how is it purified for the manufacture of gunpowder? Of what use is sulphur in the composition of gunpowder? Does it add to the effective force of gunpowder? What is charcoal? What is the best mode of carbonizing wood for the purpose of gunpowder? What woods are preferred for this purpose? In the charring of wood, what part is converted into coal, and what gas and acid are disengaged? What is the use of charcoal in gunpowder? What is gunpowder? What are considered the best proportions for forming it, and what constitutes the difference between powder for war, for gunning, and for mining? How does the combustion of gunpowder take place? Can you explain why combustion takes place without the presence of a gaseous supporter of combustion, as gunpowder will inflame in vacuo? What are the products of the combustion of gunpowder? What gases are generated? To what is the force of fired gunpowder owing? What are the experiments of Mr. Robins on the force of gunpowder? How would you separate the component parts of gunpowder, so as to determine their proportions? What are gunpowder proofs? What is understood by the comparative force of gunpowder? What are eprouvettes? &c. In noticing in the same manner the preparations used for fire-works, and for war, as the rocket for instance, the following questions were propounded; *viz.* What is a rocket? How is it formed? Is the case always made of paper? What is the war rocket? What is the composition for rockets, and how does it act? What particular care is required in charging a rocket? What is the cause of the ascension of rockets? What is the use of the conical cavity, made in a rocket at the time it is charged, or bored out after it is charged? How do cases charged with composition impart motion to wheels, and other pieces of fire-work? What is understood by the rocket principle? What is the rocket stick, and its use? Is the centre of gravity fixed, or is it shifting in the flight of rockets? How are rockets discharged? What is the head of a rocket? What is usually put in the head? Are all rockets furnished with a head? What is [xxxviii] understood by the furniture of a rocket? How are the serpents, stars, fire-rain, &c. forming the furniture of a rocket, discharged into the air, when the rocket has terminated its flight, or arrived at its maximum of ascension? What forms the difference between a balloon, in fire-works, and a rocket? As the balloon contains also furniture, and is projected vertically from a mortar, how is fire communicated to it, so as to burst it in the air? Is the fuse used, in this case the same as that for bombs, howitzes, and grenades? What is the Asiatic rocket? The fougette of the French? In what seige were they employed with success by the native troops of India? What was the nature of their war-rocket? What is the murdering rocket of the French? Is the conical head hollow, or solid, blunt or pointed? Why is it called the murdering rocket? What is the Congreve rocket? Is Congreve the inventor, or improver of this rocket? What are Congreve rockets loaded or armed with? In what part is the load placed? Is the case made of paper or sheet iron? What are the sizes of Congreve rockets?

What are the ranges of Congreve rockets? What angle of elevation produces the best range? How are Congreve rockets discharged in the field, and what number of men are usually employed for that service? Are the Congreve rockets considered to be a powerful offensive weapon; and, if so, in what particular? What is a carcass rocket? As an incendiary, is the carcass rocket equal to the usual carcass thrown from mortars? What is the carcass composition made of? What is the Congreve rocket light ball? In large rockets, are their sticks solid, or bored and filled with gunpowder? Why is that expedient used? &c.

It is obvious, that the student, after obtaining a knowledge of each subject by the preceding lecture, accompanied with demonstrations, is enabled to detail minutely all the facts in relation to it.

Pyrotechny, as known at present, is confined to a few books, and scattered in a desultory manner, without any regular or connected system. In fact the works which treat on this subject are in French, or translations from the French on particular subjects, but generally very imperfect. As applied to the uses of war, we may indeed say, that the small treatise of Bigot, (*Traité d'Artifice de Guerre*), and Ruggeri (*Pyrotechnie Militaire*) are the only works. We have, therefore, consulted these authors, as will [xxxix]
be seen in the pages of the work.

Roger Bacon, in his *Opus Majus*, has given some account of the Greek fire, and of a composition, which seems to have had the effect of our modern gunpowder.

Malthus (*Traité de l'Artillerie*) contains some formulæ for Military Fire-Works. Anzelet and Vanorchis, in their several works, have given some receipts for incendiary preparations. Henzion (*Recreations Mathématiques*) and Joachim Butelius have also something on the subject.

The celebrated Polander, Casimir Siemienowicz, has nothing of any moment, if we except the incendiary fire-rain, an account of which may be seen in the fourth part of our work. His book is considered, however, the best of the whole of them. Belidor, Theodore Duturbrie, &c. have mentioned some preparations; but their works are chiefly confined to artillery.

The improvement of Pyrotechny is ascribed to the Germans and Italians, and the French acknowledge, that they are indebted for a knowledge of it to the Italians. Be this as it may, it is certain, that it was known in China from time immemorial. Their acquaintance with gunpowder, before it was known in Europe, is a fact which appears to be generally admitted. For an account of the Chinese fire-works, and the origin of gunpowder in Europe, consult these articles respectively.

Whatever merit we may claim in this work, as the public will be able to judge impartially, it will be seen, by referring to the different chapters and sections, that we have endeavoured to form a system, by presenting a connected view of the whole subject.

Having noticed under separate heads, the particular use and application of each composition, we have added a chapter on the arrangement of fire-works for exhibition, together with the order to be observed. We may remark here, that we have enlarged in this part more perhaps than its merit or importance deserves; but, on reflection, we thought it better to embrace the whole subject, in order to form a more complete system in all its parts.

After going through the fire-works for exhibition, and noticing the different formulæ, and preparations, for arrangement, with the theory of effects, we consider, in the next place, a subject of more importance, that of Military Pyrotechny. We have adopted [xl]
this arrangement, more on account of obtaining a better acquaintance with ordinary fire-works, before the reader is prepared for military works, which he will understand with more facility; for all the preliminary operations precede the practical part.

On this head, it will be sufficient to add, to what we have already stated, that we have given in each article, generally speaking, a variety of formulæ, with ample instructions for the preparation of each composition. The table of contents will exhibit the order in which they are treated.

In noticing the substances used in fire-works, in the first part, it will be perceived, that we have noticed some of them more extensively according to their importance; as for instance, *saltpetre*. Besides the different modes of obtaining saltpetre in Europe and elsewhere, and the means employed for refining it, we mention the saltpetre caves of the western country, which furnish an abundance of this article, and which contain an almost inexhaustible supply.

The extraction of saltpetre from the earth, (principally nitrate of lime), by using a lixivium of wood-ashes; the formation of rough, and subsequently of refined nitre; the various methods of refining saltpetre, and particularly that adopted in France; with sundry facts respecting the origin of nitre, and on the formation of artificial nitre beds; all claim our particular notice.

The extraction of sulphur from its combinations, and the means used for purifying it for the purpose of gunpowder, are also considered in the same manner.

The subject of charcoal, an essential constituent of gunpowder, claims, in like manner, particular attention. The various modes of charring, the woods employed, the quantity of coal obtained, the formation of pyroacetic acid in the process of carbonization, and many facts of the same kind are considered. These subjects, *viz.* nitre, charcoal, and sulphur, are highly important to the manufacturer of gunpowder.

A knowledge of the various processes for refining saltpetre; the best and most approved modes of carbonizing wood; the purification and quality of sulphur; the different processes for making gunpowder, with the proportion of the ingredients used in France and elsewhere; the granulation, glazing, and drying of powder, the use of the steam apparatus, and the different modes of [xli]
proving it, and of examining it chemically; and the means of ascertaining the purity of nitre in any specimen of gunpowder; are, with others, subjects of particular interest to the gunpowder manufacturer.

With respect to the Theory of the explosion of gunpowder, we have noticed it at some length, and have added the experiments and observations of Mr. Robins, and of other persons, made at different periods.

In the consideration of the gaseous products, and the caloric evolved by the combustion of powder, we have taken a view of the gases produced, the cause of their production, the dilatation which they suffer, and the experiments of Lavoisier and Laplace, with regard to latent heat, and deducing therefrom some views of the probable cause of the production of caloric in fired gunpowder.[7]

Our observations respecting rockets, the theory of their ascension, of the Congreve carcass and Asiatic rockets, and some [xlii]
others, are we apprehend sufficiently extensive. As it regards the different incendiary compositions, and their use in war, the reader will find ample instructions on these heads.

We may also remark, that we have given some of the more common, or general properties of the substances, employed in the composition of fire-works, without going into that detail, which belongs exclusively to works that treat of Chemistry. It was neither our design, nor have we given, for the reasons thus stated, *all* the chemical characters or properties of the substances so employed; and, therefore, have confined ourselves, generally speaking, to an enumeration of such properties as are connected with the subject, or are indispensably necessary to be known, before a rationale of the causes and effects can be understood.

It was our intention to accompany the work with plates, exhibiting the arrangement, &c. of fire-works, which, there can be no doubt, would have facilitated in particular the knowledge of forming, and arranging, certain pieces of fire-work; but, on second reflection, as such illustrations were connected more with fancy exhibitions, and have little or no relation to Military Fire-works, the most useful branch of Pyrotechny, we were finally of opinion, that the addition of plates would greatly enhance the price, without advancing or adding to the value of the work.

If, however, a second edition should be required, various figures in illustration of particular subjects may be added, either with a distinct explanatory chapter, or a reference from the articles themselves, with the necessary explanation, to the figures respectively.

It would require at least twenty-five plates to include all the figures we originally intended to have introduced.

Before concluding this introduction, it remains for us to remark, that, in forming this work, we consulted a variety of authors,
but with little advantage, except some French works, which we shall notice. Chaptal (*Chimie Appliqué aux Arts*;) Bigot (*Artifice de* [xliii]
Guerre;) Morel (*Feux d'Artifice*;) Thenard (*Traité de Chimie*;) Ruggeri (*Pyrotechnie Militaire*;) MM. Bottée and Riffault (*Traité de L'Art de Fabriqué la Poudre à canon*;) Peyre (*Le Mouvement Igné*;) Biot (*Traité de Physique*, *Recherches Experimentales et Mathématique*, *sur les mouvement des Molecules de la Lumiere*, *&c.*;) M. Duloc (*Theorie Nouvelle sur le Mechanisme de l'Artillerie*;) the *Dictionnaire de l'Industrie*; the *Dictionnaire Encyclopedique des Arts et Metiers Mecaniques*, article *Art de L'Artificier*; *Œuvre Militaire*; *Archives des Découvertes*; *Système des Connoissances Chimiques par A. F. Fourcroy*; *Aide-Mémoire a l'usage des officiers d'Artillerie de France*.

We examined various authors in English; and with regard to the origin of inventions, we found the learned, and valuable work of professor Beckman (*History of Inventions*) very useful, and likewise James's *Military Dictionary*. To the *Encyclopedia Britannica*, we are indebted for many interesting facts, and some extracts on fire-works for exhibition.

On the subject of mining, we consulted the *Treatise on mines for the use of the Royal Military Academy*, by Landmann.

We deem it necessary to observe, that, in collecting our formulæ for military fire-works, although we have sometimes extracted from the Strasbourg *Memoir*, the *Bombardier and Pocket Gunner*, and the *Military Dictionary* of Duane and James, we have generally followed Bigot; as the formulæ which he gives for the preparation of Military fire-works have been approved by the French government; and where any thing of importance occurred in Ruggeri, we have, for the same reason, extracted such formulæ from that author.

As respects the turtle, torpedo, and catamarin, submarine machines, it appears that Bushnel (*Trans. Am. Phil. Soc.*) claims the originality of the discovery from the date of his invention, although similar contrivances had long ago been suggested. Fulton's improvements, in the torpedo, are deserving of particular attention; but it is plain, that the Catamarin of the English is the same in principle and application as Fulton's torpedo, and that Fulton deserves the merit of it. Congreve, if we believe Ruggeri, was not the inventor of the rocket, which bears his name; for, according to him, it was invented about the year 1798 by a naval officer at [xliv] Bourdeaux. It is certain, however, it was neither much known, nor used before the attack on Copenhagen.

It is certain that the present incendiary fire-stone was taken from the recipe for fire-rain contained in the military work of Cassimir Siemienowicz, or that the fire-rain gave rise to a similar preparation. The idea of the *pyrophore*, mentioned in the *Archives des Découvertes*, must have originated from the use of the powder-barrel, and of similar means of defence. We might enumerate many other inventions, which owe their origin in the same way.

A SYSTEM

OF

PYROTECHNY.

CHAPTER I.

PYROTECHNY IN GENERAL.

Sec. I. Definition of Pyrotechny.

Pyrotechny is defined the doctrine of artificial fire-works, whether for war or exhibition, and is derived from the Greek, πυρ *fire*, and τεχνη *art*. In a more general sense, it comprehends the structure and use of fire-arms, and the science which teaches the management and application of fire in several operations.

Sec. II. General theory of Pyrotechny.

In the composition of artificial fire, various substances are employed, having different properties, and designed to produce certain effects characterised by particular phenomena. These substances are either inflammable, or support the combustion of inflammable bodies. As pyrotechnical mixtures are differently formed, and of various substances, the effects are also modified, although combustion, under some shape always takes place.

Combustion is either modified, retarded, or accelerated; and in consequence of the presence of certain substances, different appearances are given to flame. [2]

The conditions necessary for combustion are, the presence of a combustible substance, of a supporter of combustion, and a certain temperature. Thus, charcoal when raised to the temperature of 800° in the open air, takes fire. This elevation of temperature enables it to act chemically on the oxygen gas of the atmosphere; the latter, as it comes in contact, being decomposed. Now, as oxygen gas is a combination of oxygen and caloric, the caloric being in a latent state, the charcoal unites with the oxygen, and the phenomena of combustion ensue; that is, an evolution of *heat* and *light*. The caloric of the decomposed gas is given out in a free state, and, according to the theory of Dr. Thomson, (*Thomson's System of Chemistry*, vol. i.) the light proceeds from the burning body. We have then an instance of combustion, in which there is a combustible, a supporter of combustion, and an elevated temperature. The old theory of combustion, called the *Stahlian* theory, which presupposes an element called phlogiston, or a principle of fire, to exist in all bodies under some modification, would explain these effects by merely supposing, that combustion was nothing more than a disengagement of phlogiston; and that when a body had lost its inflammable principle, (as a metal, when oxidized), it became dephlogisticated. But, as it proved that phlogiston is a hypothetical element, and the anti-phlogistic doctrine clearly shows, that combustion is no other than a process which unites the supporter with the combustible, forming new products; it follows, that, in all changes of the kind, the same reasoning will apply, and the same principle be tenable.

The products of combustion depend on the nature of the substance burnt, and the supporter employed. Thus, in the instance just mentioned, the charcoal, by its union with oxygen, is changed into carbonic acid, which takes the gaseous state. We say then, that carbonic acid is the product of the combustion of charcoal, or, chemically speaking, of carbon. As resins, oil, &c. contain hydrogen, as well as carbon, the products in such cases would be water, as well as carbonic acid.

The chemical effects, therefore, which we consider in fire-works, forming the basis on which a theory of sundry phenomena may be formed, are no other than the result of the action of one body on another, according to the laws which govern such action, and the consequent operation of chemical combination. Combustion, in fire-works, may be considered a primary agent in *all effects* [3] which characterise artificial fire.

The second change, with respect to the appearance of the flame, the formation of stars, serpents, rain, &c. terms used in the art, is owing either to new chemical changes which the substances undergo, or to the decomposition of the products themselves. These effects, it is obvious, must be governed by the circumstances, under which the mixtures are made. Saltpetre, for instance, is the basis of fire-works, whether used in a separate state, or employed in mixture with charcoal and sulphur, as in gun-powder; and, from its composition, is adapted to all the purposes of the art, because it yields its oxygen very readily to all inflammable bodies. In consequence of the decomposition, it undergoes at an elevated temperature, when brought in contact with charcoal, sulphur, &c. and various substances which contain carbon, as pitch, rosin, turpentine, tallow, copal, and amber, combustion results, and, according to circumstances, is more or less rapid, and the flame also more or less brilliant.

When charcoal, in the state of ignition, is brought in contact with nitre, a deflagration takes place, because, at the temperature of ignition, it has the property of decomposing the nitric acid of the nitre; and as this process unites the carbon with the oxygen, in the proportion necessary to constitute carbonic acid, this acid is accordingly produced. When, therefore, we inflame a mixture of nitre, charcoal, and sulphur, or gun-powder, the whole or greater part disappears; and if we were to collect in a pneumatic apparatus, the products of the combustion, it would be found, that they are nearly altogether gaseous, and composed, as we shall speak hereafter, of sundry elastic aëriform fluids. This decomposition, the immediate effect of the charcoal on the nitric acid of the nitre, is the same as in the preceding instance, for carbonic acid gas is formed in both cases. We have then another instance of combustion, where a number of substances are concerned, and therefore, the products must be numerous.

We notice this subject more particularly, since, as in the different fire-works, nitre and inflammable bodies are used in different proportions, the result is always affected by the same laws of chemical decomposition; for the same substances, placed under similar circumstances of proportion, mixture, &c. afford the like results. If carbon alone be employed, carbonic acid gas is the result; if oil, tallow, rosin, or turpentine be used, we have then, as we had occasion to remark, water, as well as carbonic acid, by [4] reason of the union of the hydrogen, which forms one of their constituent parts, with a part of the oxygen of the nitric acid.

Again, in a composition of mealed powder, rosin and sulphur, with or without the addition of saw dust, we infer, from the composition of the ingredients and the chemical action which subsequently takes place, that the products of combustion would be carbonic acid gas, sulphurous acid gas, water, sulphuretted hydrogen, and probably azotic, and nitric oxide gases. If the filings of steel, brass, zinc, or copper, enter into the composition, besides the products above-mentioned, there would be either an oxide of iron, an oxide of zinc, or, an oxide of copper, according as one or other of these metals are employed.

Copper, in fire-works, has the effect of communicating a green colour to the flame. M. Homberg, (*Collection Acad.*) observes, that the green colour in such cases is owing to the *dissolution* of the metal, which in fact is nothing more than the *effect* of its oxidizement.

The various compositions for brilliant fire, as the Chinese fire, owe their peculiar character to pulverised cast iron, and commonly to steel and iron filings. Now the effects in these cases are the same; for the same oxidizement ensues, more or less rapidly, which in fact distinguishes the kinds of brilliant fire. That of the Chinese is the most perfect, and next is the composition made with steel filings. It will be seen, however, that compositions generally are governed, in their respective appearances when inflamed, by the purity, as well as the proportion of other substances, which enter into them; and hence much of their effect depends on collateral circumstances, which we purpose to consider when we treat of the compositions individually.

That the light of certain burning bodies may be increased, is evident from these facts; and experiment has shown, that the intensity of the light of burning sulphur, hydrogen, carbonic oxide, &c. is increased by throwing into them, zinc, or its oxide, iron, and other metals, or by placing in them very fine amianthus or metallic gauze. Protochloride of copper burns with a dense red light, tinged with green and blue towards the edges. If the hydrogen of the oil acts in separating the chlorine from the copper, and the reduced copper is ignited by the charcoal, this appearance must necessarily ensue.

When solid matter is the product of combustion, as in the burning of phosphorus, zinc, iron, &c. the flame is remarked to be [5] more intense. Flame may be modified under other circumstances, as we will have occasion to mention hereafter. When, for instance, a wire-gauze safety-lamp is made to burn in a very explosive mixture of coal gas and air, the light is very feeble and of a pale colour; but when a current of coal gas is burnt in atmospheric air, the combustion is rapid and the flame brilliant.

Dr. Ure thinks it probable, (*Dictionary of Chemistry*, article combustion,) that, when the colour of the flame is changed by the introduction of incombustible compounds, the effect depends on the production, and subsequent ignition or combustion of inflammable matter from them. Thus he infers, that the rose-coloured light given to flame by the compounds of strontium and calcium, and the yellow colour given by those of barium, and the green by those of boron, may depend upon a temporary production of these bases, by the inflammable matter of the flame. It is inferred also, as a probable conclusion, that the heat of flames may be actually diminished by increasing their light, (at least the heat communicable to other matter), and *vice versa*; because, in the most intense heat, as in the compound blow pipe, or in Newman's blow pipe apparatus, in which a mixture of oxygen and hydrogen gases is compressed, the flame, although hardly visible in bright day light, instantly fuses the most refractory bodies; but the light of solid bodies ignited in it, is so vivid as to be painful to the eye.

Some curious facts with regard to flame, in connection with electricity, are given by Brande in the Phil. Trans. for 1814. He supposes that some chemical bodies are naturally in the resinous, and others in the positive electrical state. He supposes also, as a consequence, that the positive flame will be attracted, and neutralize the negative polarity, while the negative flame will operate a similar change by inducing an equilibrium at the positive pole. Thus he found, that certain flames were attracted by the positive ball of an electrical apparatus, and others attracted by the negative ball. The flame of sulphur and phosphorus is attracted by the positive pole, and the flame of camphor, resins, and hydrogen by the negative pole.

In relation to the production of flame, we may observe, that, as sundry solid and fluid substances are inflammable, the products of combustion depend on the composition of the substance made use of, and the condition under which it is burnt. As to gaseous substances that are inflammable, the base of some gases, we may remark, as carbon and hydrogen, unite in the process of [6] combustion with the base of other gases, (as oxygen;) and in other instances, the *gas* itself takes fire, and exhibits the phenomena of flame. Now carbonic acid gas extinguishes flame, although its base is inflammable; but hydrogen, as well as hydrogen gas, is inflammable, and when burnt in oxygen gas or atmospheric air produces water, which also extinguishes the flame of burning bodies.

As we will have occasion to notice a variety of aëriform fluids, especially when we treat of the aëriform products of fired gun-powder, a few remarks on this head may be useful at this time.

By the combustion of bodies, substances are generated that are either gaseous or solid, whence arises the variety of products. Of aëriform fluids, some are coloured, as nitrous acid vapour, (nitrous gas and oxygen), chlorine, and the protoxide and deutoxide of chlorine. The first is red, the rest yellowish-green, or yellowish. Some relight a taper, provided the wick remain ignited, as oxygen gas, protoxide of azote, and the oxides of chlorine. Others produce *white vapours* in the air, as muriatic acid, fluoboric, fluosilicic, and hydriodic. The inflammable gases, which take fire in the air by contact of the lighted taper, are hydrogen, hydroguret, and bihydroguret of carbon, carbonic oxide, prussine or cyanogen, called also carburet of azote, and phosphuretted, sulphuretted, arsenuretted, telluretted, and potassuretted hydrogen. Other gases are acid, and redden litmus, which, for that reason, are called acid gases, such as nitrous, sulphurous, muriatic, fluoboric, hydriodic, fluosilicic, chlorocarbonic, and carbonic acids; the oxides of chlorine, sulphuretted hydrogen, telluretted hydrogen, and carburet of azote. Some gases are destitute of smell, as oxygen, azote and its protoxide, and carbonic acid; while others have a strong and characteristic odour, as ammoniacal gas. Some gases are very soluble in water, and others but slightly soluble, such as fluoric, fluosilicic, carbonic, sulphurous, and muriatic acids, and ammoniacal gas. Alkaline solutions absorb some gases, as nitrous, sulphurous, muriatic, fluoboric, carbonic, hydriodic, fluosilicic, chlorine, chlorocarbonic, and the two oxides of chlorine, sulphuretted hydrogen, telluretted hydrogen, and ammonia. Alkaline gases are ammonia, and potassuretted hydrogen.

The character of gases is well defined. The compound gas of phosphorus and hydrogen takes fire spontaneously in the atmosphere, burning with a brilliant white flame; but there is another gas formed of the same substances, that does not inflame [7] spontaneously, but is inflammable, called subphosphuretted hydrogen. This gas has a strong smell of garlic or phosphorus, and is luminous in the dark. It may be this peculiar combination, which gives rise to the *ignes fatui*; but the permanent ignes fatui, observed in volcanic countries, are said to be the slow combustion of sulphur, forming sulphurous acid gas. Sir H. Davy found, that phosphuretted hydrogen produced a flash of light when admitted into the best vacuum that could be made by an excellent pump of Nairn's construction.

Naphtha in contact with red hot iron glows with a lambent flame at a rarefaction of thirty times, though its flame ceases at an atmospheric rarefaction of six. Camphor ceases to burn in an air rarefied six times, but, in a glass tube which becomes ignited, the flame of camphor exists under ninefold rarefaction; whereas phosphorus, according to the experiments of Van Marum, will burn, although the atmosphere be rarefied sixty times. Hydrogen gas will burn in a rarefied air, when it is four or five times less than the pressure of the atmosphere, and its flame be extinguished, when the pressure is between seven and eight times less; from which it is inferred, that the flame is extinguished in rarefied atmospheres, only when the heat it produces is insufficient to keep up the combustion. Olefiant gas (hydroguret of carbon) ceased to burn in an atmosphere, where its pressure was diminished between ten and eleven times. The flames of alcohol and of wax taper were extinguished in an atmosphere, where pressure was five or six times less without the wire of platinum, and seven or eight times less when the wire was kept in the flame. See *Flameless Lamp*. Several interesting conclusions may be drawn from these facts, which, to enumerate, would lead us beyond our design. It will be sufficient, therefore, to add, that although a supporter of combustion is necessary for that process, and flame may be differently modified, yet combustion ceases if the pressure of the atmosphere be diminished in certain ratios, as already noticed.

Besides nitre, other saline substances which contain oxygen feebly combined, have been used for the same purpose. Some years ago, it was proposed to substitute the hyper-oxymuriate, now called chlorate of potassa, for nitre in the formation of gun-powder. As chlorate of potassa, when mixed with sulphur, &c. produces combustion by percussion, or by the contact of fire, this effect is attributed to the same cause,—the separation of oxygen, not from azote, but from the chlorine of the chloric acid, Hence, when that salt is used in fire-works, the result of the combustion is similar to that in which nitre is employed; at least as regards the [8] union of the oxygen with the elementary principles of the inflammable body. On this subject, we shall make some remarks hereafter. Nitrate of soda, a salt which contains nitric acid, and similar to saltpetre in that particular, has been recommended also for fire-works. It has, however, several objections. Our object in noticing it at this time is to remark, that, when it is so employed, its effect is the same as nitrate of potassa, or saltpetre, by furnishing oxygen as the supporter of combustion. See *Nitrate of Soda*.

We are of opinion, that many of the nitrates might be advantageously employed in the manufacture of fire-works. Some, as nitrate of strontian, communicate a red colour to flame, as the flame of alcohol. Nitrate of lime also might be used.

All nitrates, as well as the different hyperoxymuriates, or chlorates, contain oxygen as an essential ingredient in the acid of their respective salts, which is readily given up to inflammable substances.

When nitrates are employed for fire-works, they should be free from moisture, or water of crystallization, unless otherwise required. The presence of water may, in many cases, prove injurious to the composition; and, consequently, the effect in those instances, may be influenced by this circumstance. The composition of nitric acid, and the action of carbon in the decomposition of the nitrates, or salts formed by the union of nitric acid with sundry bases, will claim our attention in the article on gun-powder.

With respect to the production of colours, some remarks on this subject may be here added.

Speaking of colours, Haüy (*Elementary Treatise of Natural Philosophy*, trans. ii. p. 253.) takes into view their formation according to the Newtonian doctrine; and in a note by the translator, several instances are given of the change of colour by oxidizement and other processes. Iron when exposed to heat in contact with atmospheric air gradually absorbs oxygen, and changes its colour. The colours produced depend entirely on the quantity of oxygen, and on the absorption of some of the rays of light, and the reflection of others. See *Iron*. The tempering of steel instruments depends on this property, and also the blueing of sword blades, and many similar operations. The first impression of fire usually developes a blue colour; a second degree produces a yellow; and, if the oxidizement augments, the iron becomes red. The major part of the metals present similar phenomena. [9]

In vegetables, the blue colour is formed by fermentation; and many of these colours are susceptible of passing to red by a greater quantity of oxygen, as they depend on the absorption of oxygen. It is thus that the green fecula of indigo becomes blue; turnsol, red by air and acids; and the protoferrocyanate of iron, blue when exposed to the air.

When meat putrefies, the first degree of oxygenation decides the blue colour; the red soon succeeds as the process goes on. It would seem that the maximum of oxidation determines the reflection of rays of every kind, in the same proportions as subsist in solar light, of which we have many instances in combustion.

The flame of burning bodies exhibits the same phenomena. It is blue when the combination of oxygen is slow; red when it is stronger, and white when the oxygenation is complete.

These facts lead to the conclusion, that the combination of oxygen, and its proportions, give birth in bodies to the property of reflecting corresponding rays of light; but, since the combination of oxygen in different proportions ought to change the thickness and density of the component laminæ, and, consequently, to produce variations in the colours, this doctrine is not easily reconciled with the received theory.

By considering the temperature necessary to inflame different bodies; the nature of flame, and the relation between light and heat, which compose it; the caloric disengaged in a free state during the combustion of bodies, and the causes, which modify the appearance of flame,—we may be enabled to account for the phenomena already noticed. Thus, phosphorus at 150°, and sulphur at 550°, are said to take fire, and two acid products are formed; at 800°, hydrogen gas explodes with oxygen, and produces water; and, according to Ure's view, the flame of combustible bodies may in all cases be considered as the combustion of an *explosive mixture* of inflammable gas, or vapour, with air; and as to the change of quiescent into distributable heat, and the causes that modify combustion and flame, the facts on these heads are numerous and very important.

Sec. III. Remarks on the Nature of particular Compositions.

The *spur fire*, which was invented by the Chinese, but brought to perfection in Europe, is remarkably beautiful when employed in some particular parts of fire-works. This fire was so named from the effect it produces, that of forming scintillations, resembling [10] a shower, or drops of rain, or the rowel of a spur. The *artificial flower pot* is formed of this fire. The *stars* and *pinks*, which it produces, are said to be brilliant. The composition of spur fire being saltpetre, lampblack, and sulphur, in the proportions we shall give hereafter, is similar in fact to that of gunpowder; for the lampblack acts in the same manner as common charcoal. As the lampblack, however, is extremely fine, and of a purer quality, its action on that account may be more powerful. While one portion of it decomposes the nitric acid of the nitre, with the oxygen of which it forms carbonic acid; another portion is thrown off in actual combustion, which puts on the appearance we have mentioned. Lampblack, it is to be observed, is a very impalpable powder, and takes fire with more facility than pulverised charcoal.

The lampblack, therefore, is consumed both by the oxygen of the nitre, and the oxygen gas furnished by the atmospheric air. With respect to the sulphur, it facilitates the combustion, as it is more readily inflamed, and it forms in the process of combustion, sulphurous acid gas. Spur fire has been improved by the addition of steel filings: They produce very brilliant scintillations, in the combustion of which, oxide of iron is formed.

With respect to the composition of rockets, the materials of which are united in different proportions, we will remark at this time, that as mealed powder, saltpetre, and charcoal constitute their principal ingredients, the chemical effect is similar to that we have stated. The combustion of such mixtures is attributed to the same cause; for whether we consider the composition of gunpowder, or the extra addition of saltpetre and charcoal, or the substitution of nitre for the gunpowder, the action must be the same, and therefore the products of combustion, similar. The action, however, as the effect evidently shows, is affected by the proportion of the substances employed, and by other circumstances which we shall notice hereafter. The different appearances, therefore, are owing entirely to the composition, as in *rocket stars*, *rains*, *gerbes*, *tourbillons*, *&c.*

It may appear surprising, that the combustion of gunpowder with other substances, previously well rammed in cases, as in the rocket, will give to the case a *momentum* of great velocity and force. This motion is regulated by the *balance* of the rocket; and its *power* depends upon the size of the case, and the compactness of the composition. There is nothing new, however, in the fact; for it is perfectly familiar with every one, if we consider the recoil of a gun when fired, the powder having a resistance to overcome, as [11] the ball, that the explosive effect of gunpowder is equal, and that the gases produced impel on all sides. Now the effect of a ball is as the difference of its weight with the weight of the gun; while the one being so much lighter is propelled forward with great celerity, and with a corresponding projectile force, the other suffers but little motion, which we term the recoil. The combustion of the materials, of which a rocket is composed, in a case, and in many fire-works where the cases are arranged on wheels, &c. which act on the rocket-principle, produces in like manner a force proportionate to the quantity of the material employed, and the manner it is driven in the case. The force in such instances is given to the rocket by the combustible substances; and the rocket itself when free, will ascend, or move in the direction required; or if small cases are fixed on wheels, which move on an axis, they communicate motion, as in the single vertical wheels, horizontal wheels, plural wheels, and the like, and may then be considered a moving power. That rockets are used as a missile weapon is well known. They were employed by the native troops of India against the British during the siege of Seringapatam in 1799. Mr. Congreve, the inventor of the *war-rocket* which bears his name, may have received his first idea of using rockets from this circumstance. This rocket will be described hereafter. The projectile force of the rocket is well calculated for the conveyance of case shot to great distances; because, as it proceeds, its velocity is accelerated instead of being retarded, as happens with every other projectile, while the average velocity of the shell is greater than that of the rocket only in the ratio of 9 to 8. The basis of this increase of power in the flight of rockets, induced Congreve to make a number of experiments, which resulted in their improvement, so far as they may be used of various calibres, either for explosion or conflagration, and armed both with shells and case shot. It may be sufficient to remark, that the 32 pr. rocket carcass, which has been used in bombardment, will range 3000 yards with the same quantity of combustible matter as that contained in the ten inch spherical carcass.

M. de Buffon, (*Mémoires de l'Académie*, 1740,) wrote an ingenious essay on sky rockets, in which he states the appendages which may be put to them.

If we inquire into the cause of the ascension of rockets, it will appear, that this apparently extraordinary effect, as we have [12] already remarked, is owing to the decomposition, and the consequent production and disengagement of a large quantity of gaseous fluid and caloric. The impelling power, as in the large Congreve rocket, of which we had occasion to speak, is regulated in proportion to its size, and the accuracy with which the materials have been driven.

The manner in which the flame, and, consequently, the gases are expelled from the orifice of a rocket, resembles the operation of an æolipile, which throws out the vapour of water, and sets in motion the air in its vicinity. As the more flexible must yield to the more solid body, so, in this respect, the gases produced are repelled by the air in contact with the orifice of the rocket. Thus it follows, that the rocket *displaces* a volume of air of a much greater weight than itself. The rocket then has upon the air, reasoning *a priori*, the same effect as the oars of a boat have upon water; and hence, the greater the volume of fire from the rocket, the greater is its velocity and ascent. The impelling force also increases as it consumes, being a uniformly accelerated motion.

It also appears, that a rocket sent in an horizontal direction will not pass over so great a distance, as when its motion is vertical; for, a rocket, directed in a line parallel to the horizon, passes through a medium of equal density, but if directed perpendicular to the horizon, from the moment it leaves the ground till it arrives at its greatest height, it penetrates and passes through an atmosphere whose density is continually decreasing, and consequently its impelling force meets with less resistance. But when we consider the increase of the force of the rocket, there is no comparison between that force, and the diminution of the density of the air.

From these premises it follows, that the ascension of rockets of all kinds is governed by one principle, namely, the disengagement of gaseous fluids and caloric, which displacing an equal volume of atmospheric air, operates by mutual contact.

Since, however, the air is heavier than the gases produced by the rocket, as the latter are greatly expanded, it is evident, that the gases will ascend; their specific gravity at the time of dilatation being less than that of the air.

The gases proceeding from the interior of the rocket, act therefore upon the air in the immediate vicinity of the orifice, and the rocket is consequently propelled, the stick guiding it in the direction given to it. If it were not for the rocket-stick or balance, its direction would be neither regular nor certain. Considering then, that, by the rocket-stick, the centre of gravity is changed from [13] the rocket itself to the stick, the motion is regulated in its perpendicular flight by the stick. The rocket-stick must be always of a proportionate length and weight to the rocket.

The motion given to rockets is always to be considered, for this depends upon the direction at first imparted; but the force of ascension is regulated by the size, and other circumstances which we have mentioned.

Assuming the principle of constant force acting upon the rocket, its velocity will increase with the time, and will be as the squares of the time, according to the principles of uniform accelerated motion; but if the force varies from uniformity, then the velocity and spaces will proportionably vary.

As action and re-action must be equal, the repulsion produced by the action of the gases upon the air is equal to the force impelling the rocket. The constant action produces equal acceleration of the motion.

On the subject of the condensation and dilatation of air, and the different pressures at a mean temperature, which is more or less connected with this inquiry, the reader may consult with advantage, the work of Mr. Biot, (*Traité de Physique*, &c. tome i, p. 110, and 141.) The conclusions of Mr. Robins on the gaseous products of gunpowder, and the elasticity of those products, may be seen by referring to the article on *gunpowder*.

It must be confessed, that the theory of rockets differs in many essential particulars from that of the usual projectiles; for the motion of rockets is more complicated than that of common projectiles, and is described to partake of all the anomalies that attend

the accelerated motion arising from the rocket composition, and the uniform motion of the rocket-case, after the composition is expended. It is a fact, which appears to be established, that little or no advantage has yet been gained from the experiments that have been made with cannon, even where the angle of elevation, and the initial velocity of the ball were both accurately known. It seems totally useless to look for mathematical investigations, with respect to determining the ranges, &c. of military rockets; because, if we could determine, with the greatest accuracy, the point, position, and velocity of the rocket, at the moment when the composition was expended, the remaining part of its track would still be subject to all the inequalities attending on common projectiles. During the burning of the rocket, however, its motion might, by a series of experiments, be reduced to precise rules. As the principles of gunnery, or rather of projectiles, involve a number of collateral circumstances, such as the exact momentum of [14]
any given ball when projected with a given velocity, and from a given distance, the subject is still not fully settled; but they are so far conclusive, that the resistance of the air to the same ball is as some function of the velocity. The remarks of Dr. Hutton on this head would be too lengthy. A rocket, however, is very different. The very medium, in this case, is the principal agent in producing the motion; and being enabled to ascertain all the successive energies of the propelling power, and the resisting force, we may thus far determine correctly. It is suggested, that a rocket fixed to the ballistic pendulum would determine its whole energy; but, in order to make the experiment more perfect, it is proposed to attach it to a wheel, or revolving body, and then to measure its successive energies by the motion of some weight attached to the revolving axis of the machine. It is worthy of remark, that it is impossible to accommodate or determine the motion of rockets by other projectiles; and, therefore, to ascertain their momentum, such a contrivance would be eminently useful.

Mr. Moore of the Royal Military Academy, Great Britain, (*Treatise on the motion and flight of rockets*,) who seems to have adopted the hypothesis of Dr. Desaguliers, respecting the momentum of the ignited composition, has given a variety of problems relative to the motion and flight of rockets in non-resisting mediums, some of which we purpose to notice.

Mariotte and Desaguliers have given two distinct theories of the motion of rockets. The latter ascribes their motion to the momentum of combustion, and the former to the elastic nature of the gaseous fluid, generated by the combustion, and the resistance of air. The observations of Desaguliers are the following: "Conceive the rocket to have no vent at the choke, and to be set on fire, the consequence will be, either that the rocket will burst in the weakest place, or if all the parts be equally strong, and be able to sustain the impulse of the flame, the rocket will burn out immoveable. Now, as the force of the flame is equable, suppose its action downwards, or that upwards, to lift 40 pounds; as these forces are equal, but their directions contrary, they will destroy each other's action. Imagine then the rocket opened at the choke; by this means, the action of the flame downwards is taken away, and there remains a force equal to forty pounds, acting upwards, to carry up the rocket and stick." This theory, however ingenious, is not altogether true; for it is asserted on the contrary, that the action of the flame or gas within the rocket, when closed, as supposed above, is conceived to arise wholly from the elastic nature of the gas, and the reaction it experiences [15]
against the ends and sides of the rocket-case; the whole of which ceases as soon as a free vent is given to the flame; and, therefore, if a rocket could be fixed in a vacuum, as the flame would, in that case, experience no resistance, there would be no reaction, and consequently, no motion would ensue. Some experiments, analogous to this position, have been made. We may merely add, with respect to Mariotte's theory, that he attributes the motion of the rocket to the resistance and reaction of the air, in consequence of which the propelling force will decrease as the velocity increases, owing to the partial vacuum left behind the rocket in its flight; so that the correct solution of the problem necessarily involves the integration of partial differences of the highest orders.

We may remark also, from the premises already established, that the first motion of the rocket, like all other motions not produced by a great momentary impulse, is slow; and before the stick is clear of the flame, gravity has been acting upon the rocket, and depressed it below its natural position, while the stick is prevented from being equally depressed, by the top of the frame; so that the angle of projection is in fact considerably less than the angle of the frame, or slope of the rocket's first position. In consequence of this, the rocket has the appearance of falling the moment after projection; and, for this reason also, the angle for producing the greatest range of a rocket exceeds very considerably that which gives the extreme range of a shell projected from a mortar. There are various propositions given by Mr. Moore respecting rockets, but to give the calculus, &c. would take up more room than we could appropriate to this abstract question. The nature of these propositions, however, may be given in a few words, *viz*: The strength or force of the gas from the inflamed composition of a rocket being given, as also the weight and quantity of the composition, the time of its burning, and the weight and dimensions of the case and stick, to find the height to which it will ascend, when projected perpendicularly upwards. After making the necessary calculation, he concludes by observing, that, having determined the height of the rocket, and its velocity, when the composition is just consumed, it follows that its whole height may be determined in the usual manner by the known formula, for the ascent and descent of heavy bodies. Another proposition is that of determining the path of a rocket near the earth's surface, neglecting the resistance of the air; and among others, for finding the horizontal range of a rocket, the angle of elevation, and the time the composition is on fire, being given. [16]

The observations of Mr. Peyre, (*Le Mouvement Igné*,) are confined principally to the effects of gunpowder; and although applied to the use of gunpowder, and the theory of its explosive effects, yet there is nothing in immediate relation with this subject. The generation of gaseous fluid, and its impelling power, and the consequent recoil of pieces, predicated in fact on the ingenious experiments and conclusions of Mr. Robins, may furnish some data on this head. But the principles of accelerated motion, on which the effective power of war-rockets depends, this accelerated motion being no other than the acquired velocity of their recoil, necessarily involves a question of a different kind from that of common projectiles.

The *caduceus* rocket has not much more than half the power of ascension as the single rockets; because, being composed of two rockets placed at an angle of 90 degrees, with the usual counterpoise, (the stick), it forms in its flight a serpentine motion resembling two spiral lines, or double worm; and although by reason of the stick it ascends vertically, yet the great resistance it meets with from the air, in consequence of this motion, causes its flight to be considerably retarded.

On the contrary, when rockets are fixed one on the top of another, called *towering rockets*, their effect is not at all diminished; for they experience no additional resistance, as the small rocket is placed in the head of the large one; and when the latter arrives at the maximum of elevation, it communicates fire to the former, which then rises as far beyond the first, if not higher, in consequence of the pressure of the atmosphere being less, as it would, if discharged by itself on the ground. Sky rockets, however, which are merely placed on one stick, do not, unless so required, act in this manner. Although two, three, or more, may be so arranged, yet the intention is nothing more than to combine their effect, so that their tails may appear as one stream of fire. Nevertheless, they may be so arranged, as that when one is consumed, another may take its place, and produce a new volume of fire, and, in this case, they would mount to a great height.

Tourbillons, usually called the common or table *tourbillons*, which receive their name from the whirling motion they take in their flight, produce also, by the arrangement of their cases, and the cross stick which serves as a balance, a horizontal and rotary motion; and while one part of the fire serves to elevate them, another part, issuing in a horizontal direction, but at opposite sides [17]
and extremities, gives to the tourbillon a wheeling motion. The mosaic tourbillons are of a different kind, and intended for another effect. Tourbillons of this kind preserve a regular and constant motion.

The *mosaic candle* owes its effect, in a great measure, to the rocket composition. Using alternately, composition, meal-powder, and a star, ramming the composition sufficiently, but not so as to break the stars, a case is formed, the effect of which is brilliant and striking. Besides the rapid combustion of the composition, the stars, when the fire comes to the meal-powder, are thrown out by it in succession, and to the height of one hundred and more feet. We have also, in this instance, the effect of the rocket composition, and that of gunpowder; the last of which, acting in the case in the same manner as powder in a musket on a ball, throws the stars to a great height. Hence the *effect* is varied according to the manner of loading the case; and by employing alternately the substances we have mentioned, the effects follow in regular succession. The use of gunpowder in this manner, is strikingly shown in many other fire-works. When, for instance, stars, serpents, &c. forming the furniture of a rocket, are to be dispersed, gunpowder is put in the head or conical cap of the rocket, and fire is communicated to it at the moment the rocket has arrived at its extreme elevation. In the bursting of paper shells, the same effect ensues, and the different substances contained in the shell are dispersed in every direction.

Balloons are nothing more than shells made either of paper, or wood turned hollow. These balloons are discharged from mortars, or fire-pots, sometimes called pots of ordnance. They are merely cylinders of various diameters, made of paper and very thick, or of metal, and are furnished at their bottom with a conical cavity lined with copper, designed to hold the charge of powder. When the balloon is filled, (see *Balloons*), it is introduced into the mortar over the charge, and being furnished with a fuse as in other shells, takes fire the moment the powder is inflamed. According to the quantity of powder made use of, so will be the height of ascension. By determining the ascension, and the time required for the fuse to burn, and communicate fire to the shell, we may fix the precise moment for its explosion. The powder contained in the shell is sufficient only to burst it, and disperse its contents. (See *Mortars*, *Fire-pots*, and *pots of Aigrette*.)

A balloon will contain more stars, serpents, &c. than the head of an ordinary rocket, and the effect which they produce, must of [18]
course be more striking. The Congreve rocket, calculated as it is to convey carcass composition, balls, grenades, &c. if furnished

with stars, crackers, &c. would produce an effect equal, if not superior to the balloon.

We remarked, that, in common sky rockets, the charges consist of a mixture of gunpowder, saltpetre, and charcoal, with occasionally other additions, as steel-filings. *Rocket-stars*, on the contrary, are usually formed of mealed powder, saltpetre, sulphur, and sometimes other substances according to the colour of the flame required. Thus, for the *white star*, composition oil of spike, (a preparation of Barbadoes tar, and spirit of turpentine), and camphor are employed; the camphor giving to the flame a white appearance. The *blue stars* owe their colour to sulphur, which is in the proportion of one to four of the meal-powder; the *variegated stars* have the same materials, with sulphur vivum, and camphor; and the *brilliant stars*, *common stars*, and a variety of others, we shall mention in their proper places, are all formed by the addition of sundry substances.

The variety of *rains*, as *gold rain*, *silver rain*, &c. are differently prepared. Besides saltpetre, meal-powder, and sulphur, gold rain contains in its composition the filings of brass, saw-dust, and pulverized glass. In this instance, the saw-dust communicates colour, while the brass and the glass are thrown out, the former partly consumed, and the latter partially fused by the intense heat. The same effect may be produced by meal-powder, saltpetre, and charcoal, or saltpetre, sulphur, antimony, brass filings, saw-dust, and pulverized glass. Here the antimony, as well as the brass, communicates the golden colour. (*See antimony.*) Silver rain is generally formed of saltpetre, sulphur, meal-powder, antimony, and sal prunelle, but without saw-dust; the antimony communicating silver brilliancy to the flame. It may also be formed, by employing, in given proportions, saltpetre, sulphur, and charcoal, the particular effect depending upon the proportions; or by using antimony in lieu of the charcoal, or in the place of the antimony, steel-filings. Whether antimony or steel-filings are used, the effect of their combustion is the same, forming in the one instance, an oxide of antimony, and in the other, an oxide of iron. Both gold and silver rain is employed chiefly for sky-rockets. As to the colours required, they may be formed of other substances.

The charges for *water-rockets* are also various. In some of which, besides the usual ingredients, (meal-powder, saltpetre, and sulphur,) sea-coal, steel-filings, saw-dust, &c. enter into their composition. [19]

As to the different compositions, it will be sufficient to remark, that for *wheels*, *fixed cases*, *sun cases*, *gerbes*, *Chinese fire*, *tourbillons*, *water balloons*, *water squibs*, *serpents*, *port-fires*, *cones*, *globes*, *air-balloon fuses*, *fire-pumps*, and many others to be noticed hereafter, the basis of them is either gunpowder or saltpetre, and sulphur and charcoal, with or without additions. With respect to the composition of the stars of different colours, it is to be observed, that the particular colour is given by pulverized cast-iron, steel-filings, camphor, amber, antimony, perchloride of mercury, (corrosive sublimate), ivory-dust, copper, frankincense, &c. To produce *tails of sparks*, pitch or rosin is added. Stars which produce *some* sparks are usually made by using gum water in mixing the composition. The gum appears to produce a separation of the inflammable substances, and, as it is not combustible, to check, as it were, the rapidity of the combustion. In some preparations, also, isinglass or fish-glue is used in solution. This, no doubt, acts in the same manner, as well as to give firmness to the composition; but its solution is also used as a vehicle. On the same principle also, we learn the use of caustic ley, quicklime, &c. in preparing match-rope. After soaking the cord in a solution of nitre, it is afterwards dipped into ley, which is nothing more than a solution of potash rendered caustic by means of quicklime. The potash evidently checks the combustion. The formulæ for slow match, are, however, various. In the match-wood, also, prepared from the wood or bark of the linden, the wood is usually first soaked in a solution of saltpetre, and afterwards in a solution of acetate or sugar of lead, &c. For the same purpose, nitrate of copper is recommended. For stars of a yellow colour, besides gum arabic, or gum tragacanth, saltpetre, and sulphur, the addition of powdered glass, orpiment, (sulphuret of arsenic), and white amber, are occasionally made. The colour is owing to the amber and the orpiment, which have the property of communicating it to flame. We may observe, generally, that the colours produced by different compositions, is a subject of importance to the pyrotechnist. He should know the properties of each substance, and the effect of each ingredient; and, with respect to their action, be able to foretell the appearance of the flame, and other circumstances connected with the art. As a general example, we may state, that sulphur gives a blue; camphor, a white, or pale colour; saltpetre, a clear white yellow; amber, a colour inclining to yellow; muriate of ammonia, (sal ammoniac), a green; antimony, a reddish; rosin, a copper colour, and Greek pitch, a bronze, or a [20] colour between red and yellow. In using these substances, the following remarks may be useful;—that for producing a white flame, the saltpetre should be the chief part; for blue, the sulphur; for flame inclining to red, the saltpetre should be the principal ingredient, using at the same time, antimony and pitch. (See *matches of different colours*, in Part ii.)

Coloured flame may be produced by various other substances, many of which are expensive, and therefore could not be employed economically. Thus, in fire-works made with hydrogen gas, or inflammable air, which have a pleasing effect, by forcing the gas, either from a bladder, oiled-silk bag, or gas-holder, through a variety of revolving jets, which are so arranged as to exhibit stars, or through pipes furnished with small apertures, &c. to resemble different standing figures,—the effect may be varied by previously mixing the gas with the vapour of ether, and other substances, which communicate to the flame, particular colours, which, in a darkened room, are extremely brilliant. Cartwright's fire-works are formed in this manner. (See *fire-works with inflammable air*.)

Muriate of strontian, mixed with alcohol, or spirit of wine, will give a carmine-red flame. For this experiment, one part of the muriate is added to three or four parts of alcohol. Muriate of lime produces, with alcohol, an orange-coloured flame. Nitrate of copper produces an emerald-green flame. Common salt and nitre, with alcohol, give a yellow flame. (See *Illuminations and Transparencies*.)

In addition to the facts already stated, it may be proper to observe, that the ingredients employed to *show in sparks*, which are rammed in *choaked cases*, are various, according to the colours required; as black, white, gray, and red. The black charges are composed of meal-powder and charcoal; the white, of saltpetre, sulphur, and charcoal; the gray, of meal powder, saltpetre, sulphur, and charcoal; and the red, of meal-powder, charcoal, and saw-dust. These are considered regular or set charges, to which we may add two others, called compound and brilliant charges. The compound charges contain a variety of substances which afford sparks; and hence, besides the usual inflammable bodies, saw-dust, antimony, steel and brass-filings, are used. The brilliant fires owe their particular effect to the presence of steel-filings, or pulverized cast-iron. Iron, in any of its states, when minutely divided, has the same effect.

Quick match is usually formed of cotton, by soaking it in a solution of nitre, and adding meal-powder. A solution of isinglass is [21] sometimes used. The etoupille of the French is of the same nature. The manner, quick and slow match, &c. are prepared, with the various formulæ, will be considered under their respective heads. Touch paper, for capping serpents, crackers, &c. will also be noticed. The pyrotechnical spunge owes its inflammability to nitre.

In the various composition of aquatic fire-works, although more care and attention are required, it is to be observed, that, in forming water-rockets, horizontal wheels, water-mines, fire-globes, water-balloons, water-squibs, water-fire-fountains, and the like, substances are generally used along with the usual ingredients, which, under particular circumstances, may be said to *repel*, as well as resist the action of the water; and in this particular they resemble the celebrated Greek fire, of which we shall speak hereafter. This remark, however, applies only to certain works. After the rockets have been filled, their ends are dipped in melted rosin or sealing-wax, or secured with grease.

Fire-works, usually exhibited in rooms, are made with odoriferous gums and perfumes, and hence are called odoriferous fire-works. We may remark, that the odour or perfume is given by a variety of substances; for these, at a high temperature, are partly consumed, and partly evaporated. Thus camphor, yellow amber, flowers of benzoin, myrrh, frankincense, cedar-raspings, and the essential oils, particularly of bergamot, are employed for this purpose. Scented fire-works are of the same character. The Italians and the French, who have made more experiments in Pyrotechny, than other nations, have improved odoriferous fire-works. In these compositions, they also employ storax, calamite, gum benzoin, and other substances. *Scented fire* was greatly in use in Egypt, Rome, and Athens, at their fetes and public ceremonies. The unpleasant smell which gunpowder, sulphur, &c. occasion in a confined apartment, has induced the modern artificers to add sundry odoriferous substances to their pyro-mixtures. On this subject, it will be sufficient to observe, that the *scented vase*, which was in use at Athens, contained the following substances: storax, benzoin, frankincense, camphor, gum juniper in grains, and charcoal of the willow. It does not appear that nitre was employed. The custom of burning frankincense before the altar, is indeed very ancient; for, in the primitive temple at Jerusalem, the custom was adopted by the priests in the Sanctum Sanctorum, and is continued by the Greeks and Armenians, the Jews, the Turks, the Persians, (especially the followers of Zoroaster), preserve this custom. The *Holy Fire* of the latter is nothing more than [22] the inflamed carburetted hydrogen gas, which comes from the naphtha ground at Baku.

Besides the use of nitre in pyrotechnical compositions, as it forms an essential part in all of them, there is another salt we had occasion to notice, of which an account will be given hereafter, that affords a variety of amusing experiments. This salt is the hyperoxymuriate or chlorate of potassa. Although it has neither been used for fire-works on an extensive scale, nor does it enter into any of the compositions usually made for exhibition, yet its effect is not the less amusing. Some general idea may be had of its effect, by stating a few experiments. If a mixture of this salt and white sugar be made in a mortar, and the mixture laid on a slab or tile, and a string wetted with sulphuric acid, (oil of vitriol), be brought in contact with it, or a drop or two of the acid be let fall upon it, a vivid combustion will take place. In this experiment, the acid decomposes the salt, and the oxygen unites with the carbon and hydrogen of the sugar, and forms carbonic acid and water. The same salt, rubbed in a mortar with sulphur, will produce a crackling noise resembling that of a whip; and if a mixture of the two be struck with a hammer, the percussion will cause a loud detonation. The same thing happens when phosphorus is used, but the detonation is more violent. Various other experiments may be made with it. It forms the principal part of the match, called the *pocket lights*. These are made, in the first place, by dipping the wood previously cut in splints in melted sulphur, and afterwards in a mixture of this salt with sugar, which is moistened with water. The match is then dried. When used, it is dipped in sulphuric acid. The red colour, usually given to the match, is formed by mixing with the composition some vermillion. Another application of the same principle, is the firing of cannon. For this purpose, after the tube is filled with powder, a covering of the same mixture is applied when mixed with water. It is then dried. When the tube is put in the vent, a drop of sulphuric acid will inflame it, and consequently discharge the gun. This salt also, when mixed with sulphur, may be used to fire fowling pieces, provided the lock be so constructed, as in a late invention, that it acts by percussion. (See Thenard's Priming powder.)

The Rev. Alexander Forsyth of Alexander Forsyth of Belhelvie, in Aberdeenshire, Scotland, took out a patent for a new kind of gun-lock, to be used without a flint, and has contrived to inflame powder merely by percussion. The powder employed for priming, [23] consists of chlorate of potassa and sulphur. The gun-lock is calculated for firing cannon as well as musquetry; it is contrived to hold forty primings of such powder; and the act of raising the cock primes the piece. Each charge of priming is supposed to contain one-eighth of a grain of the salt. There are other substances which also produce fire by percussion. The fulminating silver, mixed with any substance, or used by itself, will detonate by percussion. It should be used with great caution. A grain or two will explode with great violence. (See *Detonating Works*, *Waterloo crackers*, *&c.*)

There are several other metallic preparations which detonate violently, such as the fulminating gold, fulminating mercury, &c. all of which must be used with extreme caution. (See the respective articles.)

Sec. IV. Of Illuminations.

Although nothing of much importance can be said on the subject of illumination, yet at the same time, as it is connected with some remarks we will hereafter offer, it may be proper to observe, that the practice of illuminating, as well as the exhibition of fire-works in public rejoicings, has been in use for many years. The former indeed has been customary for many centuries. We have, however, appropriated an article to the manner of forming illuminations and transparencies, and also on imitative fire-works.

Illuminations, whether with lamps, candles, flambeaux, &c. may be rendered more impressive from the manner of their arrangement. In some instances different coloured flames have been used; and the effect in this case is more grand and beautiful.

The public lighting of cities on festivals, and particularly on joyful occasions, called illuminations, is of great antiquity. Indeed, illuminations are a general expression of the public feeling, and should, on important occasions, be encouraged. Victories gained over an enemy by the army or navy are subjects of rejoicing. While, in such cases, illuminations may be viewed as an *expression* of the feelings of the people, they serve moreover to stimulate, in the spirit of the *amor patriæ*, the future actions of the patriot and the soldier; and while such rejoicings are demonstrative of victory, they are equally expressive of that virtuous feeling, of which every one must partake, on the return of an honourable peace.

What could have been more impressive than the brilliant spectacle exhibited in Paris in 1739, on the return of peace? Besides [24] illuminations, the fire-works on that occasion were truly magnificent. The same may be said of those at Pont Neuf, and those at Versailles in the same year. We shall have occasion to speak of them, when we come to the arrangement or the order of fire-works for exhibition.

The Egyptians at an early period, made use of illuminations, and particularly at a festival, which is mentioned by the Greek authors. During the festival, as Herodotus says, lamps were placed before all the houses throughout the country, and kept burning the whole night.

During the festival of the Jews, called *festum encæniorum*, the feast of the Dedication of the Temple, the lamps were lighted before each of the houses, and the festival continued eight days. Illuminations were also used in Greece, according to a passage in Æschylus. When games were exhibited in the night-time at Rome, the forum was lighted. Caligula, on a similar occasion, caused the city to be illuminated. In honour of the great orator Cicero, as he was returning home at night, after the defeat of Cataline's conspiracy, lamps and torches were lighted in all the streets. Byzantium, afterwards Constantinople, was ordered to be illuminated with lamps and wax candles on an Easter eve, in the time of Constantine.

That this custom was prevalent among the christians in the first century, is evident from many authors. Professor Beckman, in his *History of Inventions*, vol. iii, p. 383, says, that "the fathers of the first century frequently inveigh against the christians, because, to please the heathens, they often illuminated their houses, on idolatrous festivals, in a more elegant manner than they. This they considered as a species of idolatry. That the houses of the ancients were illuminated on birth-days, by suspending lamps from chains, is too well known to require any proof."

At Damascus, the Turks always keep a lamp burning over the tomb, as it is called, of Ananias, which they much reverenced. It is said to be in the same house in which St. Paul lodged with Judas. (See *Maundrel's Travels from Aleppo to Jerusalem*.)

Lamps, according to Dr. Pococke, are kept continually burning in the Jewish synagogue at Old Cairo, said to have been built about sixteen hundred years ago. (See *Pococke's Travels through Egypt*.)

In Persia, lamps are kept burning in consequence of some religious notion, and particularly at the sepulchre of Seid Ibraham. (See *Travels through Muscovy into Persia*.)

A lighted lamp is frequently put up in Persia as a mark to shoot at. To be a good shot, the marksman must extinguish it. At the [25] celebration of the feast called Ashur or Ten, from its lasting ten days, which is kept in memory of Hossein, the youngest son of Hali, the Persians make use of rags dipped in suet and naphtha, and burn them in lamps; and their courts are lighted up with thousands of lamps, the light from which is increased by as many more lanterns made of paper, that are fastened to cords drawn across the court.

The Chinese, in celebrating their solemn feasts, especially on the 15th day of the first month, called the Feast of the lanterns, from the multitude and grandeur of the lamps they exhibit in the evening, are remarkable for the splendour of their exhibitions. We are informed, (*A Description of China, &c.*), that many of the grandees, retrenching every year something from their tables, apparel, and equipage, to show the greater magnificence in the lanterns, used on this occasion, expend the sum of 2000 crowns. The largest are about twenty feet in diameter, and are lighted by an immense number of wax candles and lamps; but those that are most common, are of a middling size. These are generally composed of six faces, or panes, each of which has a frame of varnished wood, adorned with gildings four feet high, a foot and a half broad, covered on the inside with fine transparent silk, on which are painted flowers, trees, rocks, and sometimes human figures. The painting is very curious, the colours lively, and the wax candles give the painting a beautiful splendour. These six pannels joined together, compose a hexagon, surmounted at the extremities by six carved figures, that form its crown. Around it are hung broad strings of satin, of all colours, with other silken ornaments, that fall upon the angles without hiding the light of the pictures. The feast of the lanterns is also celebrated by bonfires and fire-works.

Candles are also used for the same purpose. Chandeliers, differently made, and holding a greater or smaller number of candles, add greatly to the effect.

The candles used by the natives of Otaheite are curiously made. According to Cooke, (*First Voyage, &c.*), they have candles made of a kind of oily nut, which they stick one over another upon a skewer thrust through the middle of them. The upper one being lighted, burns down to the second, at the same time consuming that part of the skewer which goes through it; the second, taking fire, burns in the same manner down to the third, and so of the rest. These candles give a tolerable light, and some of them [26] will burn a considerable time.

The lighting of streets, Beckman considers in some respects to be a modern invention, and after quoting various authorities concludes, that, of modern cities, Paris was the first that followed the example of the ancients by lighting its streets. It appears, therefore, that the practice of illuminating was reserved by the ancients for some great occasion, that lighting of the streets was more or less partial, and confined to particular places, and that it was not general without some particular occasion called for it. (See *Illuminations.*)

Kircher, the German philosopher, had a wick made of amianthus, which burnt for two years without injury, and was at last destroyed by accident.[8] The Greenland stone flax, which is the same as amianthus, the Rev. Mr. Edge says is used in Greenland for lamp wicks, and burn without being in the least wasted, whilst supplied with oil or fat. Ellis (*Voyage for the Discovery of a North-West Passage*), found the mountain flax, (asbestus), among other minerals, on the Resolution Islands, inhabited by the Esquimaux, which is used for similar purposes. We may remark here, that the Esquimaux use stone for lamps, which they hollow out, and, according to circumstances, use also dried *goose dung* for wick.

Sec. V. Of some of the Feats or Performances by Fire.

We introduce this subject to show, that certain kinds of fire-works have been employed for the purpose of deceiving the ignorant, and amusing the better informed part of mankind. Many of the tricks of jugglers and slight-of-hand men, and the performances of certain rites, particularly by the ancient magi, and pagan priests, come under this head. Sundry substances, in [27] connection with artificial fire, have been employed by persons of this description. It is true, our account of them is rather imperfect. Had the works of Celsius, which he wrote against the ancient magi, been preserved, we would, no doubt, have been better acquainted with the art of the ancient conjurors and jugglers.

Professor Beckman has endeavoured to trace the origin of the necromantic art; but although of opinion that it is very ancient, and founded in superstition and unnatural causes, he is of opinion, that the works of Celsius, which are lost, were full on the subject, and for that reason our account must be imperfect.

Plain common sense, but with enlightened reason, has alone convinced mankind of the follies of older generations, and of relying on superstitious ceremonies, or believing in miracles, exorcism, conjuration, necromancy, sorcery, or witchcraft.

The torch of reason, and experimental philosophy have dispelled the clouds of ignorance and superstition; and men, becoming more enlightened as they progress in the investigation of truth, are no longer under the influence of false doctrines, or led away by a bigoted priesthood. Philosophical experiments, the various optical illusions, the effects of electricity, magnetism, &c. are founded on immutable truths, which become the more familiar as we progress in science.

Truth, however, although elicited by the genius of great men, who have lived in every age, was suffered to be brought to the rack; because it either militated against the views of the priesthood, and enlightened the people, or curtailed the ecclesiastical power and authority of the church.

Because Anaxagoras taught that the sun and stars were not deities, but masses of corruptible matter, he was tried and condemned in Greece. Accusations of a similar nature contributed to the death of Socrates. Copernicus, in consequence of the threats of bigots and the fear of persecution, was prevented from publishing, during his life time, his discovery of the true system of the world; and it is well known, that the great Galileo was imprisoned a year, and then obliged to renounce the motion of the earth, because he asserted it. In 1742, a commentary on Newton's *Principia*, one of the first productions of human genius, was not allowed to be printed at Rome, in consequence of its promulgation of this doctrine; and, in the true spirit of *priest-craft*, the commentators were obliged to prefix to their work a declaration, *that on this point, they submitted to the decisions of the supreme* [28] *pontiffs*! Such are the results of bigotry, ignorance, superstition, and especially of civil and ecclesiastical governments, that consider learning a curse, and ignorance a blessing! Happily for the people of the United States, their co-equal rights and enlightened reason, will ever guarantee them against tyranny on the one hand, and fanaticism on the other. Superstition has always been an engine of oppression, and wherever it prevails, the powerful are sure to make use of it to oppress and destroy the weak.

Another instance of the assumed prerogative of the holy fathers may be found in their conduct towards the house of Medici; for the pontiffs, it is known, induced the house of Medici, by granting it the cardinalship, to suppress the academy del Cimento. The reason of this step is obvious to all; for they were sensible, that, if the people became once enlightened, they would lose their weight, their influence, and authority. But as jugglers are conscious of their gross deceptions, working on the imagination and credulity of the multitude, they in this respect appear at least to know themselves. Like the juggler mentioned in Xenophon, who requested the gods to allow him to remain in places, where there was much money and abundance of simpletons, they acted as the prototype. We might enumerate, if it were not irrelevant to our subject, a number of facts concerning these impostors.[9]

The miracles wrought by Moses, as recorded in the books of Exodus, were, we have reason to believe, by the immediate [29] command of a supreme power. When Moses had commissioned Aaron (*Exodus*, chap. vii, verse 9, 10, &c.) to be a prophet, Aaron took a rod and cast it before Pharaoh and his servants, and it became a serpent; but it seems, however, that Pharaoh called the wise men and the sorcerers, called the magicians of Egypt, who performed the same thing with their enchantments; "for they cast down every man his rod, and they became serpents: *but Aaron's rod swallowed up their rods*." It appears that on another occasion, the waters were turned into blood by smiting them with the rod; "and the magicians of Egypt did so with their enchantments." When Aaron was commanded to stretch forth his hand with his rod over the streams, &c. frogs appeared upon the land, and the magicians did so likewise; but when vermin were brought forth, by smiting the land, the magicians were unsuccessful, and said unto Pharaoh, "*This is the finger of God*." In the continuation of the plague, Moses and Aaron were commanded to take the ashes of the furnace, before Pharaoh, and sprinkle them up towards Heaven; and it became a hail on man and beast, but the magicians were affected, and could not stand before Moses. When Moses stretched forth his rod towards heaven "hail, and fire mingled with hail," came down; and on another occasion, they brought forth locusts. When this plague ceased, Moses caused darkness to prevail.

We will merely observe, that, with regard to the magi of Egypt, who it is known possessed all the learning of the day, and were celebrated in after ages for superior wisdom, so much so that many of the Grecians resorted there to be initiated into their mysteries,—they were of a different description from those who really worked miracles, according to divine inspiration. Hence we find, that, although distinct in their character, the magicians of Egypt pretended to perform certain rites, and to work upon the feelings of the people. Their initiary process, which the Pythagoreans in many respects pursued, and traces of which are extant in the order of free-masonry, was merely intended to preserve their knowledge within the pale of, and veiled in, hieroglyphic [30] mystery, which none but the initiated could understand. Priestley, in his *Institutes of Moses*, points out the difference between the magi, so called, and the rites and ceremonies of the ancient Hebrews. But the imposition practised on mankind, even in modern times, aided by engines of the most abominable kind, as instruments of torture, in the inquisitorial tribunals of Portugal and Spain, are sufficient of themselves to call down the vengeance of impartial justice.

That the magicians were conscious of their inability to work miracles, is evident from their own declaration; for, after vermin had been brought forth by Moses and Aaron, they endeavoured to do the same, and being unsuccessful declared, that *this was the finger of God*; and many other instances are recorded of their attempts being altogether abortive. It appears also, that at first they believed they were able to perform all that Moses had done; and Pharaoh himself, by calling them together for that purpose, seemed to be of the same opinion, until he and his servants were finally convinced that Moses and Aaron wrought such miracles by inspiration. There can be no relation whatever between Moses and the magicians; for although he was, if we may judge from biblical history, acquainted with all the knowledge of the magicians, his mission was altogether of a different character. Many of the modern Greek and Armenian priests, in their celebration of the holy fire, palm upon their credulous followers, a belief, that they possess the power of working miracles, as will appear from the account we shall give of them. We will not enlarge on this subject at present, but pass on to consider the more common performances, which have excited the wonder and admiration of mankind.

The deception of breathing out flames, which excites the astonishment of the ignorant, is very ancient. When the slaves of Sicily, about two centuries ago, made a formidable insurrection, and avenged themselves in a cruel manner for the severities which they had suffered, there was among them a Syrian named Eunus, a man of great craft and courage, who, having passed through many scenes of life, had become acquainted with a variety of arts. He pretended to have immediate communication with the gods; was the oracle and leader of his fellow slaves; and, as is usual on such occasions, confirmed his divine mission by miracles. When, heated by enthusiasm, he was desirous of inspiring his followers with courage, he breathed flames or sparks among them from his [31] mouth while he was addressing them. We are told by historians, that, for this purpose, he pierced a nut shell at both ends, and, having filled it with some burning substance, put it into his mouth and breathed through it. Some affirm, that he used tow previously soaked in a solution of saltpetre. The deception at present is much better performed. The juggler rolls together some flax or hemp; sets it on fire; and suffers it to burn till it is nearly consumed; he then rolls round it, while burning, some more flax, and by these means the fire may be retained in it a long time. When he wishes to exhibit, he slips the ball into his mouth and breathes through it; which again revives the fire, so that a number of weak sparks proceed from it; and the performer sustains no hurt, provided he inspire the air not through the mouth but the nostrils.

By this art, the rabbi Bar-Cacheba, in the reign of the emperor Hadrian, made the credulous Jews believe, that he was the hoped for Messias, and two centuries after, the emperor Constantius was thrown into great terror, when Valentian informed him, that he had seen one of the body guards breathing out fire and flames in the evening.

It appears evident from the writings of Herodotus, that the ancients possessed a knowledge of attracting lightning, or the electric fluids with pointed instruments made of iron. He informs us, that the Thracians disarmed heaven of its thunder-bolts, by discharging arrows into the air; and the Hyperboreans by darting into the clouds, pikes headed with pieces of sharp pointed iron.

Pliny speaks of a process, by which Porsena caused fire from the heavens to fall upon a monster which ravaged his country. He mentions also, that Numa Pompilius, and Tullius Hostilius practised certain mysterious rites to call down the fire from heaven. What these mysterious rites were is of no moment; the fact is sufficient. Tullius, because he omitted some prescribed ceremony, is said to have been killed by the fire. A similar accident happened in France with the electrical kite.[10]

For deceptions with fire, the ancients employed a number of inflammable substances, which they dexterously used; among them, [32] naphtha, a fine bituminous oil, which readily inflames, was principally used. (For the effect of *naphtha*, *see Greek fire*.) Galen informs us, that a person excited great surprise by extinguishing a candle, and again lighting it without any other process than holding it against a wall or a stone. This, Galen observes, (*De Temperamentis*, iii. 2, p. 44.) was effected in consequence of the wall or stone being previously rubbed with sulphur, which, however, must have been something more. He also speaks of a mixture of sulphur and naphtha. If it had been phosphorus, or some of its preparations, it would appear more probable.

Plutarch relates the secret effects of naphtha, and observes, that Alexander was astonished and delighted, when it was exhibited to him in Ecbatana. Medea destroyed Creusa, the daughter of Creon, with this oil. This fact is stated by Plutarch, Pliny, Galen, and others, and believed by Beckman. She sent, it appears, to the unfortunate princess, a dress covered with it, which burst into flames as soon as she approached the fire of the altar. The dress of Hercules, which also took fire, was dipped in naphtha, though said to be in the blood of Nessus. On the subject of naphtha, Beckman remarks, "that this oil must have been employed when offerings caught fire in an imperceptible manner. *In all periods of the world, priests have acted as jugglers to simple and ignorant people.*"

The most ludicrous account of the necromantic art, by which similar tricks were performed, is that given by Celini, (*Life of Benvenuto Celini*, a Florentine Artist, by T. Nugent, LL. D. &c.) of a Sicilian priest, who drew circles on the floor with various ceremonies, using fire and different perfumes. Having made an opening to the circle, and thrown perfumes into the fire at a proper time, he observes, that in the space of an hour and half, "there appeared several legions of devils, insomuch that the amphitheatre was quite filled with them." Benvenuto, it seems, at the instance of the priest, asked some favours of them, which, however, he never realized. At a second exhibition he held a *pentagorun*, while the priests questioned the leaders of the demons "by the virtue and power of the eternal uncreated God," using the Hebrew, Greek, and Latin languages. The Demons appeared more numerous than at first, and more formidable. He states that "quivering like an aspen leaf, he took good care of the *perfumes*," and was directed by the priest "to burn proper perfumes." This ceremony was continued until the "bell rang for [33] morning prayers," and the priest "stripped off his gown and took up a wallet-full of books," declaring, "that as often as he had entered magic circles, nothing so extraordinary had ever happened to him!" How is it, in the language of professor Beckman, that "in all periods of the world, priests have acted as jugglers to simple and ignorant people?" * * * * *

This same Benvenuto Celini, however, was a man of intelligence. He wrote a work called the *History of Jewelry*; in which the first idea of phosphorescent mineral bodies is to be found. This work was written in the beginning of the 16th century. His life, although singularly marked, what with popes, priests, artists, and necromancers, presents a singular retrospect.

What was more absurd, and even profane, than the tricks of Joseph Balsamo, called Il Conte Cagliostro, who with Schœpfer, revived the study of the magical arts; and who with invocations, friction, fumigations, and optical deceptions astonished the ignorant of their day. Whether like Æneas, in his descent to hell, they made their way with their falchions through crowds of ghosts, or like Dioscorides, relied on the efficacy of herbs, or like Paracelsus, carried an evil spirit in their canes, or wore a *jewel* like Shakspeare's toad, which possessed marvellous virtues, or employed the magic stone (*agate*) of the east, and invoked their *urim and thummim*,—it is certain they worked upon the imagination of the people. By the application of *conium maculatum*, (hemlock) consisted the ceremony of ordaining a Hierophant; by the hartshorn of Orpheus, they had a divine remedy for the passions of the body; and by a mixture of *new mustard and olive oil*, they could produce a symphony, which invoked the spirits, and, Pythonesis like, declare to the people, that they "*had devils in their bellies*!!"

Of the phial of Cagliostro, Cardan relates that he had this phial twice exhibited to him, and complains bitterly of having seen nothing, after the anthem *Sancte Michael*, but some bubbles that issued from the bottom, though it was believed that these bubbles were angels! He says, "*Nihil tamen omnino vidi poste hanc invocationem nisi bulas pauculas quasdam ex imo gutti fundo exæstuantes*." Aulus Gellius and Hero mention tricks of this kind practised by the Egyptians. Roger Bacon, the alchymist, was excommunicated by the pope, and imprisoned ten years, for supposed dealings with the devil.

Equally absurd to a man of reflection, are the observations of antiquated writers on spontaneous generation, by heat. Borello [34] (*Physical History*) tells us, "that fresh water craw fish may be regenerated, by their own powder, calcined in a crucible, then boiled in water with a little sand, and left to cool, for a few days; when the animalcula will appear swimming merrily in the liquor, and must be then nourished with beef blood, till they attain the proper size to stock your ponds with."[11] The Sieur Pogeris and M. de Chamberlan, both agree with Signior Borello, but, in the chemistry of the matter, they add that the operation must be performed, *during the full of the moon!* If this *lunar system* be adopted, would not the *crab* also, have been a more favourable *sign* to have ruled the nativity of *craw fish*?

Swift, however, alludes to these agencies, fallacious as they are, in the following lines:

> "So *chymists* boast they have a power,
> "From the dead ashes of a flower,
> "Some faint resemblance to produce,
> "But not the virtue, taste, or juice."

Rochos, equally absurd with Borello, says, in *The Art of Nature*, that the ashes of *toads* will produce the very same effect, as the powder of *crabs' eyes*! Reasoning upon that ridiculous and unnatural principle of Cæsalpinus, in his comment on Aristotle, *Quæcumque ex semine fiunt, eadem fieri posse sine semine*, the procreation of eels from rye-meal, or mutton broth was predicated.

Julius Camillus, however, would out-do nature herself; for *Amatus Lusitanus* affirms, that he has seen his phials full of *homunculi* complete in all their parts! Paracelsus (*De Rerum Natura*,) had the same and many other absurd notions. What, we may truly say, has not been palmed upon the world, when we are told, that the following translation from a Hague Gazette, which appeared in the *British Evening Post*, No. 1645, contained facts, which were confidently believed by the ignorant:

"Mr. Tunestrick, by origin an Englishman, has just exhibited at Versailles, a very singular experiment. He opened the head of a sheep, and a horse from side to side, by driving a large iron wedge into the skull, by means of a mallet; drew the wedge out [35] afterwards, with pincers, and recalled the animals to life, by injecting through their exterior aperture with a tin syringe, a spirituous liquor of his own composition, to which he attributes surprising effects! The taste of this liquor resembles that of *Commandus Balm*!!" The remarkable effects of galvanism, however, are well authenticated; but *resuscitation*, notwithstanding all apparent life, has in no instance, to our knowledge, been effected. (See Ure's *Chemical Dictionary*, article Galvanism.)

Among other tricks, we may mention those with serpents, especially in the East Indies, and neighbouring islands, where a certain class of people exhibit them for money.[12]

Persons who could walk over red-hot coals, or red-hot iron, or who could hold them in their hands and their teeth, are frequently [36] mentioned. In the end of the 17th century, Richardson, an Englishman, was a great adept in this performance. We are assured he could chew burning coals, pour melted lead upon his tongue, swallow melted glass, &c; but the fact is incredible.

It is true, that the skin may be prepared in such a way as to become callous and insensible against the impression made on the feet and hands. It may be rendered as firm as shoes and gloves. Such callosity may be produced, if the skin is continually compressed, singed, pricked, or injured in any other manner. Beckman relates, that in 1765, he visited the copper-works at Awestad, when one of the workmen, for some money, took some of the melted copper in his hand, and after showing it, threw it against a wall. He performed a variety of other experiments with the melted metal.

The workmen at the Swedish melting-house have exhibited the same thing to some travellers in the 17th century. The skin is first rendered callous by frequently moistening it, as Beckman says, with sulphuric acid; and also, he remarks, by using the juice of certain plants. The skin must also be rubbed frequently, and for a long time, with oil. Haller, in his *Elementa Physiologica*, V. p. 16, speaks of this fact.

The manner of rendering the hands callous, or insensible, so that they may take up, and hold, ignited iron, charcoal, or other substances, may be seen in an English publication of 1667. The *Journal des Savants*, of 1677, contains the secret. "It consists in applying to the hands, various pastes, with spirits of sulphur, (sulphuric acid,) which destroys the epidermis, &c. and the nervous energy." This corroborates the account by Beckman. We read that Richardson had prepared his tongue in such a manner, that he could hold on the point of it a live coal, covering it first with pitch, rosin, and sulphur, and could hold a piece of ignited iron between his teeth. After showing the coal on his tongue, he would then extinguish it in his mouth. The *Mémoires de l'Académie* state, that a person who is salivated can put a live coal in his mouth. The *Dictionnaire de l'Industrie* observes, that the sulphur diminishes the heat of the coal, for the flame is less hot than a candle; and that the flame of a combination of pitch, rosin, and sulphur, is still less hot, and by no means so considerable as we would imagine. In the experiment, the rosin is not melted, and the [37] flame of the sulphur is inconsiderable. M. Gallois observes, that he witnessed in the Swedish iron founderies, the men hold melted cast iron in their hands, doubtless having them previously prepared.

The traces of this art may be found in the works of the ancients. A festival was held annually, on Mount Soracta, in Etruria, at which the Hirpi, who lived not far from Rome, jumped through burning coals, and on this account had certain privileges granted them by the Roman Senate.

Women also, we are informed, were accustomed to walk over burning coals, at Cartabola, in Cappadocia, near the temple dedicated to Diana. Servius remarks, that the Hirpi did not trust to their sanctity so much as they did to the preparation of their feet for the operation!

With respect to the ordeal by fire, which it seems was performed in several ways, one was, that when persons were accused, they were obliged to prove their innocence by holding in their hands red-hot iron. This mode of exculpation, as it is called, was allowed only to weak persons, who were unfit to wield arms, and particularly to monks and ecclesiastics, to whom, for the sake of their security, the trial by single combat was forbidden. In Grupius' learned dissertation, in the German, p. 679, as quoted by Beckman, we read, that the trial itself took place in the church, under the inspection of the clergy; mass was celebrated at the same time; the defendant and the iron, were consecrated, by being sprinkled with holy water; the clergy made the iron hot themselves; and they used all these preparations, as jugglers do many motions, only to divert the attention of the spectators. It was necessary that the accused person should remain at least three days and three nights, under their immediate care, and continue as long after. They covered their hands both before and after the proof; sealed and unsealed the covering: the former, as they pretended, to prevent the hands from being prepared by art; and the latter to see if they were burnt.

Some artificial preparation was undoubtedly necessary, or why prescribe three days for the defendant, who, if they wished to make him appear innocent, had a certain preventive against the actual cautery? The three days allotted, after the trial, were requisite, in order to restore the hands to their natural state. The sacred sealing secured them from the examination of presumptuous unbelievers.

When the ordeal was abolished, it no longer was kept secret. In the 13th century, an account of it was published by a Dominican [38] Monk, Albertus Magnus. In the work of this author, entitled, *De Mirabilibus Mundi*, he has given the receipt for the composition. It seems that it consisted in covering the hands with a kind of paste, and not by searing them. The sap of the althæa, or marsh mallow, the mucilaginous seeds of the fleabane, together with the white of an egg, were mixed, and by applying this mixture, the hands were as safe as if they had been secured by gloves. The use of this mixture, for the same purpose, may be traced back, it is said, to a pagan origin. In the Antigone of Sophocles, the guards, placed over the body of Polynicus, which had been carried away and buried, contrary to the orders of Creon, offered, in order to prove their innocence, to submit to any trial: "We will," said they, "take up red-hot iron in our hands, or walk through fire."

The ordeal, by heated ploughshares, was common in England. It seems, according to English History, that queen Emma had charges preferred against her, by Robert, archbishop of Canterbury, for consenting to the death of her son Alfred, and preparing poison for her son Edward, the Confessor. She claimed, by the law of the land, the ordeal, or trial, by burning ploughshares. She passed the nine ploughshares unhurt, which established her innocence, and caused the archbishop to fly the kingdom. The chief trials, by ordeal, appear to have been by fire, water, walking blindfold among heated ploughshares, and swallowing consecrated bread, which last was introduced about the time of pope Eugene. The custom was borrowed from the Mosaic law. An example of its practice occurs in the New Testament, in the story of Ananias and Sapphira; and the remembrance of it, as Blackstone remarks, still subsists among common people, as "*May this morsel be my last*;" "*May I be choked if it is so*," *and the like*; for it appears, that this ordeal was a piece of bread of about an ounce in weight, blessed by the priest, and given to the accused person, who was to try and swallow it, praying that it might choke him if he were guilty. The bible-ordeal, and the drowning-ordeal, are familiar to every one, degrading as they all must have been to human reason, and enlightened principles. Fox, in his *Book of Martyrs*, speaks of various ordeals, as well as the cruel deaths, and inhuman punishments inflicted, by the hand of bigotry, and fanaticism, under the cloak of religion, which were nothing more than a base and impious prostitution of its genuine principles.

Even among the modern Greeks, the same superstitious notions prevail. Almost every cavern about Athens has its particular [39] virtues, and is celebrated for various things; and the offerings, made by Grecian women, to the *destinies*, in order to make them propitious to their conjugal speculations, are equally absurd. These offerings, by which they are to work a miracle, consist of a cup of honey and white almonds, a cake on a little napkin, and a *vase of aromatic herbs, burning and exhaling an agreeable perfume*. We are told, however, that those evil spirits, whose assistance is invoked, for vengeance and blood, are not regaled upon cakes and honey, but on a piece of a priest's cap, or a rag from his garment, which are considered as the most favourable ingredients for the perpetration of malice and revenge. When a person is *hated*, another absurd custom is used, which is supposed to be followed by dreadful results. It consists in placing before his door, a log of wood, burnt at one end, with some hairs twisted round it. "This curse," says Mr. Dodwell, in his *Classical Tour*, "was placed with due solemnity, at the door of the English agent, Speridion Logotheti, while I was at Athens; but he rendered it of no avail, by summoning a great number of priests, who easily destroyed the spell, by benediction, frankincense, and holy water!" This story is much in character with that of the exorcism of rats, caterpillars, flies, and other insects, an old ritual of the papal church, performed between the feasts of Easter and the Ascension. A priest who resided at Bononia, performed the ceremony. "I went," he says, "to exorcise the insects in that country, accompanied by a curate, who was a droll fellow, and laughed at the credulity of the people, while he pocketed their money." It appears, however, that in all superstitious ceremonies, *fire*, under some form, was a pre-requisite; but *ecclesiastical fire-works* we leave within the pales of the priesthood.

The author of the *Dictionnaire de l'Industrie*, vol. iii, speaks of a trick, performed with a loaded musket and ball, which, although apparently inconsistent, is nevertheless true, if we consider the action of gunpowder equal. This *trick* is stated to be the firing of a musket, loaded with ball, at a person, without wounding, or in any way injuring him.

By taking a ball of solid lead of a smaller size than the calibre of the musket, and placing it on the charge in a gun, and as much or nearly so of powder, *over the ball*, the effect we are assured is, that when the gun is fired, the ball will pass out without any very sensible force, and even drop a few yards from the gun, although the report will be as great as if the charge and ball had been [40] used in the usual manner. This trick is often performed by jugglers, to the great astonishment of the spectators. The mode of *catching a cannon ball* is also of the same character.

The proper charge of powder for the cannon, is divided into two unequal portions, the lesser of which is placed in the gun as a charge; the ball is placed on it in the usual way, and the rest of the powder (by much the greater portion,) placed over the ball, the lesser quantity being not more than a twelfth part of the whole. A cannon, so charged, will not project the ball more than 20 yards, where it might be caught with safety.

Any person who has been in the custom of shooting, must have frequently observed, that when the shot happens to be mixed with the powder, its range is impeded; and, under similar circumstances, they have even been found only a few yards from the muzzle of the piece. This fact I have witnessed, although I confess I never once reflected on it.

As to the explanation of this phenomenon, it appears, that it can only be accounted for by referring to the action of two opposite forces, mutually repelling each other, added to that of the charge under the ball; hence, the *reaction* would be equal, if, under the same circumstances, both charges were alike situated: but the effect of the first charge is so much weakened by the counter effect of the second, that the projectile force of the ball becomes comparatively nothing.

There is another trick very often performed, which, however chemical, is not looked upon in that light, neither do performers attempt to explain it; we mean the exhibition of the *Glace Inflammable* of the French.

The preparation is made in the following manner: melt some spermaceti over a fire, and add a sufficient quantity of spirit of turpentine, and blend them together. The mixture when cold, will become solid, having somewhat the appearance of ice. If made in hot weather, the vessel containing the melted substances must be immersed in cold water. It does not, we are told, remain in a solid state any length of time.

It floats more or less in the fluid, which of course is the spirit of turpentine. The trick, with this preparation, after having put some of the solid and fluid substance together on a plate, is to pour upon it concentrated nitric acid, or a mixture of eight or ten parts of nitric acid, and two of sulphuric acid; inflammation ensues. It is no other in fact than accension of the oil of turpentine; the [41] addition of the spermaceti is altogether secondary, and its effect, if any, must retard instead of promoting the combustion of the turpentine. The art of making this preparation is in rendering the essential oil solid and transparent, without altering its inflammable properties.

There is another trick performed, by burning a thread, to which an ear-ring is tied, and which, notwithstanding the thread is reduced to a cinder, still holds the ring. This is what the French call the *Bague suspendue aux cendres d'un fil*. The string is first prepared by soaking it for 24 hours, in a solution of common salt, and drying it; then tying it to a ring, and setting it on fire, avoiding any vibration or oscillation of the string. It is obvious that the salt serves to render the cinder cohesive.

We have an account in Maundrel's *Travels from Aleppo to Jerusalem*, of the office of the *Holy Fire*. The ceremony is kept up by the Greeks and Armenians, from a persuasion that every Easter eve, a miraculous flame descends from heaven into the holy sepulchre, and lights all the lamps and candles, as the sacrifice was consumed at the prayers of Elijah.

"On our approaching the holy sepulchre," says Maundrel, "we found it crowded with a numerous and distracted mob, who made a hideous clamour; but with some difficulty pressing through the crowd, we got up in the gallery next to the Latin convent, where we could have a view of all that passed. The people began, by running with all their might, round the holy sepulchre, crying out 'huia,' which signifies, '*This is he*,' or, '*This is it*.' After this, they began to perform many antic tricks: sometimes they dragged one another along the floor round the sepulchre; sometimes marched round with a man upright upon another's shoulders; at others, took men with their heels upwards, and hurried them about with such indecency, as to expose their nudities; and sometimes they tumbled round the sepulchre like tumblers on a stage. In a word, nothing can be imagined more rude and extravagant than what was acted upon this occasion.

"This frantic humour continued from twelve till four, and then the Greeks first set out in a procession round the sepulchre, followed by the Armenians, and marched three times round it with their standards, streamers, crucifixes, and embroidered habits; and towards the end of the procession, a pidgeon came fluttering into the cupola over the sepulchre, at which the people redoubled their shouts and clamours, when the Latins told the English gentlemen, that this bird was let fly by the Greeks, to [42]
deceive the people with a belief that it was a visible descent of the Holy Ghost. The procession being over, the suffragan of the Greek patriarch, and the principal Armenian bishop, approached the door of the sepulchre, cut the string with which it was fastened, and breaking the seal, entered, shutting the door after them, all the candles and lamps within having been before extinguished in the presence of the Turks. As the accomplishment of the miracle drew near, the exclamations were redoubled, and the people pressed with such violence towards the door, that the Turks could not keep them off with the severest blows. This pressing forward was occasioned by the desire to light their candles at the holy flame as soon as it was brought out of the sepulchre. The two miracle-mongers had not been above a minute in the sepulchre, when the glimmering of the holy fire was seen through some chinks in the door, which made the mob as mad as any in bedlam; then presently came out the priests, with blazing torches in their hands, which they held up at the door of the sepulchre, while the people thronged with extraordinary zeal to obtain a part of the first and purest flame, though the Turks laid on with their clubs without mercy. Those who got the fire immediately applied it to their beards, faces, and bosoms, pretending that it would not burn like an earthly flame; but none of them would endure the experiment long enough to make good that pretension. However, so many tapers were presently lighted, that the whole church seemed in a blaze, and this illumination concluded the ceremony."

Maundrel afterwards observes, that the Latins take great pains to expose this ceremony as a shameful imposition, and a scandal to the Christian Religion: but the Greeks and Armenians, lay such stress upon it, that they make the pilgrimages chiefly on this account; and their priests have acted the cheat so long, that they are forced now to stand to it, for fear of endangering the apostacy of the people. They entertain many absurd ideas respecting the miraculous power of the holy fire. Even the melted wax of the candle, which had been lighted by it, is covered over with linen, and designed for winding-sheets; "for they imagine," says Maundrel, "that if they are buried in a shroud, smutted with this celestial fire, it will secure them from the flames of hell!"

Before concluding this article, we shall mention a subject highly interesting in optics, which, in some of its forms, was employed by the old magicians; we mean the phantasmagoria. The exhibitions of this kind, when first got up, drew the attention of [43]
Europeans, and particularly the French, who greatly improved the apparatus and machinery, and varied the forms and appearances. The principles of the phantasmagoria are described in every work on Natural Philosophy, which treats of optics. The *Dictionnaire de l'Industrie*, *Encyclopedie Méthodique*, Biot's *Traité de Physique*, in French and in English, the different treatises on philosophy and optics, particularly Dr. Smith's, the Cyclopedias, &c. contain either a description, or the principles of it. The third volume of Biot, especially, is full on the subject of optics. With regard, however, to the narrative and explanation of the appearance of the phantoms, and other figures, a subject which immediately concerns us, the account given by Mr. Nicholson, (*Journal of Natural Philosophy, Chymistry, and the Arts*, vol. i, p. 147.) is the most interesting. Connected with this optical illusion, is the imitation of lightning and thunder, which, from the account, appears also to have been performed.

The phantasmagoria may be considered nothing more than an application of the magic lantern, the invention of which is attributed to Roger Bacon, who was a contemporary with Vitellio, a native of Poland, who published a treatise on optics, in 1270. John Babtista Porta, of Naples, who discovered the camera obscura, having formed a society of ingenious persons at Naples, which he called the Academy of Secrets, wrote the *Magia Naturalis*, containing his account of this instrument, and, it is said, the first hint of the magic lantern. Kircher, it is known, received his first information of the magic lantern from this book, and afterwards improved it.

Adams (*Lectures on Natural and Experimental Philosophy*, vol. ii, p. 232. Appendix by the English editor) very justly observes, that persons, unacquainted with the principles of optics, have been surprised at the great illusion of their sight, by an artificial construction of many optical instruments, exhibited by showmen and others: such, for instance, as the optical and dioptrical paradox; the endless gallery; the animated balls by simple reflection; phantoms; causing the appearance of a flower from its ashes; the optical perspective box, and the cylindrical mirror: to which we may add, the enchanted bottle; the enchanted palace; the magic lantern; the magician's mirror; the perspective mirror; the camera obscura; distorting and oracular mirror; the diagonal opera glass, &c. &c.; all which may be seen in Smith's *School of Arts*.

We may also remark, that optical exhibitions sometimes accompany those of fire, when performed on a small scale. In the [44]
phantasmagoria, for instance, whether before, or at the time the exhibition commences, as well as after, thunder and lightning, if well imitated, produces a good effect.

The mechanism of the phantasmagoria is concealed from the spectators, who have only before their eyes a screen of gauze or gummed muslin posited vertically, which serves as the ground of a picture, where the images are depicted by reason of the transparency. The apartment is deprived of all light, except that which proceeds from an apparatus hid behind the screen. At the moment when the operation commences, a spectre appears (as a skeleton, the head of a celebrated person, &c.), at first extremely small, but which afterwards increases rapidly, and thus seems to advance at a great rate towards the spectators. And when the scene passes before them in a room representing a cave hung with black, a solemn silence being occasionally interrupted by mournful sounds from an appropriate musical instrument, it is not easy for an observer to defend himself from the impression of terror, at the sight of an object, in itself formed to produce the illusion, and which finds in the imagination a place already prepared for the reception of phantoms.

The instrument placed behind the gauze screen is in fact a peculiar construction of the magic lantern: only in the former, it is necessary that the lenses should run over a much greater space, and that the instrument may be susceptible of approaching to, and receding from, the frame of gauze, in such manner, that each luminous pencil may be depicted there in a single point. The general construction is this: In a square box, a lamp is placed, the luminous rays proceeding from which, are reflected by a conical mirror, towards an orifice made in the box. At this orifice is placed a tube, blackened within, and composed of several tubes which slide one into another, like those of a pocket telescope. This tube is furnished with two bi-convex lenses of about five inches diameter; one of these is fixed, the other is at the outer extremity of the tube, and is separated from the former in proportion as the tube is lengthened by the aid of a hooked lever situated along the tube, between the lamp and the lenses. A groove is properly adapted to the tube, destined to receive transparent figures; lastly, the box rests upon a table moveable on four wheels, that slide in two channels perpendicularly to the frame on which the images are depicted. It is manifest, that we may augment or diminish the dimensions of the images, and consequently make the spectre appear more or less near to the spectator, by separating farther, [45]
or by bringing nearer together, the two lenses; but then the focus of the diverging rays, which proceed from the same point of the transparent body, will be no longer upon the screen; we must, therefore, cause the machine so to recede or approach, that the two motions, being duly combined, the image may be distinctly formed.

These phantasmagoria are furnished with a great number of transparencies, in each of which, several changes may be made by slackening their springs. Thus we may change at every instant, the form, the magnitude, and the distance of the spectres, as they appear to the spectator.

What has been said hitherto, relates only to the images of transparent figures. To obtain those of opaque bodies, first place the gauze and box, at the distance of about six feet one from the other, and adapt to the orifice of the box, an apparatus of two tubes furnished with two bi-convex lenses. An opaque body, such, for example, as a medal, or a picture, is attached to a little support, posited in the middle of the box; the lamp with its supply of air, situated in one of the foremost corners of the box, illuminates that object, and the reflected rays, crossing the lenses, proceed till they trace the image upon the gauze, with an amplification which is in the ratio of the distances.

If the image be not distinct, we must infer that it is not at the focus; but it may be adjusted in three different ways; 1. By moving the box to or from the gauze; 2. By moving the object nearer to, or farther from, the lenses within the box; 3. By slowly moving the tubes, to cause a variation in the distance between the lenses.—See Haüy's *Philosophy*, translated by Gregory, vol. ii, p. 390.

Mr. Nicholson, however, witnessed an exhibition of the phantasmagoria at the London Lyceum by Philipstal, who took out a patent for his improvements in the apparatus and machinery. He observes, that the novelty consists in placing the lantern on the opposite side of the screen which receives the images, instead of on the same side as the spectator, and suffering no light to appear but what passes through, and tends to form those images. His sliders are therefore perfectly opaque, except that portion upon which the transparent figures are drawn, and the exhibition is thus conducted.

All the lights of the small theatre of exhibition were removed, except one hanging lamp, which could be drawn up, so that its flame should be perfectly enveloped in a cylindrical chimney, or opaque shade. In this gloomy and wavering light, the curtain was [46] drawn up, and presented to the spectator a cave or place exhibiting skeletons, and other figures or terror, in relief, and painted on the sides or walls. After a short interval, the lamp was drawn up, and the audience were in total darkness, succeeded by thunder and lightning; which last appearance was formed by the magic lantern upon a thin cloth or screen, let down after the disappearance of the light, and consequently unknown to most of the spectators. These appearances were followed by figures of departed men, ghosts, skeletons, transmutations, &c. produced on the screen by the magic lantern on the other side, and moving their eyes, mouth, &c. by the well known contrivance of two or more sliders. The transformations are effected by moving the adjusting tube of the lantern out of focus, and changing the slider during the moment of the confused appearance.

It must be again remarked, that these figures appear without any surrounding circle of illumination, and that the spectators, having no previous view or knowledge of the screen, nor any visible object of comparison, are each left to imagine the distance according to their respective fancy. After a very short time of exhibiting the first figure, it was seen to contract gradually in all its dimensions, until it became extremely small, and then vanished. This effect, as may easily be imagined, is produced by bringing the lantern nearer and nearer the screen, taking care at the same time to preserve the distinctness, and at last closing the aperture altogether: and the process being (except as to brightness) exactly the same as happens when visible objects become more remote, the mind is irresistibly led to consider the figures, as if they were receding to an immense distance.

Several figures of celebrated men were thus exhibited with some transformations; such as the head of Dr. Franklin being converted into a skull, and these were succeeded by phantoms, skeletons, and various terrific figures, which instead of seeming to recede and then vanish, were (by enlargement) made suddenly to advance; to the surprise and astonishment of the audience, and then disappear by seeming to sink into the ground.

This part of the exhibition, which by the agitation of the spectators appeared to be much the most impressive, had less effect with me than the receding of the figures; doubtless because it was more easy for me to imagine the screen to be withdrawn than brought forward. But among the young people who were with me, the judgments were various. Some thought they could have [47] touched the figures, others had a different notion of their distance, and a few apprehended that they had not advanced beyond the first row of the audience.

The whole, as well as certain mechanical inventions, were managed with dexterity and address. The lightning, being produced by the camera, was tame, and had not the brisk transient appearance of the lightning at the theatres, which is produced by rosin, or lycopodium powder, thrown through a light, which in Mr. P's utter darkness might easily have been concealed in a kind of dark lantern.

A plate of thin sheet iron, such as German stoves are made of, is an excellent instrument for producing the noise of thunder. It may be three or four feet long, and the usual width. When this plate is held between the finger and thumb by one corner, and suffered to hang at liberty, if the hand be then moved or shaken horizontally, so as to agitate the corner at right angles to the surface, a great variety of sounds will be produced; from the low rumbling swell of distant thunder, to the succession of loud explosive bursts of thunder from elevated clouds. This simple instrument is very manageable, so that the operator soon feels his power of producing whatever character of sound he may desire; and notwithstanding this description may seem extravagant, whoever tries it for the first time will be surprised at the resemblance. If the plate be too small, the sound will be short, acute, and metallic.

We may remark also, that the magic lantern, by new contrived sliders and machinery, may be applied to important uses, by employing it with such figures as will explain the general principles of optics, astronomy, botany, &c.

The experiment mentioned by Ferguson, with a concave mirror, reflecting into the air the appearance of fire, &c. into a focal point, (founded on a general principle of concave reflectors,) is productive of many agreeable deceptions, and which exhibited with art and an air of mystery, has been very successfully employed.

The phantasmascope of Walker is similar to the phantasmagoria. It is an optical machine, which presents a door that opens itself. The apparatus is so contrived, that, on opening the door, a phantom makes its appearance, having all the colours of a picture, which approaches the spectator. Various figures may be accurately represented.

We will not enlarge on this subject, although many other instances of tricks, performed by means of fire, &c. might be noticed. [48] We will merely remark:

1. For the performance of these exhibitions, the ancient, as well as the modern jugglers, of *all* descriptions, employed, and were acquainted with sundry mixtures, and compositions, by the use of which, they deceived the people; and some pretended to possess supernatural agencies. Of these compositions, with many of which we are unacquainted, we have enumerated some, and their effects. That of producing a callosity of the skin, &c. by means of acids, is an example.

2. That they possessed, as a trade or profession, the arts of deception. Not only by the use of chemical preparations, but by other means, they pretended to work miracles in the dark ages of science. However degraded these persons may seem, they yield in vice to another class, who practised the art of poisoning, and who kept it so profound a secret, that few then understood the effect of the now common, vegetable, and mineral poisons. Who could have been more infamous than the celebrated female poisoner, Tophania?

CHAPTER II.

OF THE SUBSTANCES USED IN THE FORMATION OF FIRE-WORKS.

Sect. I. Of Nitrate of Potassa, or Saltpetre.

Nitrate of potassa, nitre, or saltpetre, is composed, as its name expresses, of nitric acid, and potassa. When pure, it contains, according to Kirwan, potassa 51.8, nitric acid 44, and water 4.2 in the hundred. This salt, when pure, or even mixed with other saline substances, is recognised by placing it on hot coals. Slight detonations, and a hissing noise, with a vivid combustion take place. It is also decomposed by sulphuric acid, and the nitrous vapour is apparent from its smell and colour.

Nitrate of potassa crystallises in six-sided prisms, terminated by six-sided pyramids. Its specific gravity is 1.933. Its taste is sharp and cooling. One part is soluble in seven parts of water, at the temperature of 60 degrees, and in rather less than its own [49] weight of boiling water.

It melts in a strong heat, and by cooling congeals into an opaque mass, called *crystal mineral*, or *sal prunelle*.

Exposed to a red heat, it disengages *oxygen gas*, and passes to the state of a nitrate; at a higher temperature, this is decomposed, and oxygen, azote, and a portion of nitrous acid, which has not been decomposed, are evolved. What remains is potassa. When projected on ignited coals, it burns brilliantly. Detonation also ensues by mixing nitre and charcoal, and throwing the mixture into a red-hot crucible. The residuum is carbonate of potassa. Fourcroy (*Système des Connoissances Chimiques*, Tome iii, p. 124.) observes, that metals, with nitrate of potassa, will decompose this salt, and produce different coloured flame, extremely brilliant, on which account such substances are used in fire-works.

The alchymists believed, they could obtain, from nitre, a liquor, which would constitute, with other substances, the *philosopher's stone*. The *clyssus* of nitre, they imagined, possessed wonderful properties. The decomposition of nitre by charcoal, they effected in two ways, *viz.* by submitting the mixture to the action of heat in a crucible, or, otherwise in an earthen or iron retort. In the latter case, they collected a fluid, principally water, containing some carbonic acid, and the aeriform product they suffered to escape. The residue they named *nitre fixed by charcoal*, or, *the extemporaneous alkali of nitre*. When, in the place of charcoal, a mixture of sulphur and nitre was projected into a red-hot crucible, they obtained a saline substance, to which they gave the name of *sal polychrest*. This is the same as vitriolated tartar, or sulphate of potassa, and is that salt which is formed in the distillation of nitric acid from nitre, and sulphuric acid. The *crystal mineral*, of some of the old pharmacopœias, was nothing more than nitrate of potassa fused with a portion of sulphur, and, therefore, a mixed salt, consisting of nitrate and sulphate of potassa.

Nitrate of potassa, distilled with half its weight of sulphuric acid, furnishes nitric acid, or concentrated spirit of nitre. This, diluted with about an equal weight of water, forms the *aqua fortis* of the shops.

A mixture of nitre and phosphorus, if struck with a hammer, produces a violent detonation. Nitre oxidizes all the metals at a red heat, even gold and platinum.

Nitre and sulphur, thrown into a red-hot crucible, produces an instantaneous combustion, accompanied with a great [50] disengagement of light and heat. Sulphurous acid gas, with sulphuric acid, is produced.

Equal parts of cream of tartar, (supertartrate of potassa,) and nitre, deflagrated in a crucible, form *white flux*. Two parts of tartar, and one of nitre, treated in the same manner, produce *black flux*.

Three parts of nitre, one part of sulphur, and one part of sawdust, mixed together, form the *powder of fusion*.

When three parts of nitre, two parts of potash, and one of sulphur, all previously well dried, are mixed together, the compound is called *pulvis fulminans*, or, *fulminating powder*. A small portion of this powder, or as much as will lay on a shilling-piece, put on a shovel, and exposed to heat, will first melt, become liver-coloured, and then explode with great noise. The theory of this explosion is, that a part of the sulphur, and the potassa unite, and form a sulphuret; the sulphuret then decomposes water, and produces sulphuretted hydrogen gas, which appears to be decomposed by the nitric acid; and there results sulphurous acid gas, water, and, as Thenard observes, protoxide of azote, azotic gas, and sulphate of potassa. The loudness of the report depends on the combustion of the whole powder at the same instant, which is secured by the previous fusion it undergoes. Gunpowder, on the contrary, burns in succession, although apparently instantaneous. In using common potash, there is also, as the alkali contains it, carbonic acid, given out in the state of gas. In fact carbonic acid appears to assist the explosive effect of this powder, for when it is prepared with potash, containing little carbonic acid, its detonating power is considerably less.

Nitre likewise enters into the composition of another fulminating powder, invented by Dr. Higgins. *Higgins's fulminating powder* is composed of three and a half parts of nitre, two parts of crude antimony, and one part of sulphur. This is used in the same manner as the former.

Nitre enters into the composition of gunpowder, which we shall notice under a separate head. The proportions of nitre, sulphur, and charcoal, for the formation of gunpowder, which are considered the best, are, 75 parts of nitre, 12½ of charcoal, and 12½ of sulphur.

The new powder of MM. Gengembrie and Bottée, which inflames by percussion, but without explosion, is composed of 21 parts of nitre, 54 parts of chlorate of potassa, 18 parts of sulphur, and 7 parts of lycopodium.

A mixture of nitre and crude antimony projected into a red-hot crucible, produces a deflagration more or less rapid, forming a [51] composition which is used in pharmacy, and medicine.

The quality of saltpetre may be determined by a variety of experiments. Fire-workers judge of its quality by the colour of its flame.

The flame should be white. If it be *green* or *yellow*, it is said to be impure.

Nitric acid, obtained by distilling saltpetre and sulphuric acid, has a powerful effect on inflammable substances. If nitric acid, or in preference, the fuming nitrous acid, be poured on spirit of turpentine, especially if it be old, it will inflame. To succeed, however, in this experiment, a small portion of sulphuric acid is usually added to the nitric acid. As this effect is owing to the facility, with which the acid parts with its oxygen to inflammable bodies, other essential oils, besides turpentine, will have the same effect. If the same acid is poured on finely pulverized charcoal, or on lampblack, combustion will also take place. When oils are used, water as well as carbonic acid is produced, and when charcoal or lampblack, carbonic acid alone. There is also a large quantity of carbon, in the former instance, which remains on the plate, or dish. M. Delametherie (*Journal de Physique*, 1815) has shown, that olive oil may be converted into a substance, resembling, and having many of the properties of, wax, by mixing it with a given proportion of nitric acid. The acid is decomposed, deutoxide of azote is formed, and the oil acquires a hard consistence. A candle made with this artificial wax, he observes, burns with a clear light and without smoke. The experiment with the *glace inflammable* is on the same principle.

Morey (*Silliman's Journal*, vol. ii, p. 121.) states a singular experiment, in which nitre is used; *viz*: If to tallow or linseed oil, a small quantity of saltpetre be added, and the temperature raised to nearly that of the boiling point, the saltpetre appears to be dissolved by the oil; they will *evaporate together*, and the mixture, or the vapour, will burn, *wholly excluded from the atmosphere*.

Saltpetre was one of the substances employed by the alchemists. It appears from the memoir of Geoffroy, (*Coll. Academ.* 1722,) that the object of the alchemists was twofold; the transmutation of metals, and particularly what were denominated the *baser* metals into the precious, which they pretended to effect by a *universal spirit*, the *grand elixir*, the *philosopher's stone*, &c. and the reduction of metals to their *earths*. Alchemy was introduced into Europe by the crusaders, and it is remarkable, that, in the reign [52] of Henry IV, an act was passed to make it felony to transmute metals. Mr. Boyle, aware of its absurdity, suggested the propriety of repealing that act, which was done. One of their powders was composed of nitre, cream of tartar, and sulphur.

Preparation. Although nitrate of potassa is generated in abundance, particularly in the East, yet in all countries, where the circumstances are favourable to its production, it is found. It never occurs, native, in very large masses. It is generally found in an efflorescence, on the surface of the soil, or in caverns. It never exists in the soil more than a few yards beneath the surface. We may remark, that native nitre has never been found in pure clay, or pure sand, except in the *rock-ore*, as it is called, of the western United States. It is often found in caverns, and fissures in calcareous rocks.

In the East Indies, the districts which furnish saltpetre, are swept at certain seasons of the year. This is repeated two or three times a week; for the saltpetre again appears in the same places, in the form of efflorescence.

It is supposed that some countries furnish saltpetre, in consequence of the drought, which continues for some time. At Lima, M. Dombay informs us, there is seldom rain; and the fields, which serve as pasturage for beasts, are so much covered with saltpetre, as to be removed with the spade. There must then be a rapid formation of nitre. M. Talbot observes, that in the meridional provinces of Spain, the earth frequented by animals, contains it, ready formed. When saltpetre became an article of importance, the rulers of Germany, &c. justified themselves in exclusively carrying away the incrustations of walls from private houses, which, when it could be used, became *accessorium fundi*. Accordingly this *regale*, as it was called, was extended every where, and was generally unpopular. In 1419, Gunther, archbishop of Magdeburgh, issued the first grant, which was the right of searching saltpetre and boiling it, during a year, in the district of Gibicherstein, for which the person, to whom it was granted, was to pay a barrel of saltpetre, and deliver to the archbishop the remainder at a certain price.

The succeeding archbishop, Frederick, let, in 1460, to a burgher of Halle, all the earth and saltpetre that could be collected in the bailiwick of Gibicherstein, for four years, at the annual rent of a given quantity of refined saltpetre. Bishop Ernest, in 1477, let, for his time, the privilege of collecting saltpetre. In 1544, saltpetre was collected, in the same manner, from the rubbish before the [53]
gates of Halle; and in the year following, the magistrates of Halle erected a powder mill, and had saltpetre works. John VI, archbishop of Triers, granted similar privileges in 1560. The saltpetre regale, was long known, and confirmed by a Brandenburgh decree in 1583.

Old walls, and the vicinity of stables, frequently exhibit saltpetre in the state of efflorescence. It was the ancient *scrophula contra lapides*, represented as a kind of leprosy. For the spontaneous production of nitre, animal and vegetable substances, in a state of decomposition, and the presence of dry atmospheric air are necessary. That lime, and the calcareous carbonates also promote its formation, there can be no doubt.

Notwithstanding the large quantity of saltpetre collected in the East Indies, we are told, that two-thirds of the whole are annually sent into China, and other parts of Asia, to make artificial fire-works. The pyrotechny of the Chinese is said to be very perfect; in variety and beauty, some writers assert they exceed all other nations. There is a natural nitre bed at Apulia, near Naples, which affords 40 per centum of nitre. Pelletier, (*Ann. de Chim.* tome xxii.) has published an analysis. The cavity of Molfetta is one hundred feet deep, containing grottos or caverns. Nitrate of potassa is found in the interior, in efflorescence or crusts, attached to compact limestone. On removing these efflorescences, others appear. The soil in this cavity is richly impregnated with nitre.

In Switzerland, the farmers extract an abundance of saltpetre from the stalls under their cattle. During the American revolution, when every expedient was resorted to, to obtain a supply of this article, the floors of tobacco houses, &c. were dug up and lixiviated. In the reign of Charles the First, certain patentees were authorised to dig up the floors of all dove-houses, stables, &c. the floors being again laid with mellow earth.

The Ukraine, Podolia, Hungary, Spain, Italy, Peru, and India, furnish more or less of this salt, which is extracted by lixiviating the earths that compose the soil. The springs, in particular districts of Hungary, contain it.

We are informed, (*Ann. de Chim.* xx. 298,) that, during the second and third years of the French Republic, the government required every district to send two intelligent young persons to Paris. This convocation, consisting of nearly eleven hundred persons, received regular instruction from their first chemists, partly concerning the manufacture of cannon, and partly respecting [54]
the manufacture of saltpetre and gunpowder. This body of pupils was afterwards distributed among the different establishments in proportion to their abilities, and saltpetre was soon furnished in abundance.

In the United States, we have an abundant source of saltpetre in the *nitre caves* of the western country. There is now no occasion for lixiviating the soil of tobacco houses, or of stables, or the refuse of old buildings, the preparation of artificial nitre beds, as adopted in France, or for any other expedient, to furnish a supply of saltpetre; these caverns, which are calcareous, producing it in great abundance. The *earth* of these caves does not, however, contain pure nitrate of potassa, but generally a mixture of this salt and nitrate of lime, a calcareous nitrate which constitutes the principal part. The latter is changed into nitrate of potassa, as we shall observe more particularly hereafter, by making a lixivium of the earth in the usual manner, and passing it through wood ashes. The alkali, which the latter contains, decomposes the nitrate of lime, by uniting with the nitric acid; hence the fluid, which passes through, is nitrate of potassa or saltpetre. This is evaporated, and suffered to crystallize. It is then the *crude, or rough nitre*, which is purified, principally by re-solution, and crystallization.

The saltpetre makers, at the caves, have found, that two bushels of ashes, made by burning the dry wood in hollow trees, afford as much alkali as eighteen bushels of ashes obtained from the oak. Notwithstanding the *nitre earth* contains a mixture of the nitrates of potassa and lime, nitrate of potassa, nearly pure, has been discovered. It is sometimes found in the fissures of sandstone, or among detached fragments. Some of these masses are said to weigh several hundred pounds.

Besides these caverns, which have been accurately described by Dr. Brown, in the Transactions of the *American Philosophical Society*, (vol. v, vi.) similar caverns have been discovered in Tennessee, and in some parts of Virginia and Maryland. At Hughes' cave near Hagerstown, in Maryland, this salt has also been made.

We are of opinion, that most of the calcareous caverns in the United States, if carefully examined, might be found to contain nitre, or at least, the calcareous nitrate, which is readily converted into nitre by lixiviation with wood ashes, or the addition of a due quantity of potash.

Professor Cleaveland, in noticing the saltpetre caves of the western country, observes, (*Elementary Treatise on Mineralogy and Geology*,) that one of the most remarkable of these caverns is in Madison county, on Crooked Creek, about sixty miles S. E. from [55]
Lexington. This cavern extends entirely through a hill, and affords a convenient passage for horses and wagons. Its length is six hundred and forty-six yards; its breadth is generally about forty feet; and its average height, about ten feet. One bushel of the earth of this cavern, commonly yields from one to two pounds of nitre; and the same salt has been found to exist, at the depth of at least fifteen feet; even the clay, a fact which seems rather remarkable, is impregnated with nitrate of lime. Kentucky also furnishes native nitre under a very different form, and constituting what is there called the *rock ore*, which is in fact a sand stone, richly impregnated with nitrate of potassa. These sand stones are generally situated at the head of narrow vallies, which traverse the sides of steep hills. They rest on calcareous strata, and sometimes present a front from sixty to one hundred feet high. When broken into small fragments, and thrown into boiling water, the stone soon falls into sand; one bushel of which, by lixiviation and crystallization, frequently yields ten pounds, and sometimes more than twenty pounds of nitrate of potassa. The nitre from these rocks contains little or no nitrate of lime. This account is corroborated by Dr. Brown,[13] to whom our author is indebted for his remarks.

In a memoir in the American Philosophical Transactions by Dr. Brown, then of Lexington Kentucky, we have a description of a nitre cave on Crooked Creek, with the process for extracting the saltpetre. From this memoir, the following extracts are made: The water which percolates through the cave in summer, as the walls and floor are dry in winter, condenses upon the rocks, and the substance thus formed, has the same properties as the salt obtained by lixiviating the earth of the floor. As far as the workmen have dug, the earth is strongly impregnated, every bushel of which, upon an average, furnishes one pound of nitre. The same earth will be again impregnated, if thrown into the cave. What length of time it requires to saturate it, is not known.

The workmen have different modes of forming an opinion with regard to the quantity of nitre, with which the earth may be [56]
impregnated. They generally trust to their taste; but it is always considered as a proof of the presence of the nitre, when the impression made one day on the dust by the hand or foot disappears the day following. Where there is a great deal of sand mixed with the dust, it is commonly believed that a small quantity of potash will suffice for the operation. The method of making saltpetre, usually practised in Kentucky, is as follows:

The earth is dug, and carried to hoppers of a very simple construction, which contain about fifty bushels. Cold water is poured on it for some time, and in a day or two, a solution of the salts runs into troughs placed beneath the hoppers. The lixiviation is continued as long as any strength remains in the earth. The liquor is then put into iron kettles, and heated to ebullition; it is afterwards thrown upon a hopper containing wood ashes, through which it is suffered to filtrate. As the alkaline part of the ashes is discharged before the nitrate passes through, the first runnings of this hopper are thrown back, and after some time, the clear solution of nitrate of potassa runs out, mixed with a white curd, which settles at the bottom of the trough. This clear liquor is boiled to the point of crystallization, then settled for a short time, and put into troughs to crystallize, where it remains twenty-four hours; the crystals are then taken out, and the mother water thrown upon the ash hopper, with the next running of the nitrate of lime. When the quantity of the nitrate of lime is too great for the portion of ashes employed, the workmen say their saltpetre is in the *grease*, and that they do not obtain a due quantity of nitre. If too much ashes are used, they say it is in the *ley*; and when it is left to settle previous to crystallization, a large quantity of salt will be deposited in the settling troughs, which they call *cubic salts*. These salts are again thrown upon the ash-hoppers, and are supposed to assist in precipitating the lime from the nitrate of lime, and in the opinion of the workmen are changed into pure saltpetre. To make a hundred pounds of good saltpetre at the great cave, eighteen bushels of oak ashes are necessary; ten of elm, or two of ashes made by burning the dry wood in hollow trees. The earth in some caves does not require half this quantity of wood ashes to decompose the earthy salts.

When wood ashes cannot be obtained in sufficient quantity, they make a lixivium of the earth, and boil it down, which they call [57] *thick stuff.* This is put in casks, and transported to a place where ashes can be had. When dissolved and passed through wood ashes, it is changed, as in the former process, into saltpetre. Having thus given the Doctor's account, let us inquire, in the next place, into the theory of the process.

The theory is very evident. The mixed nitrate, consisting of variable proportions of nitrate of lime and nitrate of potassa, is extracted from the saltpetre earth by water, which dissolves it. Now, as the affinity of nitric acid for potassa is greater than for lime, and consequently potassa will decompose nitrate of lime, when the lixivium is passed through wood ashes, the potassa they contain will unite with the nitric acid, and the lime be separated, which remains in the hopper. The liquor holds in solution no other salt than nitrate of potassa, provided the quantity of alkali in the wood ashes be sufficient to effect the decomposition;—if *more*, it will pass through in an uncombined state; and if *less*, the liquor will contain nitrate of lime. As the alkali contains more or less carbonic acid, the decomposition is not a case of single but of double affinity, in which we form, at the same time, a carbonate of lime.

When the solution is boiled, and set aside in the troughs to crystallize, the nitre will form in a regular manner. The mother water, or the fluid which remains after the crystallization, may contain, from the circumstance before stated, either potash, or undecomposed nitrate of lime—hence it is thrown on the hopper in a subsequent operation.

The nitre, however, as made at the caves, is called *rough* or crude nitre. Before it is used for the manufacture of gunpowder, and other purposes, it is purified or refined. This operation, which we shall notice more fully hereafter, is nothing more than the separation of all earthy salts, and the alkaline muriates and sulphates; in other words, the conversion of the whole by the separation of foreign substances, into pure nitrate of potassa.

The mode of treating the *rock ore*, or sand rocks, which contain nitre, is the same as before given. It contains more nitrate of potassa, and therefore requires less potash, and in some instances, the nitre is perfectly pure. The sand rocks often yield twenty or thirty pounds per bushel. A mass of pure nitre, weighing sixteen hundred pounds, has been discovered. Smaller masses have also been found.

The rocks which contain the greatest quantity of nitre are extremely difficult to bore, and are tinged brown or yellow.

Saltpetre makers find it to their interest to work the rock ore in preference to the calcareous nitrate, as it yields more nitre. [58]

It is a fact well known, that foreign saltpetre contains a variety of deliquescent salts, or those salts which attract and absorb moisture and also common salt. The efforts of European refiners are directed to their separation. The saltpetre of the Western country, Dr. Brown assures us, does not contain common salt.

Dr. Brown, in *Silliman's Journal*, i, p. 147, in a letter to professor Silliman, observes, that there exists a black substance in the clay under the rocks, of a bituminous appearance and smell. This black substance, it appears, accompanies the sand-rock nitre, and is the same as that found in Africa, which also accompanies nitre in that country. Animal matter seems to have existed in the nitre caves of Africa, forming, as Mr. Barrow expresses it, either a *roof* or covering; no such matter, however, has ever been found in or adjacent to the nitre caves of the Western country.

The observations of Mr. Barrow on the subject of the saltpetre of Africa may be interesting to the reader. He observes, (*Southern Africa*, p. 291,) that, about twelve miles to the eastward of the wells, (*Hepatic Wells*), in a kloof of the mountain, we found a considerable quantity of native nitre. It was in a cavern similar to those used by the Bosgesmans for their winter habitations. The *under surface* of the projecting stratum of calcareous stone, and the sides that supported it, were incrusted with a coating of *clear, white saltpetre*, that came off in flakes. The fracture resembled that of refined sugar; it burnt completely without leaving any residuum; and if dissolved in water, and thus evaporated, crystals of pure *prismatic nitre* were obtained. This salt, in the same state, is to be met with under the sand-stone strata of many of the mountains of Africa. There was also in the same cave, running down the sides of the rock, a black substance, that was apparently bituminous. The peasants called it the urine of the das. The dung of this *gregarious* animal was lying upon the roof of the cavern to the amount of many wagon loads.

The Rev. Mr. Cornelius, in describing a cave in the Cherokee country at Nicojack, the north west angle in the map of Georgia, (*Silliman's Journal*, vol. i, p. 321,) observes, that it abounds with nitrate of potassa, a circumstance very common to the caves of the Western country, and is found covering the surfaces of fallen rocks, but in more abundance beneath them. There are two kinds; one is called the "clay dirt," the other the "black dirt." The earth, however, contains calcareous nitre, and for that reason an [59] alkaline lixivium is employed. In short, the process employed there is the same as at the other saltpetre caves which we have described. One bushel of the clay dirt yields from three to five pounds of nitre, and the black dirt from seven to ten pounds. It seems also, that the same dirt, if carried back to the cave, will become impregnated with nitre.

Mr. Cornelius remarks, that these caves have been used by the natives as burial places; in one of which he counted a hundred human skulls in the space of twenty feet square; and infers, that, by the decomposition of animal matter, the acid of nitric salts arises, and therefore that this may have occasioned the formation of the nitrates of potassa and lime.

At Corydon, in Indiana, there is a cave, which, according to Stilson's account, contains both nitrate of lime, and nitrate of magnesia. It is not worked.

Kain, in his remarks on the Geology and Mineralogy of East Tennessee, (*Silliman's Journal*, vol. i, p. 65,) observes, that the numerous caves which have been found in the Cumberland mountains, and other parts of Tennessee have been very productive of nitrate of potassa; and in confirmation of the remarks before made, he adds, in investigating the causes that have given rise to these salts, that wild animals burrow in these caves; that, when pursued by the hunter, they make them the places of their retreat, and probably die there; that the aborigines have made them a place of burial; and that the streams of water, which flow through them, in wet weather, carry with them not only great quantities of leaves, but many other vegetable productions.

Without offering any theory, by which we may account for the formation of nitre, in nitre caves, or in situations which cannot be influenced by the putrefactive process, we may merely remark, that as nitric acid is composed of oxygen and azote, there must be some operation unknown to us, by which the union of these elements takes place. Nascent azote must unite with the base of oxygen gas; but whence, in saltpetre caves, proceeds the azote and the oxygen? It appears that calcareous bodies facilitate the formation of nitre, as they do in artificial nitre beds. The greater part of the nitrous earth is lime; and it also appears, that the same earth, after the extraction of the saltpetre, will again furnish it. We know that lime is a compound of a base called calcium united with oxygen; but in what manner it promotes the union of azote and oxygen, or furnishes either one or the other of these [60] bodies, or perhaps both, is altogether uncertain. Nor can we account for the formation of potash in the native nitre of the nitre caves. In other situations, as for instance where nitrous efflorescence appears on the earth, and in artificial nitre beds, in which animal and vegetable substances are in the act of decomposition by the putrefactive fermentation, we may account for the generation of nitric acid.

It is extremely probable, that the azote of the atmosphere, and oxygen may combine spontaneously, under particular circumstances, in various operations of nature. Azote, it is known, forms with oxygen two gases, a protoxide and deutoxide, and the same elements in other proportions form nitric acid. Some condition, unknown to us, must, as an operating cause, produce this compound. As a condition for its generation, the presence of calcareous and alkaline matter, favours the formation of nitric acid. Of this fact, we have sufficient proof, in the generation of nitre in artificial nitre beds. But, with respect to natural causes, although the facts themselves are conclusive, we know little or nothing.

Atmospheric air is a mixture, or compound, according to some, of two gases, oxygen and azote, with carbonic acid; but the proportion of the latter rarely exceeds two per cent, while the quantity of oxygen is about twenty-two. It is a solvent, as well as a vehicle, and hence may contain water, gaseous fluids, &c. Miasmata, which is contained often in the air, are vapours or effluvia, that affect the human system, and bring on diseases, of which the principal are the intermittent, remittent, and yellow fevers, dysentery and typhus. That of the last is generated in the human body itself. The same, or analogous causes, that produce the formation of nitric acid, may, under other circumstances, cause the formation of miasmata; for moist vegetable and other matter, in some unknown state of decomposition, generates it, and is known to have caused the yellow and other malignant fevers. (See an admirable work on the *causes, &c. of the yellow fever in Philadelphia*, by Samuel Jackson, M. D. president of the board of health, etc. in reply to the observations of Dr. Hosack.) The contagious *virus* of the plague, small pox, etc. as it operates in a more limited distance than marsh, or other miasmata, is communicated only in certain localities, and through the intermedium of the atmosphere. As to the chemical nature of miasmata, there can be no doubt that azote, under some form of combination, is one of its component parts, and one of the causes of disease. Is not cyanogen, or carburet of azote, perhaps combined with hydrogen, in [61] the form of hydrocyanic or prussic acid, the substance, or *principal* substance, which forms the miasmata, that engenders the yellow fever? What compounds may be formed of hydrogen, sulphur, phosphorus, carbon, and *azote*, so as to produce miasmata, that will act specifically on the system for the production of intermittent, remittent, yellow, typhus, and other fevers?[14] This inquiry, permit me to add, is one of no small moment, as it involves in it a question of great importance relative to the origin of yellow fever. While we thus digress, in noticing the compounds of azote, let us briefly remark, as an indisputable conclusion, that the same causes of malignant disease in the West India islands, operating under similar circumstances in every respect, may engender the same disease in our cities.

The atmosphere is subject to changes of various kinds, and may be considered not only as a solvent, but a repository for different [62] foreign bodies. Electricity, an agent so essential in the economy of nature, has its ends, its uses; and while, no doubt, it unites hydrogen with oxygen, in the most elevated regions of the air, and forms water, it may act under particular circumstances to produce a union of azote and oxygen so as to generate nitric acid. Dr. Priestley, (*Transactions of the American Philosophical Society*,) detected nitric acid in snow. But of all atmospheric phenomena, the formation of meteorolites, or meteoric stones, is the most wonderful. If they be really formed in the atmosphere, there can be no doubt, that the elementary principles which compose them must exist in it; and that the phenomenon denominated meteoric, in such cases, is no other than the operating cause, by which meteoric stones are generated.[15]

Animal substances furnish azote, as it is one of their constituent parts; and in the act of its separation, by uniting with oxygen, principally furnished by the air, it forms nitric acid; which, attaching itself to the alkali of the vegetable matter, or the lime usually added to nitre beds, or to other salifiable bases, forms either nitrate of potassa, nitrate of lime, or a nitrate of the particular base. The lixiviation of the nitrous substances, and the use of wood ashes, or potash itself, will produce saltpetre.[16]

Brongniart has given the following process for purifying or refining saltpetre: Pulverize the impure nitre, and wash it three times in cold water, in the proportion of 35 lbs. of water, to 100 lbs. of the salt, taking care to pour off the water before another portion is added. These washings separate the greater part of the muriate of soda, and the deliquescent salts, such as nitrate of lime. When thus washed, the nitre is to be dissolved in half its weight boiling water. On cooling, the salt begins to crystallize, and, by agitating the liquid during the process, minute crystals are obtained. These crystals when dried are to be washed in 5 lbs. of cold water for every 100 lbs. of the salt, and then dried in a temperature of forty-five degrees.

In India, where nitrate of lime also occurs, but in situations different from those in the United States, the natives extract the saltpetre by a process similar to that we have described. They refine it by solution in water, evaporation, and crystallization. In [63] France, the potash of commerce is used; and the nitrates which are decomposed, are those principally of lime and magnesia.

According to the analysis of M. Pelletier, and the experiments of professor Vaizo, in 1781, they found the calcareous earth of the cave at Naples, to contain forty or forty-two to the hundred, of nitrate of potassa. (See *Annales de Chimie*, tome 23.)

In 1792, M. Pickel announced the discovery of native saltpetre, in a quarry in the neighbourhood of Wurtzburgh. M. de la Rochefoucald discovered nitre in the neighbourhood of chalk in France, in the departments of Seine and Oise. MM. Lavoisier and Clouet, made a number of researches with the same view. Since that time, saltpetre, or nitrous earth has been found in several of the departments of France; and it appears reasonable to conclude, that in all situations favourable to the generation of nitre, where the same causes operate, nitre must occur in more or less abundance.

From the rubbish of old buildings, saltpetre is obtained in some quantity. Old plaster is said to give five per cent. The soluble salts it contains, are six in number, viz: nitrate and muriate of lime, nitrate and muriate of magnesia, and nitrate of potassa, and muriate of soda. Now it is obvious, that besides the decomposition of the earthy nitrates, the earthy muriates also are decomposed by the potash, leaving in solution, besides muriate of soda, if it is not decomposed, by the potash, (which has this effect,) muriate, as well as the nitrate of potassa. To refine the saltpetre prepared in this manner, consists in separating the muriates. The proportions, in which these salts are to each other in a hundred parts, are stated by Thenard, (*Traité de Chimie*, Tome ii, p. 485,) to be ten, nitrate of potassa, seventy, nitrates of lime and magnesia, fifteen, marine salt, and five, muriates of lime and magnesia.

The mode of extracting saltpetre, and the various processes which have been adopted for refining it, in France, and on the continent generally, have but one object,—that of lixiviating the substances which afford it, and subsequently, separating all foreign salts. The best memoir was written by count Chaptal, occupying forty-seven pages in the *Annales de Chimie*, tome xx. In this he explains the theory at large. In the same work, tome xxiii, there is also a paper by Guyton, and many other memoirs of the same character. In Chaptal's *Chimie Appliqué aux Arts*, tome iv, p. 119, in Thenard's *Traité de Chimie*, tome ii, p. 485, and in the [64] *Annales de Chimie et de Physique*, tome v, p. 173, the subject is ably treated.

We will now give the process of extracting saltpetre from the rubbish of old buildings, principally plaster, as adopted in France. The lixiviation, in the first place, is performed in the following manner: a certain number of casks or tubs, thirty-six for instance, is placed in three ranges. These tubs are pierced laterally near their bottom, by a hole of about half an inch in diameter, and closed with a cork; they are placed above a trough connected with a reservoir. There is put then into each tub a bucket full of the plaster, previously pounded, which is supported in the casks by cross sticks, a certain distance from the hole, so as not to obstruct the passage of the fluid. After this, a bushel of wood ashes is added, and the tubs are then filled with the plaster. Water is then put into the tubs of the first row, and after some time, the stop cocks are turned; water is then put into the tubs of another row, and the lixiviation is continued until the fluid indicates the zero of Beaumé's areometer. The saline waters, which are thus obtained, are divided into three parts, in proportion to their specific gravity, or quantity of salt they contain. The lixivium, of five degrees of the areometer, is known under the name of *eaux de cuite*. The waters, which are marked between three and five degrees, take the name of *eaux de forte*; and those below three degrees are called *eaux faibles*. According as the waters are weak, they are made to run through another range of tubs, in order to saturate them.

When strong and weak solutions are made to pass through the tubs in the same manner, proceeding from the second row to the third, and from the third to the first, the *earths plaster*, &c. being renewed, the lixiviation is not interrupted.

The lixiviation, it appears, is thus continued; for we obtain, at the same time, *weak waters* from the second row, the *strong waters* from the third, and the *boiling waters*, or those fit to be put into the boilers, from the first.

When a sufficient quantity of the strong solution is obtained, it is put into the copper, or boiler, and evaporated. During the evaporation, there is a scum formed, and sundry earthy substances, in the form of a mud, are deposited. This is usually caught in a vessel placed in the boiler, which is raised from time to time, by means of a rope, moved through a pulley, and fastened to a chain from the handles of the vessel. The solution is concentrated until it indicates the strength of twenty-five degrees of Beaumé's areometer. It is then mixed with the mother water of the preceding boiling, and a concentrated solution of the potash of commerce [65] is added, until the precipitation ceases. The sulphate of potassa may be used for the same purpose, at least to decompose the nitrate of lime; but it must be used in the first instance, and the operation finished in the common way, by the addition of potash. The precipitation being finished, that is to say, the nitrates of lime and magnesia, being transformed into nitrate of potassa, the hot liquor is then carried in a large tub, called the *reservoir*, and placed on the edge of the boiler. As soon as the insoluble salts, which the solution contains, are deposited there, which takes place immediately, the liquor is drawn off clear by cocks, which are adapted to the tubs, and received into the boiler, previously cleaned. The deposite obtained in the boiling, is washed with a certain quantity of the solution, which becomes clear, and is then mixed with the preceding liquor.

From what has been said, the liquor must contain a great quantity of nitrate of potassa, a small quantity of the salts of lime and magnesia, and all the marine salt contained in the plaster. It is frequently the case, that the liquor contains muriate of potassa, and a small quantity of sulphate of lime. It is, therefore, submitted again to evaporation. When it is at the forty-second degree of concentration, some part of the marine salt separates, which rises to the surface, and is taken off, and drained through an osier basket placed over the boiler. The solution being concentrated to the forty-fifth degree of the hydrometer, it is put into copper vessels, in which, by cooling, it crystallizes. The salt is then separated from the mother water, drained and coarsely bruised, and afterwards washed in a certain quantity of the *first boiling*. It is now in a state to be delivered to the central administration, under the name of crude saltpetre, or saltpetre of the first boiling.

The crude saltpetre contains about seventy-five per cent of nitrate of potassa. The quality may be determined by treating it with a saturated solution of pure nitrate of potassa, which cannot dissolve any more of the nitrate, but will dissolve any foreign salts. The twenty-five parts of the foreign substances, contained in the crude saltpetre, are composed of a large quantity of marine salt, and of a small portion of muriate of potassa. It is necessary to separate them, and other foreign substances. The operation for this purpose, is called the *refining of saltpetre*.

The refining of saltpetre is founded principally upon the property, which nitre has, of being more soluble in warm water, than [66] the muriate of soda, and muriate of potassa. Thirty parts of saltpetre, and six parts of water are put into a boiler and the liquor is heated. By this means, there is precipitated a large quantity of marine salt mixed with muriate of potassa. A small quantity of water is added from time to time, to keep the nitre in solution.

When the foreign salt is not fully deposited, the liquor is clarified, and more water is added, sufficient to form ten parts, including that which has already been poured upon it. The liquor is removed, when it is clear and less heated, and put into copper vessels, where it is agitated to prevent crystallization, and to effect the pulverization of the saltpetre.

The saltpetre obtained by this process is not sufficiently pure. The purification is completed by washing it with water saturated with nitre, which dissolves the foreign substances. This washing is completed in a vessel, the bottom of which has been pierced with holes. The nitre, however, is left some hours in contact with the water, when the latter is permitted to run out. When the solution is of the same degree of concentration as that of the saturated water, the operation is finished. The nitre is dried for use.

The old process of refining saltpetre is thus described: Put into a copper, one hundred pounds of nitre, and fourteen gallons of water; let it boil gently half an hour, removing the scum as it forms; then stir it, and before it settles put it into filtering bags, which must be suspended from a rack. Put under the filters glazed earthen pans, to receive the liquor; in which place sticks for the crystals to form on. In two or three days, it will all crystallize.

In some saltpetre works, sulphate of potassa is used with advantage. This salt is furnished in abundance, by the combustion of a mixture of nitre and sulphur, in the manufacture of oil of vitriol. It forms the residue after the combustion. It is likewise produced in the preparation of nitric acid, in the decomposition of nitrate of potassa, by sulphuric acid. It may, therefore, be obtained in quantity, from the oil of vitriol manufacturers, and the aquafortis distillers. It is usually called *vitriolated tartar*.

It is known that sulphuric acid forms, with lime, an almost insoluble compound, called sulphate of lime, or gypsum; and hence, when sulphate of potassa is mixed with a solution of nitrate of lime, nitrate of potassa is formed, which remains in solution, and sulphate of lime is precipitated. The same effect takes place with all earthy nitrates. For the application of sulphate of potassa, in this way, we are indebted to M. Berard. It might be advantageously employed in decomposing the calcareous nitrate of the nitre- [67]
caves of the western country.

M. Longchamp has recommended the use of sulphate of soda, or Glauber's salt, for decomposing the muriate of lime, which exists occasionally in impure nitre. These two salts reciprocally decompose each other; sulphate of lime is precipitated, and muriate of soda remains in solution. The latter is separated by evaporating the nitrous solution.

M. de Saluces (*Mémoire de l'Académie des Sciences de Turin, Année, 1805 à 1808*,) has proposed a new process for purifying nitre. It consists in filtering it through argillaceous earth, or clay. Although the process is highly spoken of, yet we can see no particular advantage it possesses.

Chaptal observes, that the process mostly in use is that of dissolving 2000 pounds of crude saltpetre in a copper boiler, in 1600 lbs. of water. As the solution is made by the heat, the scum, which forms, is taken off. Twelve ounces of glue, dissolved in ten pints of boiling water, and mixed with four pails full of cold water, are then added. This addition cools the solution. As to the manipulations of the process, they have been given. The principal thing to be attended to, is to separate the marine salt, which is done during the boiling.

To pass this saltpetre through a second operation, in order the more to purify it, it is again dissolved, in the proportion of 2000 pounds, in one-fourth of its weight of water. Heat is applied. The scum is separated; a solution of 8 ounces of glue in one or two pails full of water is then added. After the solution becomes clear, it is suffered to cool, and at the expiration of five days, it will crystallize, or form in a mass, which is then exposed to the air six or eight weeks to become completely dry.

In treating of the formation of nitre in France, Bottée and Riffault (*Traité de l'Art de Fabriquer la Poudre à Canon*,) consider it under the following heads:

1. *The constituent principles of nitre; its generation, and the theories respecting it.* In this article, the composition of nitric acid and its union with potassa, and the production of artificial nitre, are taken into view.

2. *Nitrous earths, and substances which yield saltpetre.* This subject comprehends a view of the substances, which contain saltpetre, as well as those which afford it by nitrification.

3. *The preparation of the substances to produce saltpetre.* This article relates to the manipulations required for the production of nitre.

4. *The manner of lixiviating saltpetre earths.* The lixiviation is an important part of the process, however simple it may appear; as [68]
upon its accuracy depends the quantity of the product.

5. *The treatment of the different waters (lixiviums) with potash, sulphate of potassa, and wood-ashes.* This article points out the use of potash in decomposing the earthy salts, such as nitrate of lime; of sulphate of potassa, which converts the nitrate of lime by double decomposition into nitrate of potassa, the sulphate of lime being precipitated; and of wood-ashes, which act in the same manner as potash, as they contain this alkali.

6. *The evaporation of saltpetre waters, and the crystallization of nitre.* In this article, they consider the separation of foreign alkaline salts, as muriate of soda, and the crystallization of the nitre, to obtain it in a state of purity.

7. *The treatment of the mother water of crystallization.* This article refers to the manner of using the mother water, in order to obtain more nitre from it, and its employment in lieu of fresh water for other lixiviums.

8. *The refining of saltpetre by the old process.* They describe here the old process, in which a variety of substances were used to purify the saltpetre, but which is now generally abandoned, or laid aside.

9. *The process of refining saltpetre, as adopted in the establishments of the administration.* Under this head they give, in detail, the process employed throughout France, as uniform and the same, in every refinery.

10. *The manner of proceeding in the examination of various kinds of saltpetre in the magazines of the administration.* This article relates to the different modes of examining saltpetre.

11. *On the manufacture of potash and pearlash.* This subject is important, as potash is an indispensable article in the preparation of saltpetre, and the formation of the alkali may be considered as of primary magnitude in establishments, conducted upon so large a scale as those of France.

It is thus, that a regular system is adopted, by the French government, for the production of saltpetre; and we may add also, for the manufacture of gunpowder, which we notice in that article.

It may be proper to mention some facts, respecting the formation of nitre-beds, and the means adopted, in this way, to obtain saltpetre, and to offer, at the same time, some observations on this mode of obtaining nitre.

The *Mémoires de l'Académie des Sciences*, 1720, contain the observations of M. Bouldoc, relative to the process of lixiviating [69]
saltpetre earths. Lacourt published a pamphlet some years after, entitled, *Instruction concernant la Fabrication du Saltpetre*. Various dissertations appeared on the same subject. In 1775, the French Academy of Sciences proposed a prize-question, which produced a more thorough investigation. The Memoirs of Thouvenal, of the Chevalier de Lorgna, and of MM. de Chevrand, and Ganivel, were highly approved, some of which took the prize. Chaptal, who has done more, perhaps, than any other person in France, to promote this all-important object, published, in 1794, an excellent dissertation, founded on experiment and observation. This Memoir was published in the *Journal des Arts et Manufactures*, t. iii, p. 12.

Kirwan (*Geological Essays*, p. 143,) remarks, that the saline crust, which is found on the walls of the houses of Malta, is owing to the walls being built of fine grained limestone. When wetted with sea-water, it never dries. The crust is nitrate of potassa, nitrate of lime, and muriate of soda, and is some tenths of an inch thick. Under this crust, the stone moulders into dust. When the first falls off, it is succeeded by a second, and so on, until the whole stone is destroyed. This particular effect, however, is attributed to the presence of marine salt.

Mr. Kirwan observes, that, "M. Dolomieu shows, at the end of his Tract on the Lipari Islands, that the atmosphere of Malta, in some seasons, when a south wind blows, is remarkably fouled with mephitic air; and, at other times, when a north wind blows, remarkably pure; and hence, of all others, most fit for the generation of nitrous acid." Mr. Kirwan remarks, "How the alkaline part of the nitre, which is one of the products resulting from the decomposition of this stone, is formed, is as yet mysterious: Is it not from the tartarin lately discovered in clays and many stones?" He adds, after speaking of animal and vegetable decomposition, "I should rather suppose, that the alkali is conveyed into these earths by the putrid air, than newly formed; and the reason is, that tartarin, (potash,) notwithstanding its fixity, is also found in soot; and, in the same manner, may be elevated in putrid exhalations."

Artificial nitre-beds consist of the refuse of animal and vegetable substances, undergoing putrefaction, mixed with calcareous earth; the refuse of old buildings, particularly plaster; earths from the vicinity of inhabited buildings; blood, urine, &c. They are [70]
covered, from the rain, by a shed, open at the sides. Cramer, an author of credit, informs us, that he made a little hut, with windows to admit the wind. In this, he put a mixture of garden mould, the rubbish of lime, and putrid animal and vegetable substances. He frequently moistened them with urine, and in a month or two found his composition very rich in saltpetre, yielding at least one-eighth part of its weight. The practice of obtaining nitre from nitre beds, was followed in France and Germany. It is extracted and refined by the process already given.

When oxygen gas is presented to azote at the moment of its liberation, nitric acid is formed. As ammonia is the result of animal putrefaction, or is formed in the process, hydrogen must unite also with azote. The azote is furnished by the animal substances. These facts being known, we are enabled to account for the generation of nitric acid, and, consequently, of the earthy and other nitrates, in artificial nitre beds.

In noticing this subject, it is unnecessary to quote the opinion of Stahl, who believed that there was but one acid in nature, the sulphuric; and that nitric acid was the sulphuric acid, combined with phlogiston, which he affirmed was produced by putrefaction; nor is it necessary to mention the opinion of Lemery, who believed that nitre exists ready formed in animals and vegetables by the processes of vegetation and animalization. The experiments of the French philosophers have put these opinions at rest.

Thouvenal discovered, that nothing more was necessary for the production of nitre than a basis of lime, heat, and open air; so that nitre beds, formed of putrefying animal and vegetable substances, with the conditions thus stated, must produce saltpetre; a fact which experience abundantly justifies.

The process for the formation of nitre, is called *nitrification*.

Although animal substances, by putrefaction, furnish azote, and nascent azote unites with facility with the oxygen of the atmosphere, by which nitric acid is generated—(hence the spontaneous decomposition of nitre composts)—yet Vauquelin is of opinion, that the presence of calcareous or alkaline substances is indispensable, and that the production of carbonate of ammonia from the animal matter, is another compound, which results from the same decomposition. Ammonia is produced by the union of azote and hydrogen, and carbonic acid by that of carbon and oxygen. He considers then, that the presence of lime, magnesia, potash, &c. *determines* the union of the azote with oxygen, and of course, the formation of nitric acid; and as this acid unites with [71] one or other of these substances, according to circumstances, we have either nitrate of lime, or of magnesia, or nitrate of potassa. The idea that water is decomposed in the change which animal and vegetable substances undergo, in the process of nitrification, is contrary to observation; for the presence of air in dry situations, is indispensable to the process.

If a compost, made up of animal, vegetable, and calcareous substances, and put in small beds or heaps, and covered with a shed open at both sides, be frequently turned to admit new surfaces to the air, and occasionally moistened with urine, &c.—nitric acid will be generated as the putrefaction goes on. When this process is suffered to proceed until the decomposition is complete, and the beds then lixiviated, the quantity of nitre will be considerable. In all cases, we are to observe, that, as various earthy nitrates are produced, and mostly nitrate of lime, potash, or wood-ashes which contain this alkali, are to be used.

It was long since shown by Glauber, that a vault plastered over with a mixture of lime, wood-ashes, and cows' dung, soon becomes covered with efflorescent nitre; and that, after some months, the materials yield, on lixiviation, a considerable proportion of this salt. M. de Roder, speaking of nitrous walls, observes, that the efflorescence of nitre on them is in consequence of the stone, lime, and sand employed in the building.

What is denominated the *saltpetre rot*, is an efflorescence observed on the walls of old buildings, and on the ground. Dr. C. F. Gren, professor at Halle, in Saxony, (*Principles of Modern Chemistry*, vol. ii, p. 128), very justly remarks, that, among the matters capable of corruption, those are the most convenient in making nitre, which contain the greatest portion of azote, of which animal substances are the first; among which he enumerates flesh, blood, skins, excrements of animals, old woolen stuffs, and urine. He also mentions marsh plants, green herbs, mud from streets trodden by cattle, and the ground from marshes or bogs. As a compost he adds, that the ground from church-yards, where corpses have successively, and during a long series of years, undergone corruption, would be the best for artificial nitre beds. On the subject of nitre beds, the reader may consult the *Recueil de Mémoires et de Pièces sur la formation et la fabrication du saltpetre, à Paris*, 1786, 4to. These remarks on the generation of nitre, although of more ancient date, are confirmed by James and Herman Boerhaave, (*Chemistry, &c.*) Hoffman, (*de Salium Medicorum,* [72] *et de Præstantissima Nitri Virtute*), Stahl, (*de Usu Nitri Medico*), Neuman, (*chemical works*), and Lewis, (*Materia Medica*)—all of whom have written more or less on the formation of saltpetre; to which we may add the observations of Parr, (*London Medical Dictionary*, vol. ii, p. 24.)

The process for extracting saltpetre from damaged gunpowder is nothing more than putting it into a boiler, and adding water sufficient to cover it. On applying heat, the nitre will be dissolved. If any scum forms, it must be removed. When the solution is effected, pour it on a sufficient number of filters, and collect the fluid which passes through. The residue may be treated with more water, and the whole again filtered. After boiling the solution, set it aside to crystallize. The sulphur may be recovered, by subliming the residue in a temperature not sufficient to inflame it. The charcoal may be used again for the same purpose.

Saltpetre, when properly refined, does not contain any foreign salts, and its purity may be known by a variety of experiments, as follows: make a solution of the salt in distilled water, and filter it through paper. Put a portion of it in a wine glass, and add a solution of carbonate of potassa. To another portion, add a small quantity of muriate, or in preference, nitrate of barytes. To a third portion, add nitrate of silver. If the fluid in the first glass remains clear, without any turbidness, we are to infer the non-existence of earthy salts; if turbid, that it contains lime, or some other earth, either in the form of a nitrate or muriate. The addition of oxalate of potassa to another portion of the solution will show the presence of lime by forming a precipitate, and the addition of carbonate of ammonia, and then of phosphate of soda, will indicate magnesia. If the second glass remains transparent, it shows that neither sulphuric acid, nor any of the sulphates are present. If the fluid in the third glass continues also clear, we infer that none of the muriates exist. These experiments are sufficient to show the purity of saltpetre. It would afford perhaps more satisfaction to institute also the same experiments on other samples of nitre, by which a comparison may be formed of the relative purity of each. To make an analysis of the salt, with the view to determine the proportion of the foreign substances would be altogether unnecessary for common purposes. A regularly defined crystal would, in a great measure, point out its purity. The double refined saltpetre is chemically pure. Artificers determine the purity of nitre by its flame; if white, they call it pure, if yellow, [73] impure.

The same reagents may be used in the examination of gunpowder, as we shall notice hereafter. If a portion of powder be mixed with distilled water, the water will dissolve only the saline substances, leaving the charcoal and sulphur. When the whole is thrown on a filter, the fluid, which passes through, will contain the saltpetre, and foreign salts, if any are present. The same experiments may then be performed with the solution, and the quality of the nitre, of which the gunpowder was made, be determined. Some gunpowder absorbs a large portion of water, which is owing to the presence of deliquescent salts. These salts may be detected by proceeding in the way we have pointed out. The art of refining saltpetre is so well known of late in the United States, especially by the Messrs. Dupont of Brandywine, Delaware, that our gunpowder is of a very superior quality. I have examined various specimens of this saltpetre, and gunpowder made with it, and could not detect any of the sulphates or muriates, either alkaline or earthy. For the manufacture of gunpowder, and fire-works generally, the nitre, it may be observed, cannot be too pure.

In pyrotechny, it is necessary to have the nitre in powder. Pulverizing it in a mortar is a tedious method, if a large quantity is required for use. There is an advantage, likewise, in the mode we will describe; because the saltpetre, besides being extremely fine, is made perfectly dry. Put into a copper kettle, whose bottom must be spherical, fourteen pounds of refined saltpetre, with two quarts or five pints of water. Put the kettle on a slow fire, and if any impurities rise and form a scum, remove them; keep constantly stirring with two large spatulas, till the water evaporates, and the nitre is reduced to a powder. This will be perfectly white, and almost impalpable. If it should boil too fast, remove the kettle, and set it on wet sand, which will also prevent the nitre from adhering to the pot. It should be kept in a dry place. This process of powdering saltpetre is performed on a large scale for the manufacture of gunpowder.

Sec. II. Of Nitrate of Soda.

This salt has been recommended in lieu of nitre, for preparing certain fire-works; but we confess, we can see no particular advantage in using it. It has the property of attracting humidity from the air, and on that account is rendered unfit for the [74] manufacture of gunpowder. This salt is composed of nitric acid and soda. It was formerly called *cubic nitre*. It may be formed, very readily, by saturating nitric acid with soda, and evaporating the solution. It crystallizes in rhomboidal prisms. It may be formed more economically, by mixing together the solutions of nitrate of lime and sulphate of soda, filtering the mixture, and evaporating the filtered liquor. It will be sufficient to observe, that it deliquesces, or absorbs moisture, and in the fire, that its phenomena are the same as those of nitre. It does not melt so readily.

Used in the same proportion as nitre, it will form a gunpowder, which soon, however, spoils by exposure. It will, like nitre, communicate a yellow colour to the flame of alcohol. Experiments were made with this salt, with the view to the fabrication of gunpowder, by MM. Bottée and Riffault. Their conclusions, as we have stated, may be seen in their work on *gunpowder*. Professor Proust says, that five parts of nitrate of soda, with one of charcoal, and one of sulphur, will burn three times as long as common powder, so as to form an economical composition for fire-works.

The *cubic nitre*, and the *nitrum flammans* were known, and so called, by the older chemists. The former we have seen, is the nitrate of soda, and the latter, is a combination of nitric acid and ammonia. Nitrate of soda, consists of 6.75 acid + 3.95 soda.

Nitrate of ammonia possesses the property of exploding; and, when exposed to a temperature of about six hundred degrees, is decomposed, furnishing the nitrous oxide, called also the protoxide of azote, and exhilarating gas, besides water. Nitrate of ammonia is composed of 6.75 acid + 2.13 ammonia + 1.125 water.

Sec. III. Of Chlorate of Potassa.

This salt, formerly called hyperoxymuriate of potassa, is used for sundry preparations, and especially for experimental fire-works. It is prepared by dissolving one part of carbonate of potassa in six parts of water, and saturating it with chlorine, formerly called oxymuriatic acid gas. This operation is usually performed in a Woulfe's apparatus. The gas, as it proceeds from the retort or gas bottle, is brought in contact with, and passes through, the fluid. It is formed by pouring liquid muriatic acid on the black oxide of manganese, or by pouring sulphuric acid on a mixture of muriate of soda, and the black oxide. When the saturation is nearly [75] complete, crystals fall down. These being dissolved in boiling water, and the solution allowed to stand, pure chlorate of potassa will be formed.

This salt is composed of 9.5, chloric acid, and 6 potassa; and chloric acid is formed of 28.87, chlorine, and 32.28, oxygen. It is to the oxygen in the salt, that its particular properties in fire-works are to be ascribed.

This salt is decomposed by all combustible bodies, and detonations generally accompany the decomposition. Hence it is used in a variety of experiments, some of which we will give.

Three parts of the salt and one of sulphur detonate when rubbed in a mortar. The same mixture, struck with a hammer on an anvil, produces a loud explosion. Phosphorus detonates with this salt either by trituration or percussion. The quantity of each should not exceed a grain. Treated in the same manner with almost all the metals, the same effect takes place. Cinnabar, antimony, pyrites, &c. produce the same effect. Nitric acid, poured on a mixture of this salt with phosphorus, produces flashes of fire. A mixture of the chlorate and white sugar, when touched with sulphuric acid, immediately inflames. Hence it is used in the preparation of pocket lights; the mixture being put on a common sulphur match, and immersed in sulphuric acid. The same preparation of sugar and chlorate of potassa, put over a tube used for firing artillery, will set fire to the priming fuse, by dropping on it sulphuric acid. Owing to this effect, M. Gassicourt (*Archives des Découvertes*), recommended a similar mixture for discharging cannon by means of this acid. As it contains a large quantity of oxygen, that gas may be obtained from it by distillation. Light decomposes it. It should, therefore, be excluded from the light.

As this salt, when mixed with inflammable substances, detonates when struck with a hammer, it has been used for the purpose of inflaming gunpowder without the use of the flint and steel. There are several formulæ given for the purpose. We remarked, when treating of the general theory of fire-works, that the Rev. Alexander Forsyth discovered a new kind of gunpowder, which inflames merely by percussion; that the gun-lock, which he contrived, was calculated for firing cannon, as well as musquetry; that it was so contrived as to hold forty primings of such powder; and that the act of raising the cock primes the piece. In his composition, each charge of priming contains no more than one-eighth of a grain of chlorate of potassa. Since that period, it appears, that the lock, as well as the powder, has been improved, although neither of them is in general use. Thenard, (*Traité de* [76] *Chimie*, tome ii, p. 559, troisième édition), has given a formula for preparing a priming powder of this salt, adapted to the new lock, which is made by mixing it with 0.55 of nitrate of potassa, 0.33 of sulphur, 0.17 of the raspings of peach-wood passed through a fine sieve, and 0.17 of lycopodium, or puffball. (See *Inflammable Powder.*)

This salt also produces powerful effects with charcoal and sulphur. Three parts of it, with half a part of sulphur, and half a part of charcoal powder, produce most violent explosions. Two persons, in 1788, lost their lives by it. If this mixture be thrown into concentrated sulphuric acid, a brilliant flame is produced. Such mixtures, we are informed, will explode spontaneously. It should not, for that reason, be kept prepared. Chlorate of potassa has been used in the place of nitre, for the manufacture of gunpowder, in consequence of its decomposition by charcoal. From its explosive effects, M. Berthollet was induced to propose it as a substitute for nitre. The proportions used by Chaptal, (*Chimie Appliqué aux Arts*, tome iv, p. 198), are six parts of chlorate of potassa, one of sulphur, and one of charcoal. They are to be mixed in a marble mortar with a wooden pestle. The first experiment was made at Essone, in France, in 1788. No sooner, however, had the workmen begun to triturate the mixture, than it exploded with violence, and killed two persons.

The force of this gunpowder is greater than that of the common sort; but the danger of preparing it, and even of using it, is so great, that these circumstances will always prevent its introduction. A salt, containing so much oxygen, and so loosely combined, that even the slightest friction, in contact with inflammable bodies, will separate it, must, of necessity, prevent its use in that way.

The experiments, which were made at the arsenal at Paris, on the 27th of April, 1793, comparing the effects of muriated powder, and the superfine common powder, have given us the following results:

1st. By the eprouvette of Darcy, consisting of a cannon, which, being suspended to the extremity of a bar of iron, described by its recoil an arc, of which the degrees can be measured.

			Recoil.		
2 drachms	muriatic powder,		15 deg.	2/20	
2 ——	do do	moistened,	14 —	1/20	
2 ——	common powder,		10 —	7/20	
2 ——	common powder,		10 —	1/20	[77]
3 ——	muriatic powder,		20 —	9/20	
3 ——	common powder,		16 —	6/20	

From these results, it appears, that, by the eprouvette of Darcy, the muriated powder, or that prepared with chlorate of potassa, gave a superiority of force of about one-fourth.

2nd. By the eprouvette of Regnier, which is repelled by the explosion, to a distance greater or less, measured by the degrees of the arc which it describes:

Muriated powder,	42
Idem,	51¾
Idem, moistened,	52
Common powder, superfine,	23
Idem,	22½

From which it results, that by the eprouvette of Regnier, the force of the powder of the oxymuriate is double that of the nitrate, or common powder.

M. Ruggieri is of opinion, that chlorate, or hyperoxymuriate of potassa may be employed with advantage in the composition of rockets, but we have not heard that it has been used. It is more powerful in its effects, and probably for this reason he recommended it. This salt, mixed with other substances, will produce the *green fire* of the palm-tree, in imitation of the Russian fire.

Chloric acid may be obtained in a separate state, by boiling the compound solution formed by passing chlorine gas through a solution of barytic earth, with phosphate of silver, which separates the muriatic acid. By evaporation, the chlorate of barytes will crystallize in fine rhomboidal prisms. When these crystals are dissolved in water, and diluted sulphuric acid added by degrees, an acid liquid will be obtained, which, if the sulphuric acid be added cautiously, will be found entirely free from the latter acid and barytes, and not affected by nitrate of silver. This is the chloric acid dissolved in water. Chloric acid unites with sundry bases. Combined with ammonia, it forms a fulminating salt, formerly described by M. Chenevix. This salt is formed, by mixing together carbonate of ammonia, and chlorate of lime. The carbonate of lime is then separated by the filter, and the clear liquid, holding the chlorate of ammonia in solution, is evaporated. Chlorate of ammonia is very soluble in water and alcohol, and decomposed by a moderate heat.

Chlorates, as the chlorate of potassa, are formed more readily in the manner already stated: *viz.* by saturating the base with [78] chlorine, but in this case two salts are produced, the chlorate and hydrochlorate. Chloric acid has also been obtained in a separate state, from chlorate of potassa, by a process recommended by Mr. Wheeler.

Perchloric acid, composed of seven primes of oxygen and one of chlorine, is obtained from chlorate of potassa, treated in a particular manner. Three parts of sulphuric acid and one of chlorate of potassa, when heated, will give a saline mass, consisting of bisulphate of potassa, and perchlorate of potassa. Deutoxide of chlorine will be evolved. The perchlorate detonates feebly when triturated with sulphur.

Sulphur, or brimstone, is a principal ingredient in almost all the compositions of fire-works. It should, therefore, be pure. The flowers may be considered the purest kind of sulphur.

Sulphur is found native, either alone, or accompanying certain minerals, such as gypsum, rock-salt, marl, and clay, as in Switzerland, Poland, and Sicily. In the neighbourhood of salt-springs, it is also found; and frequently in water, in combination with hydrogen, forming the natural hepatic waters. It is also found on the surface of the earth, as in Siberia. Volcanic sulphur, or that which occurs in the fissures and cavities of lava, near the craters of volcanoes, is very common.

Solfatere, Sicily, the Roman states, Guadaloupe, and Quito, in the Cordilleras, are most celebrated for native sulphur. It has been found in the United States, but in no quantity. We have a number of mineral springs, which deposite sulphur. The Clifton Springs of Ontario are of this kind. It occurs abundantly, in combination with hydrogen, as sulphuretted hydrogen gas, in various parts of the United States.

Native sulphur is abundant in the island of Java. It is obtained from the now almost extinct volcano, about sixty miles from the town of Batavia. At the bottom of the crater, there is said to lie many hundred tons of native sulphur. Silliman (*Journal*, vol. i, p. 58) observes, that it is in the crater of this volcano, that the celebrated lake of sulphuric acid exists, "and from which it flows down the mountain, and through the country below, a river of the same acid."

Sulphur, however, is usually obtained from pyrites or metallic sulphurets, by fusion and sublimation. It is usually denominated by [79] the name of the place whence it comes. Hence we have the Italian and Sicilian sulphur; the crude, roche, or stone brimstone of Marseilles, &c.

The quantity of sulphur, which may be obtained from the galena, or sulphuret of lead, by sublimation, is considerable. Twenty-five per cent is the loss sustained in the reduction of the lead ore, which occurs so abundantly in the neighbourhood of St. Louis. When general, the then lieut. Pike, (*Expeditions, &c. Appendix*) interrogated Mr. Dubuque in 1805, respecting the quantity of lead obtained from those mines, a detailed account of which is given by Schoolcraft, he replied that the mineral would yield seventy-five per cent. of lead, and hence the twenty-five per cent. loss must be the sulphur, together with any foreign matter it may contain.

The experiments of M. Vauquelin, (*Annales de Chimie*, 1811) to determine the quantity of sulphur contained in some metallic sulphurets, show, at once, the proportion which may be obtained from those combinations. Thus he found, that sulphuret of copper contains 21.31 per cent of sulphur; sulphuret of tin, 14.1; sulphuret of lead, 13.77; sulphuret of silver, 12.73; sulphuret of iron, 22; sulphuret of antimony, 25; sulphuret of bismuth, 31.75; sulphuret of manganese, 74.5; and sulphuret of arsenic, 43.

Of native or prismatic sulphur, there are two species, the common and volcanic. The former is of two kinds, the compact and earthy.

Sulphur, says Hanway, (*Travels, &c.*) is dug at Baku on the western side of the Caspian sea. It is found in the neighbourhood of the celebrated naphtha springs, some of which form a mouth of 8 or 10 feet diameter.

Von Humboldt (*Annales de Museum National*) communicated to the French national institute, that he discovered, in the province of Quito, a bed composed of sulphur and quartz, in a mountain of mica slate, and also sulphur in primitive porphyry. Kirwan (*Geological Essays*, p. 143) observes, that sulphur promotes decomposition, by absorbing oxygen, while it is thus converted into vitriolic acid; but moisture is also requisite. He attributes, in the same manner, the decomposition of stones that contain pyrites.

As the sulphur, which occurs in commerce, is chiefly obtained from its native combinations, it may be proper to make some brief remarks on this head. Sulphur in the state of combination is abundantly met with, and in all countries. It is found in the state of sulphuric acid, in various salts, as gypsum, epsom salt, native alum, &c.; and united with metals, forming natural sulphurets, as in [80] sulphuret of iron, or iron pyrites, sulphuret of copper, or copper pyrites, sulphuret of lead, or potter's lead ore, called also galena, sulphuret of antimony, or crude antimony, sulphuret of zinc, or blende, sulphuret of mercury, or cinnabar, sulphuret of arsenic, or orpiment, &c. In fact, it appears to be a general mineralizer. It is found also in some plants, and in animal substances.

Without detailing minutely the processes employed for extracting sulphur from its combinations, which may be seen in Thenard, (*Traité de Chimie*, tome i, p. 184) it will be sufficient to observe, that, in general, pyrites, both of iron and copper, are arranged in alternate layers in the form of a pyramid, and the *roasting* is continued for several months. Part of the sulphur is consumed, and part is sublimed, and is condensed and collected in hollows, in the upper part of the pyramid, whence it is removed several times a day. It is also obtained from pyrites, by a kind of distillation. They are reduced to coarse powder, and put into hollow iron cylinders, or retorts, where the sulphur is disengaged and melted, and thence runs into vessels of water. This process is employed in Saxony, where nine hundred pounds of pyrites will yield one hundred to one hundred and fifty pounds of sulphur, which is afterwards purified.

When melted and cast into wooden moulds, it forms the roll brimstone; and, by sublimation, conducted in large chambers, as we shall afterwards mention, it is converted into the flowers of sulphur. The residue of the sublimation is *sulphur vivum*, which is also used in fire-works. The roll brimstone is frequently adulterated.

In the island of Anglesea, it is obtained by the sublimation of the yellow copper ore. The operation is conducted in kilns, and the sulphur is conveyed by means of long horizontal flues, and collected in large chambers. As the United States furnish an abundance of martial pyrites, and also galena, sulphur might be manufactured in this country, and advantageously, especially from galena, which is very abundant in the neighbourhood of St. Louis. In the roasting of the ore, all the sulphur is now lost, tons of which might be collected.

For the purpose of gunpowder, the purer the sulphur, the better will be the powder; hence attention is always paid to this circumstance. M. Michel, one of the principal refiners of sulphur at Marseilles, has improved the process for purifying sulphur for the purpose of gunpowder. M. Libaw, connected likewise with the French national powder establishment, has furnished a very useful and important memoir on the same subject.

Two methods are proposed for the refining of sulphur, which we will briefly state, namely, fusion, and sublimation. The first is [81] conducted in iron pots fixed in a furnace; and the sulphur, before it is thrown in, is beaten into small pieces with a mallet. This facilitates the fusion, and renders it more uniform. Small portions at a time are thrown into the boiler, and stirred frequently with a wooden spatula. This manipulation ought to be continued till the boiler is filled. The heat must be regulated so as not to inflame, or sublime the sulphur.

The sulphur of commerce is commonly of three different colours, viz: citron-yellow, deep yellow, and brownish-yellow. These colours depend on the different degrees of heat to which the sulphur was exposed, in its extraction. The operation of refining consists in conducting the fire in such a manner, as that the colour of the sulphur will assume a brilliant yellow, bordering on a green. We must, therefore, to produce this effect, operate on the sulphur according to its colour. For the green sulphur, as little heat has been used for its extraction, the fire may be left under the boiler until there is no more left to melt than the top. The sulphur of the yellow colour may be kept longer on the fire, which may be removed when the mass is melted three-fourths. The sulphur of a brown colour, being already much burnt, may be removed when the mass is melted one-half. If it is required to operate on all the varieties at the same time, in order to produce sulphur of a uniform colour, in that case we must fill the boiler one-half with the green sulphur, one-fourth with the yellow, and the remainder with the brown, and removing the fire when the yellow is almost wholly melted. The boiler is then covered with a lid. The fusion is completed by the heat of the mass. The light bodies then raise themselves to the surface, forming a black scum, which is removed, and the heavy bodies fall to the bottom. The boiler remains for four or five hours, uncovering it from time to time to take off the scum. The fluid part is removed, and is suffered to congeal, taking care not to disturb the deposite.

The second process of refining is by sublimation. This operation consists in subliming it in a close apparatus, which in sulphur refineries are boilers placed in brick work, and furnished with heads. These heads communicate by a pipe with a vaulted chamber, placed at some distance from the furnace. The chamber serves to collect the sulphur. There is usually a stone slab fixed between the chamber and the head. The chamber is furnished with one or two iron-plate valves. There is an opening in the head of each [82] boiler, in order to renew the sulphur: it is closed very tight by a plate of iron. There is an opening also in the chamber, to admit a person, which is closed likewise by an iron plate. The heads are luted before the process is commenced.

By this process the sulphur is refined; for the pure part is sublimed, and the foreign substances remain in the pots. The product thus obtained is the ordinary flowers of sulphur. If the heat be moderate, the sublimation is more perfect. It is necessary at the same time that the temperature of the chamber should be low, otherwise the sulphur will melt, which frequently takes place. Coarse particles are separated from the flour, should they occur, by a sieve.

During the first part of the process, there is formed some sulphurous acid gas, which is not produced after the vapour of sulphur forms the atmosphere in the head. This is known to exist, by the acid taste of the sulphur, and its black colour.

Detonation very frequently takes place, and sulphurous acid gas is produced. In the sublimation of brimstone, about ten to eleven per cent. is the usual total loss, of which six or seven per cent. is residue. The acid may be separated from the sulphur by washing it in water, and afterwards drying it. It is then called the washed flowers of sulphur. (See *Traité de l'Art de Fabriquer la Poudre à Canon*, p. 153.) by MM. Bottée and Riffault, for a minute description of this process.

Sulphur undergoes no change by exposure to the air. It is insoluble in water. It breaks in the hand with a crackling noise. At 170 degrees it begins to evaporate, and when collected it is called sublimed, or flowers of sulphur. It melts at 218 degrees. When melted and poured into water, it forms the *sulphurs* for taking the impression of coin, &c. If melted, and cooled slowly, it will crystallize in the form of needles. It is soluble in different degrees in alcohol, ether, and oils. When sulphur is burnt very slowly in the open air, it unites with oxygen and forms sulphurous acid. This acid is used in bleaching. When mixed with nitre, and burnt in leaden chambers, it forms sulphuric acid, or oil of vitriol, by which process it combines with a larger quantity of oxygen. There is another compound called hyposulphurous acid, all the salts of which are inflammable and burn with a blue flame. Sulphur unites with the alkalies, earths, and metals. If the alkaline sulphurets be dissolved in water, and an acid added, the sulphur will [83] precipitate of a white colour, known by the name of milk of sulphur. It is considered by some a hydrate of sulphur. The same preparation is made by subliming sulphur in a vessel containing the vapour of water. Sulphur unites with chlorine and iodine, forming chlorides, and iodides. With hydrogen, it forms the sulphuretted hydrogen, or hepatic gas, called also the hydrothionic and hydrosulphuric acid; with carbon, the sulphuret of carbon; and with nitre and charcoal, in the state of mixture, it constitutes gunpowder.

The motionless *ignes fatui* of Italy, which are seen nightly on the same spot, are attributed to the slow combustion of sulphur, emitted through clefts and apertures in the soil of that volcanic country; but the *Will-with-the-Wisp*, which moves in undulations, near the surface of the ground, in swampy situations, and where the putrefactive process is going on, originates in all probability from decaying vegetable and other matters, and the extrication of phosphorus. It is known that the acid of phosphorus is found in plants, and especially those that grow in marshy places, in turf, and several species of the white woods.

Mealing of Brimstone. What is termed the mealing of sulphur by fire-workers, is no other than reducing it, if it be the roll, to powder. Large mortars and pestles made of ebony, and other hard wood, and horizontal mills with brass wheels are used. The *mealing table* is used by artificers. It is generally made of elm, with a rim around its edge four or five inches high. One end is narrow, and furnished with a slider that runs in a groove, and forms part of the rim. After using as much of the powdered brimstone as is required, copper shovels being employed, the rest may be swept out at the slider. This table is also used for the mealing of gunpowder and saltpetre. The muller is generally made of ebony. After reducing it to powder, it is then passed through a lawn sieve, furnished with a cover.

As brimstone is frequently adulterated with different substances, it may be of importance to discover the fraud. We may remark, that, if it is pure, it will be taken up entirely by chlorine gas, or by using a solution of caustic potassa. The latter, however, cannot be depended on in all cases. But the best mode, is that of melting some of it in a ladle; if any residue remains, after the fumes have ceased, the presence of foreign substances may be inferred, for pure sulphur will sublime without leaving any residue. It is not unfrequently adulterated with common flour. There is another mode of determining the quality of sulphur, It should, if pure, be [84] completely soluble in boiling oil of turpentine. If any residue remain, we may infer the presence of foreign substances, either vegetable, earthy, or metallic.

It is obvious, that if the brimstone is impure, the effect of it in fire-works will be imperfect. Flowers of sulphur, however, may be almost always depended on. In all artificial fire, in which sulphur forms a part, the *flame* is more clear, as the sulphur is pure.

Several modes are recommended for the separation of sulphur from charcoal, in gunpowder, which may be seen by referring to the analysis, or chemical examination of gunpowder.

Sulphur constitutes one of the ingredients, generally speaking, of incendiary compositions, used for military purposes, and, in such cases, is usually mixed with pitch, tar, saltpetre, and sometimes gunpowder. It is said to be one of the substances, which entered into the composition of the ancient and celebrated Greek fire; but the principal character of which, that of burning in water, was owing to the presence of camphor. This substance, associated with sulphur, pitch, and nitre, forms one of the most effective incendiaries of all military fire-works. For such purposes, it is hardly necessary to add, that the common roll brimstone is sufficiently pure.

As to the mode of preparing these works, the custom is to melt the resinous substances first, then to add the sulphur, and finally the saltpetre; and after the whole are melted and thoroughly mixed, to remove the pot from the fire, and add gradually the gunpowder. If a carcass is to be made, tow or hemp, or untwisted rope, is immersed in the composition while hot, and taken out and formed into a ball of the size required. Rope, treated in the same manner, with the same composition, will make a more active tourteaux than the common kind. (See *Carcass and Tourteaux*.)

All oils, whether expressed or essential, can dissolve sulphur. To make this solution, the oil must be poured on the sulphur, and sufficient heat applied to melt the substance. While the oil dissolves the sulphur, it acquires a reddish or brown colour, an acrid, disagreeable taste, and a strong fetid smell, somewhat hepatic, resembling that of oil with sulphuric acid.

Sec. V. Of Phosphorus.

We mention this substance, because it is used in some experiments, although not in extensive fire-works. It is a very inflammable [85] substance, inflaming either by friction, or an increase of temperature. It produces a most brilliant fire, and when mixed with some substances, exhibits very pleasing phenomena. It usually comes to us in sticks, which must be constantly kept in water to prevent its inflammation. Phosphoric matches, phosphoric fire-bottles, &c. are made of it. These are made in various ways. Phosphorus and sulphur melted together in a small phial, forms the fire-bottle, or some add a portion of lime. A sulphur-match dipped in this mixture and gently rubbed, immediately inflames. They do not last any time, in consequence of the acidification of the phosphorus. Phosphoric tapers are usually made with a glass tube, on the breaking of which, it inflames. When rubbed upon a wall in a dark room, it appears very luminous. Dissolved in ether, and poured upon boiling water in the dark, the vapour as it ascends appears remarkably luminous, and has a pleasing effect. Dissolved in oil, as olive-oil, it forms the phosphorized oil, which may be rubbed on the face and hands without injury. This oil has the same appearance in the dark. The time of night may be known by the light it produces. When mixed with nitrate of silver, sulphuret of antimony, sulphur, chlorate of potassa, &c. and struck with a hammer, it produces an explosion more or less loud. A variety of explosive compounds may be made with it, but they must be used with great care.

When combined with hydrogen, it inflames spontaneously when brought in contact with atmospheric air. It inflames also in chlorine gas. It is supposed to be the cause of the *ignes fatui*, or *Will-with-the-Wisp*. The formation of phosphoretted hydrogen gas may be shown in a variety of ways, as the following: throw some pieces of phosphuret of lime into water, and bubbles of gas will rise, which will take fire on coming to the air; or, put into a flask some phosphorus, iron or zinc filings, water, and sulphuric acid, and the gas will be generated; or, introduce into a small retort, a solution of potassa, and a piece or two of phosphorus, and apply heat, immersing the beak of the retort in a basin of water, the gas will pass over, and inflame as it comes to the surface of the water. In all these experiments, the water is decomposed; its oxygen goes to a part of the phosphorus in the first experiment, and the hydrogen of the water then unites with another portion of phosphorus, which is then evolved; in the second experiment, the oxygen oxidizes the metal, and the hydrogen dissolves a part of the phosphorus; and in the third experiment, the phosphorus unites with the potassa, forming a phosphuret, which decomposes the water, the hydrogen of which passes off in combination with [86] some of the phosphorus, forming the phosphuretted hydrogen gas.

The cause of the spontaneous combustion is, that the oxygen of the atmosphere unites with the hydrogen and the phosphorus, and forms water and phosphoric acid; the latter producing a beautiful corona as it rises in the air. The heat and light given out proceeds as well from the oxygen gas, as from the phosphuretted hydrogen gas. When saturated with oxygen, it is no longer inflammable.

There are some other experiments which can be made with this singular substance.

It was formerly obtained from urine, as that fluid contains some phosphoric salts. It is now prepared from bones. These are burnt to an ash, and diluted sulphuric acid is poured on it; the phosphoric acid it contains is then disengaged, and remains in the fluid. The sulphate of lime is then separated, the fluid boiled to dryness, and the dry mass is mixed with charcoal, and distilled in the open fire.

The phosphoric pencil, for writing on a wall, paper, &c. to be luminous in the dark, is nothing more than a bit of phosphorus put into a quill. It must be kept in water, and when used, frequently dipped in water, to prevent its taking fire.

The *phosphoric* stone of M. Bucholz, described in the *Archives des Découvertes*, ii, p. 109, is a phosphuret of magnesia, prepared by melting thirty grains of phosphorus in a small flask, and adding twenty or thirty grains of calcined magnesia. Although this process is given by Bucholz, yet, as it is difficult to prevent the inflammation of the phosphorus, the best mode would be to bring the vapour of phosphorus in contact with magnesia, in the same manner as in preparing phosphuret of lime.

The pyrophorus of Wurzer is nothing than a phosphuret of lime. It is prepared by taking two parts of pulverized quicklime, and one part of phosphorus; introducing them into a bottle, and covering it with three parts of quicklime, leaving one-third of the bottle empty; then putting the bottle into a crucible surrounded with sand, previously stopping the mouth with clay, and applying heat. Remove the phial when the phosphorus appears to sublime of a red colour. When the bottle is opened it becomes luminous, and brought out it inflames.

Phosphorus in the state of acidification, and united with lime, is found in abundance. Whole mountains in the province of [87] Estremadura in Spain, are said to be composed of this combination. According to Mr. Bowles, this stone is whitish and tasteless, and affords a blue flame without smell when thrown upon burning coals. Mr. Proust observes, that it is a dense stone, not hard enough to strike fire with steel, and is found in strata, which always lie horizontally upon quartz, and which are intersected with veins of quartz. He adds, that it does not decrepitate on burning coals, but burns with a beautiful green light. This stone is the common phosphorite. It contains, according to Klaproth, 32.25 per cent. of phosphoric acid.

Several substances are known under the name of phosphorus, although they do not contain it, such as Baldwin's phosphorus, or ignited muriate of lime, Canton's phosphorus, or oyster-shells calcined with lime, and Bologna phosphorus, or calcined sulphate of barytes.

Sec. VI. Of Charcoal.

Charcoal performs an important part in all the various kinds of fire-works. The facility with which it decomposes nitric acid, when it is combined with salifiable bases, as with potassa in saltpetre, and its action in all cases wherein nitre is concerned, are sufficient examples of its effect.

Pure carbon is the diamond. It affords by combustion in oxygen gas, the same gas as common charcoal, when charcoal is burnt in oxygen, or in atmospheric air. This gas is carbonic acid, or fixed air. Charcoal has been considered a long time an oxide of carbon, and according to some, as Berthollet, a compound of carbon, hydrogen, and oxygen.

Charcoal is insoluble in water. It is not affected by the most violent heat, if confined in close vessels. It is an excellent conductor of electricity, but a bad conductor of heat. It is very indestructible; and, therefore, when wood is charred, it will remain a long time under ground without rotting. As an antiseptic, it is powerful. It will therefore prevent the putrefaction of bodies, and even recover tainted meat. As a preservative of water, for sea-voyages, it has been long known. The charring of water casks is designed for the same purpose. The quality of wine is said to be improved by having the casks previously charred. It possesses the property of absorbing gases, and to this property is ascribed its use as an antiseptic, and its disinfecting quality. To the distiller it is useful, as it destroys effectually the burnt or empyreumatic smell of liquor. When heated to eight hundred degrees in the open air, it burns. [88] In oxygen gas the combustion is brilliant, forming in both instances carbonic acid gas, called also aerial acid, fixed air, mephitic air, and calcareous acid. This acid is formed in a variety of processes, and is carbon saturated with oxygen.

Carbon exists in various states of combination, and many of the compounds into which it enters are inflammable; hence carbonic acid is generated in the combustion of coal, oils, fat, &c. In the form of an acid, it is abundant in various stones, such as the calcareous carbonates, as chalk, marble, limestone, and calcareous spar, barolite, &c. all which effervesce with acids, the carbonic acid being liberated. When limestone is burnt, to obtain quicklime, the carbonic acid is disengaged, for the presence of this acid distinguishes limestone from pure lime. Carbonic acid is generated in various processes of nature as well as art. Hence it is produced in the respiration of animals, and is found in a gaseous state in wells, cellars, caverns, &c. It neither supports animal life, nor combustion. In mines it is called choke damp; and the Grotto del Cani, in the kingdom of Naples, has been long celebrated, on account of it. This cave is in the side of a mountain, near the lake Agnano, measuring not more than eighteen feet from its entrance to the inner extremity; where if a dog or other animal that holds down its head be thrust, it is killed by the gas. Some experiments were made in this cave with gunpowder, which see. Carbonic acid, during the formation of alcohol, in the vinous fermentation, is generated, and its production appears to be designed by nature to carry off the excess of carbon, which gives rise to that phenomenon called fermentation. When combined with water, it forms aerated water, and with alkalies and water, the aerated alkaline waters. Its union with bases forms salts called carbonates. Plants have the property of decomposing it, and in this respect nature has employed a mean of regenerating the atmosphere, on the purity of which depends, in an eminent degree, the very existence of animal life. The prime equivalent of carbonic acid is 2.75, and carbonic acid is composed of carbon 0.75 + 2.0 oxygen.

Carbonic acid may be decomposed when combined with a base, as lime, by phosphorus and heat, for charcoal and a phosphate of lime will be produced. But carbonic acid in the state of gas may be decomposed by potassium. Five grains of potassium will decompose three cubic inches of gas, and be converted into potassa, producing at the same time three-eighths of a grain of charcoal. If passed over a coil of fine iron wire heated to redness, in a porcelain tube, and the operation repeated, the iron will be [89] oxidized, and the carbonic acid changed into carbonic oxide gas.

Charcoal will not burn in dry chlorine. It unites with a less proportion of oxygen, and forms carbonic oxide gas, which burns with a deep blue flame. This combination is formed by distilling in a red heat, a mixture of equal parts of iron filings and chalk. This gas mixed with chlorine gas, and exposed to the sun's rays, will unite with it, and form chlorocarbonic acid gas. Carbon unites with azote, and forms cyanogen, the base of Prussic acid. It unites likewise with hydrogen in two proportions, forming the hydroguret and the bihydroguret of carbon, both of which are carburetted hydrogen gases. The former is obtained by distilling a mixture of four parts of sulphuric acid, and one of alcohol. The gas is very inflammable, and burns with great splendour; and on that account may be used for exhibition, in an apparatus similar to that of Cartwright. (See *Fire-works with Inflammable air.*) It was called by the German chemists olefiant gas. The other species, called also the light carburetted hydrogen gas, may be obtained by agitating the mud at the bottom of stagnant pools; and by the distillation of moist charcoal, wood, pitcoal, pitch, or almost any animal or vegetable substance. The gas, used for *gas-lights*, is the same. It is usually obtained from pit coal. We may merely observe, that the gas used for that purpose, *i. e.* for illuminating streets, theatres, manufactures, &c. as obtained in the common method, is not altogether the bihydroguret of carbon; but, according to the experiments of Dr. Henry, a mixture of that gas with the hydroguret, and occasionally carbonic oxide.

Carbon enters into other combinations. It exists as a component part of gums, resins, sugar-starch, and other vegetable products, as the vegetable acids, its union with iron forms steel, a substance greatly used in the preparation of some fire-works, especially in some of the *rains* and *stars*, and in the composition of *brilliant fire*. (See *Iron.*)

As charcoal enters into the composition of gunpowder, and the effective force of powder depends considerably on the quality, as well as the proportion of charcoal, it is obvious for this purpose, it should be as pure as possible.

Carbon is always obtained from some of its combinations, as from pitch, tar, rosin, wood, and oil. Various processes are employed for this purpose. Thus, by the combustion of rosin and oil, as well as pitch, tar, turpentine, &c. a soot is formed that [90] collects, called lampblack, which is nothing more than the carbon or charcoal. When pit-coal is *charred* in an oven, called a coke oven, all the bitumen and sulphur contained in it are disengaged, and a charcoal remains, called, however, *coke*. Wood, when charred is decomposed; all the volatile parts are disengaged with carburetted hydrogen gas, and the woody fibre is converted into coal. This coal is more or less dense according to the compactness of the wood. Hard woods furnish the most solid coal, and light woods on the contrary.

When the solid parts of animals, as bone, are charred, the volatile products, principally ammonia or volatile alkali, are dissipated, and there remains a substance called bone-black, improperly called, *ivory black*.

The carbonization of wood in the common way is well known: after it is cut to the lengths required, it is piled on the ground in a pyramidal form, and covered with sod and clay, leaving a place for the current of air, and the smoke. The wood is then set on fire, and when the whole is burnt to a coal the vents, &c. are closed with sod and clay.

Nicholson (*Chemical Dictionary*) observes, that in the forest of Benon, near Rochelle, great attention is paid to the manufacture, so that the charcoal made there fetches twenty-five or thirty per cent. more than any other. The wood is that of the black oak. It is taken from ten to fifteen years old, the trunk as well as the branches, cut into billets about four feet long, and not split. The largest pieces, however, seldom exceed six or seven inches in diameter. The end that rests on the ground is cut a little sloping, so as to touch it merely with an edge, and they are piled nearly upright, but never in more than one story. The wood is covered all over about four inches thick with dry grass or fern, before it is enclosed in the usual manner with clay; and when the wood is charred, half a barrel of water is thrown over the pile, and earth to the thickness of five or six inches is thrown on, after which it is left four-and-twenty hours to cool. The wood is always used in the year in which it is cut.

Turf or peat has been charred lately in France, it is said, by a peculiar process, and, according to the account given in Sonnini's

Journal, is superior to wood for this purpose. Charcoal of turf kindles slower than that of wood, but emits more flame, and burns longer. It boiled a given quantity of water four times, while an equal weight of wood charcoal boiled the same quantity but once. In a goldsmith's furnace, it fused eleven ounces of gold in eight minutes, while wood charcoal required sixteen. The malleability of [91] the gold, too, was preserved in the former instance, but not in the latter. Iron heated red-hot by it, in a forge, was rendered more malleable.

In charring wood it has been conjectured, that a portion of it is sometimes converted into a pyrophorus, and that the explosions that happen in powder-mills are sometimes owing to this.

Bartholdi supposes, that such explosions are owing to the formation of phosphoretted hydrogen gas, while others attribute them to the absorption of oxygen, by the hydrogen contained in the coal, and the consequent evolution of free caloric. Percussion, which necessarily takes place in mixing the materials of gunpowder by stampers, no doubt accelerates the combustion. The addition of water, and having the charcoal previously pulverized, will prevent such accidents. (See *Gunpowder.*)

Coal prepared in the manner above stated, is liable to many foreign admixtures, nor can the process be so well regulated as to produce coal of a uniform quality throughout. The present improved process has many advantages, as experience has proved. It consists in charring the wood in confined vessels, made of iron. These are usually cylindrical, furnished with an iron cover, and placed in furnaces. The pyroacetic, formerly called the pyroligneous, acid, which is formed in the destructive distillation of wood, is caught for use. This acid is useful to the calico printer, dyer, &c. in making their iron liquor, and when purified, is employed in Europe in the place of vinegar, as it is more pungent, and highly concentrated.

When pine and various kinds of wood, which yield turpentine, are carbonized, we obtain tar during the process.

Chaptal informs us, that tar is obtained from the wood of the trunk, branches, and roots of the pine, which are heaped together, covered with turf, and set on fire to produce a close combustion, in the same manner as for making charcoal. The oily parts which are disengaged, trickle down, and are received in a gutter, which serves to convey them to a tub. The most fluid part is sold under the name of huile de cade; and the thicker part is the tar used for paying or painting the parts of shipping and other vessels.

According to the wood submitted to the process of charring, the products are, more or less, various; but in all cases it is only the solid part, or ligneous fibre, that furnishes the coal. By the ordinary process we obtain sundry volatile products, among which are [92] pyroacetic acid and carburetted hydrogen gas.

When wood is carbonized in the usual manner, it yields from 16 to 17 parts of charcoal in the hundred; but when the operation is conducted in close vessels, the product is 28 per cent. a saving of eleven or twelve per cent. By this difference in the quantity, it appears that eleven or twelve per cent. is burnt in the common process.

M. Mollerat was the first who tried the experiment with iron cylinders.

M. Vauquelin (*Annales de Chimie*, tome lxvi, p. 174) has given some observations on the carbonization of wood in close vessels, predicated on a Memoir of M. Mollerat; both of which are interesting. The apparatus used by M. Mollerat is described by Thenard, (*Traité de Chimie*, iii, p. 373,) to be composed of two parts, viz: a furnace with a moveable dome, and a cylindrical kettle, or vessel of iron sufficiently large to contain a cord of wood. It is furnished with a cover and pipe. The pyroacetic acid is collected. Smaller cylinders are preferred, because the wood is ignited more readily and the charcoal is more of a uniform quality.

From 100 parts of the following named woods, Messrs. Allen and Pepys (*Phil. Trans.* 1807) obtained the following proportional parts of charcoal:

Beech	15.00	Oak	17.40
Mahogany	15.75	Fir	18.17
Lignum Vitæ	17.25	Box	20.25

See also the experiments of Mr. Mushet, in the third volume of Tilloch's *Magazine*.

It appears by the *Annales de Chimie*, vol. 66, and the *Retrospect of Discoveries*, vol. vi, p. 100, that three brothers have established at Pellerey, near Nuits, Cote d'Or, a manufactory on a large scale, for making charcoal in close vessels.

The quantity of charcoal they obtained is double that by the usual mode, while it requires only one-eighth part of wood to be consumed in the distillation; it is also better than the common, as a given quantity evaporates one-tenth more water than the other; hence iron masters may obtain twice as much iron from the use of a given quantity of wood; and in addition to this, there is also prepared a number of other articles, of each of which in order.

350 kilogrammes (700 lbs.) of wood, yield 25 or 30 of tar, which retains so much acid that it is soluble in water; but when it is [93] washed, and rendered thick by boiling, for some time, it offers more resistance to water. If mixed with one-fifth of rosin it is rendered equally fit for the use of ships, &c. as the common tar.

Four sorts of vinegar are prepared, all of which are perfectly limpid, which do not, like the common, contain any tartar, malic acid, resinous or extractive matter, nor indeed any mineral acid, lime, copper, or other substances. The simple vinegar marks—2° hydrometer for salts, at 12° centigrade thermo. it is stronger tasted than common vinegar, and produces a disagreeable irritation. The aromatic vinegar is prepared with tarragon, the smell is agreeable, but it has the same fault as the former. The vinous vinegar is formed by adding some alcohol to simple vinegar; it has a very sensible odour of acetic ether; the alcohol softens the flavour in some degree, but the vinegar is still very sharp. The acid, called strong vinegar, is in fact a very good acetic acid at $10\frac{1}{2}$° hydr., it is very white, clear, and sharp, without the usual burnt flavour, and seems to form the basis of the preceding kinds. It can be sold for 8 or 9 francs (7s.) per lb. which is only half the price of that distilled from verdigris. Although not so agreeable to the taste as common vinegar, these new kinds are more elegant to the eye, and do not mother.

The editor of the Retrospect makes the following observations:

The proprietors of this manufactory seem to be perfectly aware of all the several productions which could be prepared from the refuse of their principal object; and we have no doubt but that the substances they procure in this manner will amply compensate them for the use of the capital that must be invested in building the furnaces.

The nature of the vessels in which they distil the wood is not mentioned, but they are probably cast iron retorts, or vessels of a similar nature, in which a distillation *per latus* takes place. The application, therefore, of lord Dundonald's furnaces for procuring coke to this purpose would be still more advantageous.

A cubic yard of wood yields 100 quarts of acid liquor, besides 50 or 60 lbs. of thick oil.

The method of making charcoal of a *uniform quality*, for which a Mr. Kurtz has taken out a patent, is the following:

A sheet-iron chest, which has a cover that fits it tight, and a pipe, or tube, that descends nearly to the bottom, and coming out from its side above, is fixed in brick work. In this the billets of wood are put. Fire is then made underneath. It is obvious, that the [94] wood is kept at one temperature from its being immersed in vapour, as the vapour cannot escape at the top, but must descend to the bottom, and then proceed up the pipe, by which it is conveyed away. The effect is, that the charring process goes on regularly, and the wood is charred equally. The carbonization is finished when the vapour ceases to appear, and nothing but carburetted hydrogen gas escapes. The charring of bones is performed in iron cylinders, furnished with tubes to receive, and convey away, the impure ammonia.

In the manufacture of powder, particular kinds of wood are selected for carbonization. These are generally, willow, hazle, maple, poplar, linden, buckthorn, or alder, or those which are tender and light, because, as they are less dense, and consequently more friable, they enflame and consume more rapidly: they are known in the arts by the name of *white wood*. When a less sudden effect is to be produced with the gunpowder, and the combustion prolonged, as in some sky-rockets, the charcoal of hard wood is to be preferred, such as the oak, beech, &c. When the wood is gathered, the bark is removed, and the wood exposed to the sun to dry: it is then cut into billets, and charred. The ashes, if any be formed, are to be carefully separated.

In considering the use of charcoal, therefore, for the preparation of gunpowder, we are to direct our inquiries to the choice of wood for carbonization, and the best process for carbonizing it. All light woods, we remarked, as the linden, willow, poplar, &c. furnish the lightest coal, and on that account are preferred. It is remarked, that tender wood, besides making a light, friable, and porous coal, is more combustible than ordinary hard, and more compact wood, and the coal that it furnishes leaves less residue after combustion.

Many experiments have been made with coal prepared from different kinds of wood, with a view of ascertaining the kind best adapted for the manufacture of gunpowder. M. Letort, at the powder mills of Essonne, in France, instituted a number of experiments of this kind. He made gunpowder with the coal of several kinds of wood, and compared its effects by a mortar eprouvette. The result was, that the powder made with the coal of poplar, was the strongest; and the other powder, made with the coal of the linden, willow, &c. was of the same quality throughout. As to the second inquiry, it is hardly necessary to repeat, that for the complete and thorough carbonization of the wood, to produce at the same time coal of a uniform quality, the process of [95] charring in iron cylinders or close vessels, is to be preferred. The point to be attended to is, to bring the wood to a complete state of ignition, and consequently to disengage all the volatile or fluid parts. When the gas (carburetted hydrogen) ceases to appear, it is a criterion that the operation is finished. This gas, it is to be recollected, will come over even after the whole of the wood is completely ignited. The first volatile product is the pyroacetic acid. Some saturate the acid liquor with chalk, and decompose the acetate of lime with sulphate of soda, and separate the acetic acid from the acetate of soda by distillation with sulphuric acid. The acetic acid is then tolerably pure, and may be diluted for use.

It is observed, however, that when charcoal, prepared in iron cylinders, is designed for gunpowder, the last portion of vinegar and tar must be allowed to escape, and the reabsorption of the crude vapours prevented, by cutting off the communication between the interior of the cylinders and the apparatus for condensing the pyroacetic acid, whenever the fire is withdrawn from the furnace. If this precaution be not taken, the gunpowder made with the charcoal would be of inferior quality.

On a large scale, when the object is also to prepare the vinegar of wood, a series of cast-iron cylinders, about four feet diameter, and six feet long, are built horizontally, in brick-work, so that the flame of one furnace may play round about two cylinders. Both ends project a little from the brick-work. One of them has a disc of cast iron well fitted and firmly bolted to it, from the centre of which disc an iron tube about six inches diameter proceeds, and enters at a right angle, the *main* tube of the refrigeration. The diameter of this tube may be from 9 to 14 inches, according to the number of cylinders. The other end of the cylinder is called the mouth of the retort. This is closed by a disc of iron, smeared round the edge, with clay lute, and secured in its place by wedges. The charge of wood for such a cylinder is about 8 cwt. The hard woods, oak, ash, birch, and beech, are alone used. Fir does not answer. The heat is kept up during the day-time, and the furnace is allowed to cool during the night. Next morning the door is opened, the coal removed, and a new charge of wood is introduced. The average product of crude vinegar is 35 gallons. Its total weight is about 300 lbs. But the residuary charcoal, according to Ure, (*Chemical Dictionary*), from whom we have taken this account, is found to weigh no more than one-fifth of the wood employed. The crude pyroacetic acid is rectified by a second [96] distillation, in a copper still, in the body of which about 20 gallons of viscid tarry matter are left for every 100. Its acid powers are now superior to the best household vinegar in the proportion of 3 to 2. Ure observes, that by distillation, saturation with quicklime, evaporation of the liquid acetate to dryness, and gentle torrefaction, the empyreumatic matter is so completely dissipated, that on decomposing the calcareous salt by sulphuric acid, a pure, perfectly colourless, and grateful vinegar rises in distillation. Pyroacetic acid is said to be a powerful antiseptic. M. Monge, Dr. Jorg, and more lately, Mr. Ramsay, of Glasgow, have made experiments with it. Fish dipped in it have been preserved for many days, and meat treated in the same manner, has also been preserved from putrefaction.

With respect to the pulverization of charcoal, the operation is so exceedingly simple, that we deem it unnecessary to notice it. It is obvious, that mortars, mills, &c. may be used, with fine or coarse sieves. For fire-works, charcoal is frequently pulverized in a leather sack, in the same manner as grained powder is reduced to meal-powder. It may be made either coarse or fine, to answer different purposes, by employing sieves of different kinds. Charcoal may be separated from nitre and sulphur, in gunpowder, by a simple process, which may be seen by referring to the section on gunpowder.

The quantity of carbon in coal, is directly proportionate to the quantity required for the decomposition of nitrate of potassa, a fact necessary to be considered in the theory of the action of charcoal in gunpowder. Thus, Mr. Kirwan found that, 12.709 of carbon are necessary to decompose 100 of nitrate of potassa. It will be easy to deduce the quantity of carbon, in a given weight of coal, from the quantity of nitrate of potassa it is capable of decomposing. The experiment is made very readily by fusing in a crucible, five hundred or more grains of nitre, and when red-hot projecting by degrees the powdered coal on the nitre. When the detonation produced by one projection of coal has ceased, add a new portion till it produces no farther effect.

Charcoal may be made intensely black, resembling ivory black, according to M. Denys-de-Montfort, (*Bibliothèque Physico-Economique*, for March 1815,) by pulverizing it very fine, mixing it with wine lees, and drying the mixture, and then subjecting it to a strong heat in a covered crucible, or other vessel.

[97]

Sec. VII. Of Gunpowder.

Having remarked, that the quality of gunpowder depends upon the purity of the materials, of which it is formed, and that they should be prepared in a state of purity; the subject that will now particularly claim our attention, is the proportions of the ingredients, their mixture, and the final preparation of gunpowder for use. To this, we purpose to add, the theory of its explosive effects, the different modes of proving it, and the experiments necessary to determine the quality of its respective ingredients, on all which we will be as brief as the importance of the subjects will admit. Previously, however, it may be interesting to notice the *history of gunpowder*, the invention of which has so completely changed the art of war.

The history of gunpowder has been fully treated by many writers of eminence; but by none more largely, and, at the same time, more satisfactorily than by the French. Beckman, in his History of Inventions, is full on this subject. Our purpose is not to go into details, as it would enlarge our volume, to the exclusion, perhaps, of other and more important matter. We shall, therefore, confine ourselves to a few facts and observations.

Notwithstanding much has been written on the subject, the original invention of gunpowder seems to be in obscurity. By whom, and at what time it was invented, is a question not fully settled. It is said to have been known in the east from time immemorial, and whatever claim Roger Bacon, who died in 1292, may have had to the discovery, or that he knew the properties of gunpowder, it is certain, that the use of fire-arms was then unknown in Europe.

Professor Beckman, who examined all the authors extant on the origin of gunpowder, is of opinion, that it was invented in India, and brought by the Saracens from Africa to the Europeans, who improved the preparation of it, and employed it in war, as well as for small arms and cannon.

M. Langles, who read a memoir on this subject to the National Institute, in 1798, observes, that the Arabians obtained a knowledge of gunpowder from the Indians, who had been acquainted with it from the earliest periods. The use of it was forbidden in their sacred books, the veidam or vede. It was employed in 690 at the battle near Mecca. As nitre was employed in all probability in the Greek fire, invented about the year 678, it is supposed, that that composition gave rise to the invention of [98] gunpowder.

Various prescriptions, or formulæ, have been given for the preparation of this fire. The oldest is by princess Anna Commena, in which, however, there is only resin, sulphur, and oil. Beckman observes, that the first certain mention of saltpetre will be found in the oldest account of the preparation of gunpowder, which, in his opinion, became known in the thirteenth century, about the same time that the use of the Greek fire, of which there were many kinds, began to be lost. The oldest information on this subject is to be found in the works of Albertus Magnus, and the writings of Roger Bacon. The true recipe for making the Greek fire, and the oldest for gunpowder, were found in a manuscript, preserved in the electoral library at Munich. Various copies of this manuscript were made. Bacon employed this writing, which was mentioned by Jebb, in the preface to his edition, from a copy preserved in the library of Dr. Mead. Whether the writer was Marcus Græcus, is of no moment; for Cardan observes, that the *fire that can be kindled by water*, or rather not extinguished by water, was prepared by Marcus Gracchus.

The former Marcus, mentions two kinds of fire-works; and the composition, which he prescribes for *both*, is two pounds of charcoal, one pound of sulphur, and six pounds of saltpetre, well powdered and mixed together in a stone mortar.

Friar Bacon, who lived three centuries after Græcus, was in possession of the recipe. It was concealed, however, from the people, veiled in mystery. In his treatise *De Secretis Operibus Artis et Naturæ, &c.* the secret of the composition is thus expressed: "sed tamen salispetræ, LURU MOPE CAN URBE et sulphuris; et sic facies tonitrum et corruscationem, si scias artificium." *Luru mope can urbe*, is the anagram for *carbonum pulvere*. Bacon supposes, that it was with a similar composition that Gideon defeated the Midianites, with only three hundred men. Besides the use of gunpowder in the 9th century, in the war between the Tunisians and the Moors, in which the former are said to have employed "certain tubes or barrels, wherewith they threw thunderbolts of fire," the Venetians employed it against the Genoese, and it was reprobated as a manifest contravention of fair warfare.

Peter Mexia, in his "*Various Readings*," relates, that the Moors, being besieged, in 1349, by Alphonso the eleventh, king of Castille, discharged a kind of iron mortars upon them, which made a noise like thunder. This, with the sea-combat between the [99] Tunisians and the Moors, stated on the authority of don Pedro, bishop of Leon, places the invention much earlier than by some writers.

Polydore Virgil ascribes the invention of gunpowder to a chemist, who, having put some of his composition in a mortar, and covered it with a stone, was blown up, in consequence of its accidentally taking fire. The person here alluded to, according to Thevet, was a monk of Friburg, named Constantine Anelzen. Others, as Belleforet, with more probability, hold it to be Bartholodus Schwartz, or the black, who discovered it, as some say, about the year 1320. Du Cange, however, remarks, that there is no mention made of gunpowder in the registers of the chamber of accounts in France, as early as the year 1338. Roger Bacon knew of gunpowder, near one hundred years before Schwartz was born. (See the invention of cannon, in *military fire-works*, fourth part.)

It is certain, that Albert de Bollstædt indicated the constituent parts of gunpowder, when he says, in his *Mirabilis Mundi*, "Ignis volans, accipe libram unam, sulphuris, libras duas, carbonas salicis, libras sex, salis petrosi, quæ tria subtilissime terantur in lapide marmorea; postea aliquid posterius ad libitum in tunica de papyro volante, vel tonitrum faciente ponatur.

"Tunica ad volandum debet esse longa, gracilis, pulvere illo optime plena, ad faciendum vero tonitrum brevis, grossa et semiplena."

Gunpowder was of a much weaker composition than that now in use, or that described by Marcus Græcus. Tartalgia, (*Ques. and Inv.* lib. 3, ques. 5), observes, that, of twenty-three different compositions, used at different times, the first, which was the oldest, contained equal parts of the three ingredients. When guns of modern construction came into use, gunpowder of the present strength was introduced.

The strength of powder depends upon the proportions of the ingredients, they being pure; and Mr. Napier observes, (*Trans. Royal Irish Academy, ii.*) that the greatest strength is produced, when the proportions are, nitre, three pounds, charcoal, nine ounces, and sulphur, three ounces. The cannon powder was in meal, and the musket powder in grain.

In the time of Tartalgia, the cannon powder was made of four parts of nitre, one of sulphur, and one of charcoal; and the musket powder of forty-eight parts of nitre, seven parts of sulphur, and eight parts of charcoal; or of eighteen parts of nitre, two parts of [100]
sulphur, and three parts of charcoal.

The intimate mixture, therefore, and the determinate proportions of saltpetre, charcoal, and sulphur, form gunpowder; the different qualities of which, depend, as well upon the proportions which are used, as on the purity of the materials, and the accuracy with which they are mixed.

Gunpowder is reckoned to explode at about 600° Fahr; but, if heated to a degree just below that of faint redness, the sulphur will mostly burn off, leaving the nitre and charcoal unaltered.

The saltpetre should be perfectly refined, and entirely free from deliquescent salts; the sulphur as pure as possible, and, for that reason, a preference should be given, to that which is sublimed, or distilled; and the charcoal should be prepared in iron cylinders, as described under that head, from woods, which are light and tender, as the linden, willow, hazle, dogwood, etc.

There is a considerable difference in the proportions used by different nations; but, from the many accurate and conclusive experiments of the French chemists, their formula is certainly the most perfect. In English powder, three-quarters of the composition are nitre, and the other quarter is made up of equal parts of charcoal and sulphur; but sometimes, to seventy-five parts of nitre, fifteen of charcoal is used, adding ten of sulphur. Their government powder is the same for cannon, as for small-arms.

According to a number of experiments, made at Grenille, it was found, that the proportion of saltpetre in gunpowder, must be in a given ratio with the charcoal, so that the latter might effectually decompose it in the act of combustion; and hence the ratio is as 12 of the latter to 75 of the former, and these, with 12 of sulphur, are the proportions generally employed. Ruggeri (*Pyrotechnie Militaire*, p. 91,) gives, as the proportions, 12 parts of saltpetre of the third boiling, 2 parts of charcoal, and 1 part of sulphur. The proportions, used in Sweden, are 75 saltpetre, 9 sulphur, and 16 charcoal; in Poland, 80 saltpetre, 8 sulphur, and 12 charcoal; in Italy, 76 saltpetre, 12 sulphur, and 12 charcoal; in Russia, 70 saltpetre, 11 sulphur, and 18$^1/_2$ charcoal; in Denmark, 80 saltpetre, 10 sulphur, and 10 charcoal; in Holland, 76 saltpetre, 12 sulphur, and 12 charcoal; in Prussia and Austria, 78 saltpetre, 11 sulphur, and 11 charcoal; and in Spain, 77 saltpetre, 11$^1/_2$ sulphur, and 11$^1/_2$ charcoal.

According to Klaproth and Wolff, (*Dictionnaire de Chimie*, translated into French by MM. Lagrange and Vogel), Berlin powder is [101]
composed of three-quarters nitre; one-eighth sulphur, and one-eighth charcoal; Chinese powder, of 16 parts nitre, 6 charcoal, and 4 sulphur; Swedish powder, of 75 parts nitre, 16 sulphur, and 9 charcoal; the powder of Lissa, of 80 nitre, 12 sulphur, and 8 charcoal; and English powder, on the authority of Beckman, as follows: Powder for war, 100 parts of nitre, 25 charcoal, and 25 sulphur; musket powder, 100 nitre, 18 sulphur, and 20 charcoal; pistol powder, 100 nitre, 23 sulphur, and 15 charcoal; strong cannon powder, 100 nitre, 20 sulphur, and 24 charcoal; strong musket powder, 100 nitre, 15 sulphur, and 18 charcoal; and strong pistol powder, 100 nitre, 10 sulphur, and 18 charcoal. German powder, for war, is composed, generally, of 0.70 saltpetre, 0.16 charcoal, and 0.14 sulphur. A small portion of gum is sometimes added, to make the grain firmer; but such additions retard the combustion, and the effect.

The addition of gum arabic, however small, must injure the quality of gunpowder, although it has the effect of making the grain firmer, and less liable to fall into meal powder. The grain is also made heavier, and less liable to absorb moisture. M. Proust, in his second memoir on gunpowder, mentions the use of icthyocolla, a fish glue, for the same purpose; and, nevertheless, speaks of some advantages that the gunpowder, prepared with it, possesses.

It is observed by Mr. Coleman, of the Royal Powder Mills of Waltham abbey, that it is not exactly ascertained, whether there is any one proportion, which ought always to be adhered to, and for every purpose. We have no hesitation in believing, for our own part, that the French formula is the most correct, from the numerous experiments made at the royal manufactory at Essone, near Paris.

A very considerable variation is found in the proportions of the ingredients of the powder of different nations and different manufactories. The powder made in England, is the same for cannon as for small arms, the difference being only in the size of the grains; but in France, it appears, that there were formerly six different sorts manufactured; namely, the strong and the weak cannon powder, the strong and the weak musquet powder, and the strong and the weak pistol powder. The following are the proportions in each, though the reason of this nicety of distinction is not very obvious. For the strong cannon powder, the nitre, sulphur, and charcoal were in the proportions of 100 of the first, 25 of the second, and 25 of the third: for the weak cannon [102]
powder, 100, 20, and 24: for the strong musket powder, 100, 18, and 20; for the weak, 100, 15, and 18: for the strong pistol powder, 100, 12, and 15; for the weak, 100, 10, and 18.

The Chinese powder appears, by the analysis of Mr. Napier, to be nearly in the proportions of 100 of nitre, 18 of charcoal, and 11 of sulphur. This powder, which was procured from Canton, was large-grained, not very strong, but hard, well coloured, and in very good preservation.

The following proportions are *now* used in France, for the manufacture of gunpowder for war, for hunting, and for mining.

	For war.	For the chase.	For mining.
Saltpetre,	75.0	78	65.
Charcoal,	12.5	12	15.
Sulphur,	12.5	10	20.

After having made choice of the materials, the nitre being pulverized, is passed through a brass sieve; the sulphur is pulverized by means of a muller, or other contrivance, and also sifted in a bolter; the quantities are then weighed, as well as the charcoal.

The mixing of these substances is performed in a series of mortars, hollowed out of a strong piece of oak wood; and by the aid of pestles or stampers, which are set in motion by machinery and water power, the mixture is thoroughly made. The end of the stampers is usually covered with, and sometimes made of, brass, and the mortars are also, in some powder mills, lined with brass. The mill has generally two rows of mortars and stampers, of ten each. The nitre, sulphur, and charcoal, in proper proportions, are put into each mortar. The charcoal is first introduced into the mortar, being sometimes previously pulverized; then wetted with water, and the pounding is continued for thirty minutes. The nitre and the sulphur are then added, and the whole is stirred with the hand. More water is then added; it is again stirred, and the operation of pounding is continued. The object of adding the water is to prevent the so called volatilization of the ingredients, and to give the mixture the consistency of paste, and at the same time to prevent the explosion of the powder; a circumstance, which must be always guarded against.

After the operation is continued for half an hour, the pounders are stopt, and the powder is then *re-exchanged* by means of [103]
copper or brass ladles; that is to say, the powder of the first mortar is removed, and put into a box, and the contents of the second mortar are put into the first, that of the third is put into the second, that of the fourth into the third, &c. in succession, and in the last, the contents of the first mortar.

We make, in this manner, twelve exchanges, allowing one hour between two, and adding water from time to time, to the mixture, and especially during the summer months. After this, the pounders are again set in motion, for the space of two hours, and the operation is finished. Fourteen hours are generally required to complete the mixture, which is then in the form of paste. It is then granulated. After being partially dried, the graining is performed by passing it through sieves, which are more generally formed of parchment. These sieves are made to work horizontally, and the powder is caught in vessels placed beneath. The size of the grain depends on the sieve; hence, fine grain, or coarse grain powder is thus obtained. In the sieve is usually placed a contrivance to break the masses, and to cause the powder to pass through in grains. After this, the powder is again passed through a second sieve, commonly called a *grainer*, the holes of which are of the same diameter as the powder we wish to obtain. It is then put into another sieve, which permits only the dust to pass, whilst the grain-powder remains. As the powder, however, contains some grains too large, as well as others too small, we may separate the former by a fourth sieve, of a suitable size. The dust and fine grain are carried to the mill, and worked over. The powder for war, and for mining, is dried immediately after the graining.

Formerly, the powder was dried in the open air, by spreading it on tables lined with cloth, or in oblong boxes; but serious inconveniences resulted from it, and, particularly, the powdermakers were obliged to watch the temperature, as well as the state of the atmosphere. When the latter was moist, the *drying* was suspended.

M. Champy, however, has obviated these inconveniences by a very advantageous process, which consists in raising the temperature of the air to 50 or 60 degrees, and causing it to pass from the chamber in which it is heated, through cloths, on which is spread a bed of powder, of a certain thickness. By this means, large quantities of powder may be dried, in all seasons of the year, in a short time, and at little expense. In whatever manner the *drying* is performed, there is always more or less *dust* formed, [104]
which, to make the grain of one uniform appearance, must be separated by a hair sieve. This operation is called the *dusting*.

Whether we adopt the plan recommended by M. Champy, or heat the rooms for the drying of powder to a certain temperature, by means of steam pipes, a plan which presents every advantage, or use the old mode, the effect is the same.

The musket, or *hunting powder*, undergoes an operation more than the powder for war, namely, that of glazing, which is performed before it is dried. With the exception of this process, it is made in the same manner, using, however, a finer sieve in granulating it. The glazing has for its object the smoothing, or removing the asperities of the grain, and to prevent its falling into dust, and soiling the hands.

The powder intended for glazing is first exposed an hour to the sun on one cloth, in winter, and between two cloths in summer, in order to dry it more perfectly, which is very necessary before the operation of glazing. For this purpose, it is put into a vessel like a barrel, which is turned horizontally upon its axis, by machinery. This barrel is furnished with bars that go across, intended to augment the friction, or rubbing of the grain, and expedite the process. The barrels are made to turn slowly, to avoid breaking the grain, and at the expiration of eight or twelve hours, the glazing is finished, the powder having acquired a sufficient hardness and polish. After removing the powder, the dust is separated in the usual manner.

Gunpowder-mills are mills, in which powder is prepared, by pounding and beating together the ingredients of which it is composed. They are always worked by water-power, and as there are generally many of them belonging to the same manufactory, one dam of water will furnish a sufficient supply. In the construction of powder-mills, the frame of the house is made very stout, and the roof put on lightly, so that in case of explosion, it may be carried off easily, and thus give vent to the powder, without much injury to the works. The lights, to enable the work to be carried on at night, are placed on the outside of the building, beyond the reach of the powder, and by means of glass windows, the light passes into the mill. It is lamentable, indeed, that so many accidents occur in the operation of making powder. This may take place, as it has to our knowledge, by the friction of the pounders. Their weight, the rapid succession of the blows, and the dryness of the powder, are the principal causes of such accidents, and [105]
sometimes by the inattention of the workmen, suffering nails, and the like, to get among the materials. I once witnessed the effect of an explosion of the kind, in the neighbourhood of Frankford, in the vicinity of Philadelphia, at the old and well-known powder mills, at that place. It was produced, in consequence of the friction, by the neglect of the men not adding water at a proper time, to keep the materials moist. The mill in which the explosion took place was not much injured; but the roof, together with the men, were sent a considerable distance. Some of the latter fell into the mill-race, and were much injured. The effect, however, did not stop here; for the fire communicated, strange as it may appear, to some of the other mills, although at some distance, and blew them up. Several explosions have happened at the same mills.

An experiment, made at the same works, by the then proprietor, the father of the late commodore Decatur, by putting the nitre, charcoal, and sulphur, into a barrel, with iron balls covered with lead, which was turned upon its axis, terminated in the same way. It exploded, but no other injury or accident was sustained. On examining the balls, we found, that the lead was entirely worn off, and the explosion must have been owing to the iron. This experiment was performed, in order to find if the mixture could be made in this manner, a plan which was afterwards adopted in France, with success, but brass balls were used. In a series of essays, which I wrote for, and published in, the Aurora, in 1808, on the "*Application of Chemistry to the Arts and Manufactures*," as manufactures are vitally important to the *practical* independence of this country, I mentioned the subject of gunpowder, and the different modes of preparing it, and among which, the various experiments on this subject.

The machinery, required in gunpowder mills, is exceedingly simple. The power of the water, which may be given by an overshot, or undershot wheel, is communicated to the parts of the mill, which perform the work. Thus it is, that pounders, like the snuff, or plaster-paris mill, are put in motion, by a horizontal shaft, furnished, at different distances, with pieces of wood, which, by the revolution of the shaft, and meeting with the projecting pieces from the pounders, raises them in succession. They fall, then, in the same order of succession, in the respective mortars.

The mortars of the powder-mill, are hollow pieces of wood, capable of holding twenty pounds of paste, composed of the substances before mentioned, which are incorporated by means of the pestle. There are usually twenty-four mortars in each mill, [106]
where are made, each day, four hundred and eighty pounds of gunpowder; care being taken, to sprinkle the ingredients with water, from time to time, lest they should take fire. This precaution is absolutely necessary, and if attended to, would prevent many of the explosions, which, unhappily, take place, in the manufacture of powder. The friction must be great, and, therefore, the increase of temperature, occasioned in this manner, ought to be guarded against. This can only be done, by diminishing the time, or number of the blows, or by proportioning the weight of the pestle, and the frequent addition of water. The last is the most certain, and indeed, the water is in some respects, necessary to promote a more intimate mixture of the materials. The observations of M. David, on the use of water in the manufacture of powder, are certainly correct. The pestle is a piece of wood, ten feet high, and four and a half inches broad, armed at the bottom with a round piece of metal. It weighs about sixty pounds.

Having mentioned one cause of the explosion of powder-mills, that of friction produced by the pestle, we find that it has been accounted for on another principle. The *Annales de Chimie*, tome xxxv, mentions some instances of spontaneous combustion in powder mills. It is well known, that charcoal has the property of absorbing several gases, and the observations of Rouppe and Berthollet, on this subject, are conclusive. It is also known, that charcoal, which contains hydrogen, when exposed to atmospheric air, will absorb oxygen, and form water; and during this combination, heat must be generated, by the emission of caloric from the oxygen gas. It is said, then, that in cases of spontaneous combustion, when nitre, sulphur, and charcoal, are mixed together, (unless water be added to prevent it), this effect will ensue, and fire be produced. We know, however, that percussion is one source of heat; and in truth, if that opinion be well founded, percussion itself may facilitate the union of hydrogen, with the oxygen of the air, and necessarily operate as a secondary cause of such explosions.

Another opinion has been advanced by Bartholdi, to account for the spontaneous combustion in powder mills: namely, that charcoal sometimes contains phosphorus, combined with hydrogen, which, by the action of the pestle, is disengaged in the form of gas, and inflames, the moment it comes in contact with the air. Others again suppose, that it sometimes contains pyrophorus.

Pulverizing the charcoal, in the first instance, by itself, and adding water, during its mixture, from time to time, a measure [107]
proposed in 1808, by M. David, and now generally adopted, will prevent such accidents; for it appears, they have not occurred in France, since the adoption of this plan. Some remarks on spontaneous combustion, may be seen in the article on *artificial volcanoes*.

M. Sage, (*Journal de Physique*, vol. lxv, p. 423, or *Nicholson's Journal*, vol. xxiii, p. 277), has written on the spontaneous ignition of charcoal, and adduced some facts on the subject; by which it appears, that M. de Caussigni was the first, who observed, that charcoal was capable of being set on fire, by the pressure of mill stones.

Mr. Robin, commissary of the powder mills of Essonne, has given an account, in the *Annales de Chimie*, of the spontaneous inflammation of charcoal, from the black berry bearing alder, that took place the 23d of May, 1801, in the box of the bolter, into which it had been sifted. This charcoal, made two days before, had been ground in the mill, without showing any signs of ignition. The coarse powder, that remained in the bolter, experienced no alteration. The light undulating flame, unextinguishable by water, that appeared on the surface of the sifted charcoal, was of the nature of inflammable gas, which is equally unextinguishable.[17]

The moisture of the atmosphere, of which fresh made charcoal is very greedy, appears to have concurred in the development of the inflammable gas, and the combustion of the charcoal.

It has been observed, that charcoal powdered and laid in large heaps, heats strongly.

Alder charcoal has been seen to take fire in the warehouses, in which it has been stored.

About thirty years ago, M. Sage saw the roof of one of the low wings of the mint set on fire by the spontaneous combustion of a large quantity of charcoal, that had been laid in the garrets.

Mr. Malet, commissary of gunpowder at Pontailler, near Dijon, has seen charcoal take fire under the pestle. He also found, that [108] when pieces of saltpetre and brimstone were put into the charcoal mortar, the explosion took place between the fifth and sixth strokes of the pestle. The weight of the pestles is eighty pounds each, half of this belonging to the box of rounded bell metal, in which they terminate. The pestles are raised only one foot, and make forty-five strokes in a minute.

"In consequence of the precaution now taken," M. Sage observes, "to pound the charcoal, brimstone, and saltpetre separately, no explosions take place; and time is gained in the fabrication, since the paste is made in eight hours, that formerly required four and-twenty.

"Every wooden mortar contains twenty pounds of the mixture, to which two pounds of water are added gradually. The paste is first corned: it is then glazed, that is, the corns are rounded, by subjecting them to the rotary motion of a barrel, through which an axis passes: and lastly, it is dried in the sun, or in a kind of stove.

"Experience has shown, that brimstone is not essential to the preparation of gunpowder; but that which is made without it falls to powder in the air, and will not bear carriage. There is reason to believe, that the brimstone forms a coat on the surface of the powder, and prevents the charcoal from attracting the moisture of the air.

"The goodness of the powder depends on the excellence of the charcoal; and there is but one mode of obtaining this in perfection, which is distillation in close vessels, as practised by the English.

"The charcoal of our powder manufactories is at present prepared in pots, where the wood receives the immediate action of the air, which occasions the charcoal to undergo a particular alteration."

In 1724, (*Coll. Academ.* t. v, p. 413,) M. de Moraler proposed a new mode of mixing the materials for gunpowder. In 1759, M. Musy proposed another method to prevent explosions; and in 1783, the baron de Gumprecht constructed a very ingenious powder mill, a model of which he presented to the king of Poland, whose approbation it received.

There is an account in detail, of the results of the experiments made by MM. Regnier and Pajot Laforet, with different fulminating powders, in the *Archives des Découvertes*, iii, p. 337. These experiments, although interesting in a philosophical view, cannot be of service in the present case. They were made with gunpowder, fulminating silver, fulminating silver and mercury [109] combined, fulminating mercury alone, &c. See also the *Bulletin de la Société d'Encouragement, cahir 65*.

The observations of M. Proust (*Journal de Physique* for May, 1815) on the mixing of powder, and the consequences that result by following the old process, may be consulted.

The process of manufacturing gunpowder, which we have described, is followed in all, or the greater part of the factories of France. It is, however, tedious, and not exempt from danger. The same process, with some modifications or improvements, is adopted in this country; but of all our gunpowder manufactories, that of the messrs. Dupont of Brandywine, Delaware, has heretofore produced the best powder. Powder, however, equally powerful, has been made in other factories.

The improved process of M. Champy, which, in many respects, is superior to the foregoing, is the following:

1. The nitre, sulphur, and charcoal are first reduced, separately, to very fine powder. This operation is performed in barrels, which are made to turn upon their axis, similar to the barrel-churn, and the substances are introduced gradually. Balls, made of an alloy of copper and tin, are then put in, which by their action reduce the substances to powder.

2. The second operation has for its object, the intimate mixture of the ingredients. The quantities to be mixed are weighed, and put into a drum with a quantity of shot, which is made to revolve during an hour and a quarter. In this manner, three hundred pounds of the mixture are at once operated upon.

3. The mixture is then moistened with water. About fourteen per cent. is added. It is then passed through a sieve made with round holes, and then put into a drum, and submitted for a half hour, to a rotary motion. A number of small round grains are thereby formed, which are separated from the mass by means of a sieve, the holes of which are very small.

4. When a sufficient quantity of these grains are procured, they are put into another drum, of a suitable size, with one and a half times their weight of the original mixture. The drum being put in motion, some water is added, which serves to make them increase in size, by constant rubbing: at the end of a certain time, the whole becomes granulated, or perfectly round. The density [110] of the grains depends on the mixture, and the time they were kept in motion.

5. The powder being thus grained, is passed through sieves, whose holes are of different diameters; and hence it is divided into three kinds: *viz.* cannon powder, musket powder, and fine grained powder.

6. Finally, the powder is dried, and preserved in the usual manner. Its strength is equal to that made by the old process, and is perfectly round.

It may be proper to observe, that this process presents many important and decided advantages. Although, in our description, we have not gone into details, yet the whole operation will be seen at one view. It was practised in France, by its inventor, M. Champy, and, besides being introduced into the United States, it has also been adopted in Prussia.

M. Proust endeavoured to show, that charcoal made of shoots or branches, makes the best powder, and will mix with more facility with the nitre and sulphur; and in employing the ordinary charcoal, two hours beating is necessary to obtain a perfect mixture. The pestles, as Chaptal observes, usually make fifty-five strokes in a minute. Their weight is various; he gives them at eighty pounds.

M. Carney discovered a new process for the fabrication of powder, and although Chaptal himself made some advantageous changes in the process, yet the merit of the discovery he gives entirely to Carney. The process of M. Champy, is in some particulars the same. It will be sufficient, however, to observe, that it is reduced to three heads: *viz.*

1. The pulverization, and sifting of the materials;

2. Mixing the materials intimately in vessels similar to casks; and,

3. Giving the mixture the necessary consistence, and the final granulation.

For some details of the process, the reader may consult Chaptal's *Chimie Appliqué aux Arts*, tome iv, p. 145.

Chaptal is of opinion, that Carney's mode of fabricating powder, presents many advantages, among which he considers the facility of its formation, economy in the expense, and the superiority of the powder. In a memoir on the subject, and the formation of powder at Grenelle, Chaptal has described the process very minutely.

Bottée and Riffault reduce the manufacture of gunpowder in France to the following heads:

1. The mixture of the ingredients. This relates to the manner of uniting the nitre, charcoal, and sulphur, the quantity of the [111] composition put into each mortar, and observations respecting the manipulation.

The time required for reducing gunpowder to its proper consistency, and for effecting the mixture is termed by the French, *Battage*. They are usually twenty-four hours, (or eight according to the new mode,) in pounding the materials to make good gunpowder. Supposing the mortar to contain sixteen pounds of composition, it would require the application of the pestle 3500 times each hour.

The order in which they are beaten, and mixed, is as before given, and also the rechanging, or transferring the materials from one mortar to another.

2. *Granulation*, (*Grenage Fr.*) This operation consists, as before observed, in passing the mixture through different sized sieves, employing also parchment sieves, and afterwards separating the dust by a fine sieve. The size of the grain depends altogether on the sieve. Hence we have cannon-powder, gunning or musket-powder, pistol-powder, and mining-powder. Superfine powder is the very small grained.

3. *Glazing.* (*Lissage Fr.*) This operation takes off the asperities of the grain, renders it hard and less liable to soil the hands, and gives it a kind of lustre. It is only used for fine powder, such as the pistol, and hunting-powder. Cannon powder is never glazed. It is performed in a barrel-shaped vessel, which is made to revolve on its axis, like the ordinary barrel-churn. The quantity of powder glazed in one of these barrels at a time, in France, is 150 kilogrammes.

By the rotary motion, the grains of powder rub against each other, by which each grain becomes smooth, and receives a polish. According to the motion of the barrel, so is the glazing more perfect. This, however, is regular. After the operation, which continues several hours, the dust is separated from the grain by a sieve. The state of the atmosphere influences the process. If dry, the grain receives a better polish; if wet or damp, the operation is retarded, and the gloss imperfect. It has been customary to introduce a very small portion of finely pulverized plumbago, (carburet of iron), in order to give the grain a better polish. But such additions, however small, are obviously injurious to the powder. It is said that it prevents the absorption of moisture. Powder, which has been glazed with black lead, (plumbago), may be known by its peculiar shining lustre, and also by experiment. M. Cagniard Latour made some experiments with glazed powder, which may be seen in the work of Bottée and Riffault, p. 233.

4. *Drying.* (*Séchage. Fr.*) The drying of powder is performed in two ways, *viz.* by exposure to the sun, and by exposure to heat in close rooms. The English mode, that of drying by steam pipes, MM. Bottée and Riffault are of opinion, presents many advantages, and particularly that the powder may be dried in all weathers, and with perfect safety. [112]

The mode of drying gunpowder by the vapour of water, (confining it, however, in iron pipes or vessels,) was suggested in 1781, and 1787. See *Mémoires de l'Académie des Sciences de Suede*, 1781, the *Journal des Savants*, 1787, and the *Transactions of the Society of Arts*, vol. xxiv. Mr. Snodgrass, in the last work, gave an account of a method of communicating heat by steam, by using pipes of cast iron, for which the society of arts voted him forty guineas.[18] Chaptal (*Elements de Chimie*) has some judicious remarks on the exsiccation of powder.

The experiment made at Essonne near Paris, by M. Champy, in 1808, on a contrivance for the drying of powder, was satisfactory. This experiment may be seen in page 242 of Bottée and Riffault.

5. Dusting, (*Epoussetage.*) This operation is confined merely to the sifting. It is nothing more than the separation of the dust from the grain, which we have before noticed. The dust is put in the mortars, and worked over.

6. *Barrelling &c.* After the powder has gone through the several operations described, it is then put into barrels, and taken to the magazine.

After speaking of gunpowder under these heads, they describe the manner of treating the green, (*verd*) and dry meal powder; the police of powder establishments, for order and economy; the workmen necessary in a powder manufactory;[19] the process of making powder in the revolution; and for the manufacture of *imperial powder* (which contains 0.78 saltpetre 0.10 sulphur, and [113] 0.12 charcoal); the process of Berne, where the powder is made of 0.76 saltpetre, 0.14 charcoal, and 0.10 sulphur; the process of Mr. Champy, noticed in this article; observations respecting different processes; on powder magazines; gunpowder made of other saline substances besides nitre; different modes of proving powder, examination of powder; description of workshops, mechanics, and utensils, &c. &c. with a variety of engravings. We have merely to remark, that this work of Bottée and Riffault (a large quarto volume, of 340 pages, besides the plates, which make a distinct volume) ought to be in the possession of every gunpowder manufacturer, as it contains all the information known on that subject. Of this fact there can be no difference of opinion, that in consequence of the great attention paid to the subject of gunpowder in France, not only by the government, but by scientific associations and individuals, their knowledge generally must be more minute and accurate, and their works, as authentic records of facts, *more to be depended on*.

Besides many interesting works, and memoirs in French,[20] there have appeared some valuable dissertations in the English language. Mr. Coleman, in his paper in the Phil. Mag. ix, p. 355, may be considered the first, who, as superintendant of one of the Royal powder mills, was enabled to present a body of facts on this subject.

As the mode of manufacturing gunpowder at the Royal Powder Mills of Waltham Abbey, in England, may be interesting and useful, in connection with the different processes already given; we will introduce in this place the account of Mr. Coleman, having extracted it from the *Artist's Manual*, &c. of the author, and having taken it from the original memoir of that gentleman.

The ingredients of gunpowder are taken in the following proportion, namely, 75 of saltpetre, 15 of charcoal, and 10 of sulphur. The saltpetre used is almost entirely that which is imported from the Indies, which comes over in the rough state mixed with earthy and other salts, and is refined by solution, evaporation, and crystallization. After this it is fused in a moderate heat, so as to expel all the pure water, but none of the acid, and is then fit for use. The great use of refining the nitre is to get rid of the [114] deliquescent salts, which by rendering the powder made of it liable to become damp by keeping, would most materially impair its goodness. The sulphur used is imported from Italy and Sicily, where it is collected in its native state in abundance. It is refined by melting and skimming, and when very impure, by sublimation. It should seem that the English sulphur, extracted in abundance from some of the copper and other mines, is too impure to be economically used for gunpowder, requiring expensive processes of refining.

The charcoal formerly used in this manufacture was prepared in the usual way of charring wood, piles being formed of it and covered with sods or fern, and suffered to burn with a slow smothering flame. This method however cannot with any certainty be depended on to produce charcoal of a uniformly good quality, and therefore a most essential improvement has been adopted in this country, to which the present superior excellence of American powder may be in a good measure attributed, which is, that of enclosing the wood, cut into billets about nine inches long, in iron cylinders placed horizontally, and burning them gradually to a red heat, continuing the fire till every thing volatile is driven off, and the wood is completely charred. But as the pyroligneous acid, the volatile product of the wood heated *per se*, is of use in manufacture, it is collected by pipes passing out of the iron cylinder, and dipping into casks where the acid liquor condenses. This acid is used in some parts of calico-printing, chiefly as the basis of some of the iron liquors and mordants for dark-coloured patterns. The wood before charring is barked. It is generally either alder or willow, or dog-wood, but there does not appear to be any certain ground for preferring one wood to another provided it be fully charred.

The above three ingredients being prepared, they are first separately ground to fine powder, then mixed in the proper proportions, after which the mixture is fit for the important operation of thoroughly incorporating the component parts in the mill. A powder mill is a slight wooden building, with a boarded roof, so that in the event of any moderate explosion, the roof will fly off without difficulty, and the sudden expansion will thus be made in the least mischievous direction. Stamping mills were formerly used here, which consisted simply of a large wooden mortar, in which a very ponderous wooden pestle was made to work, by the [115] power of men, or horses, or water, as convenience directed. These performed the business with very great accuracy, but the danger from over-heating was found to be so great, and the accidents attributable to this cause were so numerous, that stamping mills have been mostly disused in large manufactures, and the business is now generally performed by two stones placed vertically, and running on a bed-stone or trough.

The mixed ingredients are put on this bed-stone in quantities not exceeding 40 or 50 pounds at a time, and moistened with just so much water, as will bring the mass in the grinding to a consistence considerably stiffer than paste, in which it is found by experience that the incorporation of the ingredients goes on with the most ease and accuracy. These mills are worked either by water or horses.

The composition is usually worked for about seven or eight hours before the mixture is thought to be sufficiently intimate, and even this time is often found, by the inferior quality of the powder, to be too little. The fine powder manufactured at Battle in Sussex, is still however made in large mortars or stamping mills, in the old way, with heavy lignum vitæ pestles. Only a very few pounds of the materials are worked at a time.

The composition is then taken from the mills and sent to the *corning-house*, to be corned or grained. This process is not essential to the manufacture of perfect gunpowder, but is adopted on account of the much greater convenience of using it in grains than in fine dust. Here the stiff paste is first pressed into hard lumps, which are put into circular sieves with parchment bottoms, perforated with holes of different sizes, and fixed in a frame connected with a horizontal wheel. Each of these sieves is also furnished with a *runner* or oblate spheroid of lignum vitæ, which being set in motion by the action of the wheel, squeezes the paste through the holes of the parchment bottom, forming grains of different sizes. The grains are then sorted and separated from the dust by sieves of progressive dimensions.

They are then *glazed* or hardened, and the rough edges taken off, by being put into casks, filling them somewhat more than half-full, which are fixed to the axis of a water-wheel, and in thus rapidly revolving, the grains are shaken against each other and rounded, at the same time receiving a slight gloss or glazing. Much dust is also separated by this process. The glazing is found to lessen the force of the powder from a fifth to a fourth, but the powder keeps much better when glazed, and is less liable to grow [116] damp.

The powder being thus corned, dusted and glazed, is sent to the stove-house and dried, a part of the process which requires the greatest precautions to avoid explosion, which in this state would be much more dangerous than before the intimate mixture of the ingredients.

The stove-house is a square apartment, three sides of which are furnished with shelves or cases, on proper supports, arranged round the room, and the fourth contains a large cast-iron vessel called a *gloom*, which projects into the room, and is strongly heated from the outside, so that it is impossible that any of the fuel should come in contact with the powder. For greater security against sparks by accidental friction, the glooms are covered with sheet copper, and are always cool when the powder is put in or taken out of the room. Here the grains are thoroughly dried, losing in the process all that remains of the water added to the mixture in the mill, to bring it to a working stiffness. This Mr. Coleman finds to be from three to five parts in 100 of the composition. The powder when dry is then complete.

The government powder for ordnance of all kinds as well as for small arms, is generally made at one time, and always of the same composition; the difference being only in the size of the grains as separated by the respective sieves.

A method of drying powder by means of steam-pipes running round and crossing the apartment has been tried with success: by it all possibility of an accident from over-heating is prevented. The temperature of the room when heated in the common way by a gloom-stove is always regulated by a thermometer hung in the door of the stoves.

The strength of the powder is sometimes injured by being dried too hastily and at too great a heat, for in this case some of the sulphur sublimes out (which it will do copiously at a less heat than will inflame the powder) and the intimate mixture of the ingredients is again destroyed. Besides if dried too hastily, the surface of the grain hardens leaving the inner part still damp.

Mr. Coleman deduces from experiment the following inferences, namely: that the ingredients of gunpowder only pulverized and mixed have but a very small explosive force: that gunpowder granulated after having been only a short time on the mill, has acquired only a very small portion of its strength, so that its perfection absolutely depends on very long-continued and accurate mixture and incorporation of the ingredients: that the strength of gunpowder does not depend on granulation, the dust that [117] separates during this process being as strong as the clean grains: that powder undried, is weaker in every step of the manufacture than when dried: and lastly, that charcoal made in iron cylinders in the way already mentioned, makes much stronger powder than common charcoal. This last circumstance is of so much consequence, and is so fully confirmed by experience, that the charges of powder now used for cannon of all kinds have been reduced one-third in quantity, when this kind of powder is employed.

In barrelling powder, particular care must be taken to avoid moisture, and this business is also generally reserved for dry weather.

When powder is only a little damp, it may be restored to its former goodness merely by stoving; but if it has been thoroughly wetted, the nitre (the only one of the ingredients soluble in water) separates more or less from the sulphur and charcoal, and by again crystallizing, cakes together the powder in whitish masses, which are a loose aggregate of grains covered on the surface with minute efflorescences of nitre. In this case the spoiled powder is put into warm water merely to extract the nitre, and the other two ingredients are separated by straining and thrown away.

The specific gravity of gunpowder is estimated by Count Rumford to be about 1.868.

The strength and goodness of powder is judged of in several ways; namely, by the colour and feel, by the flame when a small pinch is fired, and by measuring the actual projectile force by the *eprouvette*, and by the distance to which a given weight will project a ball of given dimensions under circumstances in all cases exactly similar.

When powder rubbed between the fingers easily breaks down into an impalpable dust, it is a mark of containing too much charcoal, and the same if it readily soils white paper when gently drawn over it. The colour should not be absolutely black, but is preferred to be more of a dark blue with a little cast of red. The trial by firing is thus managed; lay two or three small heaps of about a dram each on clean writing paper, about three or four inches asunder, and fire one of them by a red-hot iron wire: if the flame ascends quickly with a good report, sending up a ring of white smoke, leaving the paper free from white specks and not burnt into holes, and if no sparks fly off from it, setting fire to the contiguous heaps, the powder is judged to be very good, but if [118] otherwise, either the ingredients are badly mixed, or impure.

Gunpowder mixed with powdered glass, and struck with a hammer is said to explode.

An advertisement appeared in the public papers some time in 1813 or 14, signed T. Ewel, addressed to powder manufacturers, by which it appears, in the words of the advertisement, that "he obtained from the United States a patent right for three very simple and important improvements in the manufacture of gunpowder, which do most truly diminish more than one half the risk, the waste, and the expense of the manufacture. They consist in boiling the ingredients by steam, in incorporating them without the objection of barrels, the danger of pounders, or the tediousness of stones running on the edge: and in the granulation effected by a simple machine turning by hand or water, and graining more in a day than twenty hands, losing not a particle of dust, and making not half the quantity for re-manufacture. The advantages of this mode have been so great that he had to discharge half his workmen from his manufactory, as will be readily accounted for by those accustomed to the tediousness and loss from graining, particularly the press powder by the sifter and rollers, &c."

We have not seen the plan in operation, and, therefore, can say nothing respecting it; but it would appear, from the description, that the process was conducted altogether by steam. It is true, that the use of steam is no new application, nor was it then, as it had been used in Europe for heating of dye kettles, in soap boiling, distilling, for warming apartments, and many other purposes. The application to that particular use, that of the manufacture of gunpowder, may be original as far as we know, notwithstanding steam has been applied by means of pipes, &c. as is used at present in some manufactories, for the drying of gunpowder. Professor, now president Cooper, of Columbia College, S. C. (*Emporium of Arts and Sciences* vol. ii, p. 317) in making some observations respecting that publication, believes, that the application of steam to the manufacture of gunpowder to be practicable, and in reference to the advertisement, also a real improvement; and speaking of steam for that purpose adds, "whether it be adopted in England or not, or whether among the numerous patents granted for the application of steam to the arts and manufactures of that country, I know not."

On a general principle of heating apartments by steam, we may remark, that one *cubic foot* of boiler will heat about *two* [119] *thousand feet* of space, in a cotton mill, whose average heat is from 70° to 80° Fahr. One square foot of surface of steam pipe, is adequate to the warming of two hundred cubic feet of space. Cast iron pipes are preferable to all others for the diffusion of heat. For drying muslins and calicoes, large cylinders are employed, and the temperature of the apartment is from 100° to 130°. Dr. Black observes that steam is the most effectual carrier of heat that can be conceived, and will deposite it only on such bodies as are colder than boiling water.

Dr. Ure (*Researches on Heat*) has given a new table of the latent heat of vapours, by which it appears that the vapour of water, at its boiling point, contains 1000 degrees, while that of alcohol of the specific gravity, .825 contains 457°, and ether, whose boiling point is 112°, only 312.9. We see then not only by the recent experiments of Ure, but also those of Dr. Black, Lavoisier and Laplace, Count Rumford, Mr. Watt and some others, that water is the best carrier of heat, using the expression of Dr. Black, and hence is admirably calculated for the warming of apartments and other purposes.

Steam may be applied for the heating of water or other fluids, either for baths or manufactures, and consequently for the saltpetre and sulphur refineries, attached to a gunpowder establishment, either by plunging the steam pipe with an open end into the water cistern, if it be for the heating of water, or by diffusing it around the liquid in the interval between the wooden vessel and an interior metallic case. This last mode is applicable to all purposes.

A gallon of water in the form of steam will heat 6 gallons at 50° up to the boiling point, or 162 degrees; or one gallon will be adequate to heat 18 gallons of the latter up to 100 degrees, making an allowance for waste in the conducting pipe.

Mr. Woolf (*Monthly Magazine* vol. xxxii, p. 253) has taken out a patent for a steam apparatus for various purposes, among which that for the drying of gunpowder is specified. This patent is considered under three heads; *viz.* the construction of the boilers, which are cylindrical vessels properly connected together, and so disposed as to constitute a strong and fit receptacle for water, or any other fluid, intended to be converted into steam, and also to present an extensive portion of convex surface to the current of [120] flame, or heated air or vapour from a fire. Secondly, of other cylindrical receptacles placed above these cylinders, and properly connected with them, for the purpose of containing water and steam, and for its reception, transmission, &c. Thirdly, of a furnace so adapted to the cylindrical parts just mentioned, as to communicate heat with facility and economy. By means of this invention, he states, that any desired temperature, necessary for the drying of gunpowder, may be produced where the powder is to be dried, without the necessity of having fire in, or so near the place as to endanger its safety; for by employing steam only, conveyed through pipes, and properly applied and directed, without allowing any of it to escape into the room or apartment where the powder is, any competent workman can produce a heat equal to that found necessary for drying gunpowder, or much higher if required. The heat may be regulated, to effect the purpose, without producing the sublimation of the sulphur, which has sometimes taken place.

Among the numerous patents of the late D. Pettibone are some for ovens, both fixed and portable, for the drying of gunpowder. Speaking of the use of heated air (*Description of the Improvements of the Rarefying air-stove*, p. 19) he observes, that powder makers would derive a very great advantage by using rarefied air for drying their gunpowder.

Mr. Ingenhouz (*Nouvelles experiences et observations sur divers objects de physique*) attributed the effect of gunpowder to the simultaneous disengagement of dephlogisticated air from the nitre, and inflammable air from the charcoal at the moment of ignition. He followed the calculation of Bernouilli with respect to the quantity of gas generated, *viz*: that one cubic inch of gunpowder at the moment of inflammation, calculating at the same time its expansion, occupies not less than 2276 cubic inches.

That the effective force of gunpowder depends on the generation and expansion of sundry gaseous fluids, is evident, from the chemical action which takes place in the combustion. At a *red* heat gunpowder explodes. This ensues even in a vacuum; a fact at once conclusive, that, while it possesses the inflammable principle, it has also the supporter of combustion. It is to be observed that the particle of powder which is struck by the spark, is instantaneously heated to the temperature of ignition, and is thereby decomposed; and the affinity existing between its oxygen or the oxygen of the nitric acid, and the charcoal and sulphur produces [121] the principal part of the gases. The caloric thus evolved, inflames successively, though with rapidity, the remaining mass. The expansive force of powder, is therefore attributed to the sudden production of carbonic acid gas, sulphurous acid and nitrogen gas, with the water which is instantaneously converted into steam; all of which are greatly augmented by the quantity of caloric liberated.

The combustion, therefore, is owing to the action of the charcoal and sulphur on the nitre; and the decomposition is the effect of the union of the charcoal with a part of the oxygen of the nitric acid, with which it forms carbonic acid, and also with the sulphur producing sulphurous acid gas. It is asserted, that sulphuretted hydrogen gas is also produced; if so, there must be a sulphuret formed, which decomposes a part of the water. After combustion, what remains is carbonate of potassa, sulphate of potassa, and a small proportion of sulphuret of potassa and unconsumed charcoal. Good powder, however, should leave no very sensible residue when inflamed: this is one of the proofs recommended. Thenard observes, (*Traité de Chimie*, ii, p. 498,) that the products of the combustion of gunpowder are numerous; some gaseous, and some solid. The gaseous products are carbonic acid, deutoxide of azote (nitrous gas) and azotic gas, besides the vapour of water; and the solid products are sub-carbonate of potassa, sulphate of potassa, and sulphuret of potassa.

M. Proust considers, that nitrite of potassa, prussiate of potassa, charcoal, sulphuretted hydrogen gas, carburetted hydrogen gas, nitrous gas, and carbonic oxide gas may be generated or result, as the products of the combustion, when the materials have not been properly mixed. Our object in all cases should be to render the materials pure, and the proportions so accurate, as to produce the greatest possible effect, which, of course, must depend on the formation and the consequent expansion of the gases. The effect of fired gunpowder is owing in a great degree to the generation of carbonic acid gas; for while the charcoal acts primarily in the combustion, by taking a greater part of the oxygen from the nitric acid of the nitre, with which we have said it produces carbonic acid; the sulphur has a secondary influence, by forming sulphurous acid gas, although it renders the combustion more rapid, and in this respect enables the charcoal to act at once on the nitric acid of the saltpetre.

We learn then, that in gunpowder, the quantity of charcoal should be such as to effect the decomposition; and, that while the [122] sulphur has a secondary effect, in the formation of sulphurous acid gas, it promotes, if so we may term it, the *rapid* combustion, and consequent action of the charcoal.

MM. Bottée and Riffault (*Traité de l'art de Fabriqué la poudre à canon, p. 197*,) after making some observations on the constitution of powder, and the action which takes place when it is burnt, with the aeriform products that result, give some remarks on the proportion of charcoal necessary to decompose a given quantity of nitric acid; and conclude generally, that in the production of carbonic acid gas, the principal gas which is formed, while the nitric acid is decomposed, and gives up its oxygen to the carbon, the azote is liberated in the state of gas, and at the same time caloric is evolved. They observe then, that the ancient formula for the manufacture of gunpowder, as used in France, consists of the following proportions, *viz*: 0.750 saltpetre, 0.125 charcoal, and 0.125 sulphur, which agrees with modern experiments, although chemistry at that period was in its infancy. M. Pelletier, a member of the National Institute, and M. Riffault made several experiments at Essonne, on different proportions of nitre, charcoal, and sulphur in the fabrication of powder. It is unnecessary to state the different proportions, made use of, or the experiments on the strength of the powder made with the eprouvette. They observe, however, that powder made in the following proportions, was more satisfactory, *viz.* 0.76 saltpetre, 0.15 charcoal, 0.09 sulphur, and 0.76 saltpetre, 0.14 charcoal, and 0.10 sulphur.

Before we give the gaseous products, according to these gentlemen, it will be necessary to observe, that the quantity of nitric acid in nitrate of potassa, is 48.62 in the hundred, and according to Gay-Lussac, nitric acid is composed in volume of 250 oxygen and 100 azote, or in weight of 69.488 oxygen, and 30.512 azote.

Using the French *gramme* in the present instance, it appears that 75 grammes of nitrate of potassa, the proportion of this salt which enters into 100 grammes of gunpowder for war, contains 36.47 grammes of nitric acid; and that this quantity of acid is formed of 25.34 grammes of oxygen, and 11.13 grammes of azote. That quantity of oxygen (25.34) is disengaged from its combination with azote in the nitric acid, at the instant of the inflammation of the powder by the charcoal, forming carbonic acid; the constituents of which, according to the proportions established by Gay-Lussac and others, must be in the ratio of 27.376 of carbon and 72.624 of oxygen. If 25.34 grammes of oxygen exist in 75 grammes of nitrate of potassa, the proportion usually [123] admitted, then it will require 9.55 grammes of carbon to saturate it, so as to produce carbonic acid. It is necessary to consider, that this is independent of any foreign earthy or saline matter or moisture which may exist.

With respect to the presence of hydrogen in charcoal, the observations of Dr. Priestley, Cruikshanks, Kirwan, Berthollet, Gay-Lussac, Thenard, Vauquelin, Lowitz and some others, are conclusive on that head. Lavoisier made the quantity of hydrogen in charcoal upon an average, to be 0.125 of its weight. See *Memoirs de la Société d'Arcueil*, tome ii, p. 343, and the *Statique Chimique*, tome ii, pages 44 and 45, and also *charcoal* in a preceding section.

It is said, that by employing more charcoal than is necessary to decompose the nitric acid of the nitre, the excess passes off, not as carbonic acid, but carbonic oxide, or gaseous oxide of carbon, which is necessarily inflamed, and finally forms carbonic acid, as one of the products with the carbonic acid originally formed. But the carbonic oxide, to be changed into carbonic acid, requires in fact the oxygen of the atmosphere.

If 34.89 grammes of carbonic acid result from the combustion of 9.55 grammes of carbon, it must unite with a quantity of oxygen, as before expressed, and according to the temperature, be more or less expanded. The 11.13 grammes of azote thus disengaged from its combination with oxygen, in the nitric acid, remains, of course, in the gaseous state, and is also expanded by caloric. The quantity of the latter is stated by Lavoisier, to be 430 degrees, using a scale of 80 parts; and according to more recent experiments, it is fixed at 600 degrees of the centigrade thermometer. The experiments of Gay-Lussac are more recent, in which he has given the dilatation of the gases, and the quantity of free caloric evolved, which corresponds with the last data. We have not room to insert his remarks.

The use of sulphur with the charcoal, in the fabrication of powder, Bottée and Riffault state to be, (page 204) that it inflames more rapidly than charcoal, and at a lower temperature, which accelerates the combustion of the charcoal, and consequently the detonation of the powder. The presence of the sulphur augments the volume of gas, by producing sulphurous acid gas. The proportion of sulphur in the powder for war, is, 0.125, for musket powder, 0.10, and for mining powder, 0.20, according to the same gentlemen.

M. Fourcroy (*Système des Connaissances Chimiques*, tome iii, p. 122.) among other products of the combustion of powder, [124] mentions ammonia. If ammoniacal gas be formed, the hydrogen must proceed from decomposed water, and the azote from the nitric acid. Prussine, cyanogen, or carburet of nitrogen, the radical of prussic acid, may also be generated by the union of carbon and nitrogen or azote, in the same manner. We know that cyanogen may exist in the form of gas; but as it is inflammable, burning with a bluish flame mixed with purple, we may infer, nevertheless, that, if generated, it must undergo decomposition by the process of combustion. Although I know of no experiments on this subject, either by Gay-Lussac, Vauquelin or Davy, all of whom have investigated the properties of this compound of carbon and azote, which Dr. Ure has called *prussine*; yet it would appear, that during its combustion, the carbon is changed into carbonic acid, and whether the azote be also combined with oxygen, or merely set at liberty, is altogether uncertain. Many difficulties present themselves to a complete and satisfactory set of experiments on the gaseous products of fired gunpowder.

With respect to the granulation of powder, we may observe, that although some writers consider that granulated powder is *stronger* than the fine powder, yet others are of opinion, that its strength is not increased by granulation. Grained powder is more fit for use; but the graining of it prevents the whole of the powder from taking fire instantaneously. Gunpowder, although prepared in the best manner, is not wholly consumed by inflammation. However remarkable it may appear, yet nevertheless it is true, that a considerable portion of gunpowder fired in a confined space is thrown out without being kindled. That gunpowder passes through a volume of fire without being consumed, may seem incredible, yet the fact may be proved by firing with a musket upon snow, or upon a paper screen.

M. Morveau communicated to the Institute some experiments, which may be seen in the *Archives des Découvertes*, i, p. 269, relative to the time necessary for the inflammation of a given mass of gunpowder, &c. He infers that large grain powder inflames more readily than the fine grain.

Since during the combustion of powder, gaseous bodies more or less considerable are generated, it follows that the full force of fired gunpowder must depend on the maximum of the quantity of those gases; and the powder is more strong as it is susceptible of forming more gas in a given time. Besides the purity and the proper proportion of the materials, the gunpowder, to produce the [125] greatest possible effect, should not only be intimately mixed, but dried perfectly and with care.

It is a fact which is well known, that a musket, fowling piece, &c. are very apt to burst, if the wadding is not rammed down close to the powder. Hence it is obvious, that in loading a screw barrel pistol, care should be taken that the cavity for the powder be entirely filled with it, so as to leave no space between the powder and the ball.

Experience has shown, that if a shell is only half or two-thirds filled with gunpowder, it breaks into a great number of pieces, and on the contrary, if completely filled, it separates only into two or three pieces, which are thrown to a very great distance.

It is also found that the same principle, of leaving a space for air, is applied with success in blasting rocks, and splitting trunks of trees. If the trunk of a tree is charged with gunpowder, and the wadding is rammed down very hard upon the powder, in that case (unless the quantity of powder is great,) the wadding is only driven out, and the tree remains entire; but if, instead of ramming the wad close to the powder, a certain space is left between them, the effects of the powder are then such as to tear the tree asunder.

Addison (*Travels through Italy and Swisserland*) speaking of the celebrated Grotto Del Cani, which contains carbonic acid gas, and on that account extinguishes flame, and is fatal to animal life, observes, that he laid a train of gunpowder in the channel of a reed, and placed it at the bottom of the grotto, and on inflaming it, that it burnt entirely away, although the carbonic acid gas in the same spot would immediately extinguish a lighted taper, snuff and all; for, he remarks, fire is as soon extinguished in it as in water. If gunpowder did not contain within itself that which was necessary to produce combustion, how are we to account for its combustion in an atmosphere of carbonic acid gas, or in vacuo?

Whether gunpowder be fired in a vacuum or in air, a permanently elastic fluid is generated, the elasticity or pressure of which is, *cæteris paribus*, directly as its density.

Gregory, (*Treatise on Mechanics, &c.* ii, p. 56) has given a summary of the results of the experiments of Mr. Robins, which we insert verbatim. "To determine the elasticity and quantity of this fluid (the elastic) produced from the explosion of a given quantity of gunpowder, Mr. Robins premises, that the elasticity increases by heat, and diminishes by cold, in the same manner as that of [126] the air; and that the density of this fluid, and consequently its weight, is the same with an equal bulk of air, having the same elasticity at the same temperature. From these principles, and from the experiments by which they are established (for a detail of which we must refer to the book itself,) he concludes that the fluid produced by the firing of gunpowder, is nearly $^{3}/_{10}$ths of the weight of the generating powder itself; and that the volume or bulk of this air or fluid, when expanded to the rarity of common atmospheric air, is about 244 times the bulk of the said generating powder. Count Salace in his *Miscel. Phil. Math. Soc. Priv.* Taurin, p. 125, makes the proportion as 222 to 1; which he says agrees with the computation of Messrs. Hawkesbe Amontons, and Belidor. Hence it would follow that any quantity of powder fired in any confined space, which it adequately fills, exerts at the instant of its explosion against the sides of the vessel containing it, and the bodies it impels before it, a force at least 244 times greater than the elasticity of common air, or, which is the same thing, than the pressure of the atmosphere; and this without considering the great addition arising from the violent degree of heat, with which it is endued at that time; the quantity of which augmentation is the next head of Robins's inquiry.

He determines that the elasticity of air is augmented in a proportion somewhat greater than that of 4 to 1, when heated to the extremest heat of red-hot iron; and supposing that the flame of fired gunpowder is not of a less degree of heat, increasing the former number a little more than four times, makes nearly 1000; which shows that the elasticity of flame, at the moment of explosion, is about 1000 times stronger than the elasticity of common air, or than the pressure of the atmosphere. But, from the height of the barometer, it is known that the pressure of the atmosphere upon every square inch is on a medium of 14$^{3}/_{4}$ths, and therefore 1000 times this, or 14750 lbs. is the force of pressure of inflamed gunpowder, at the moment of explosion, upon a square inch, which is very nearly equivalent to six tons and a half. This great force, however, diminishes as the fluid dilates itself, and in that proportion; viz. in proportion to the space it occupies, it being only half the strength, when it occupies a double space, one-third the strength, when a triple space, and so on. Mr. Robins further supposed the degree of heat above mentioned to be a kind of medium heat; but that in the case of large quantities of powder the heat will be higher, and in very small quantities lower; and that [127] therefore in the former case the force will be somewhat more, and the latter somewhat less, than 1000 times the force of the atmosphere.

He further found, that the strength of powder is the same in all variations in the density of the atmosphere: but that the moisture of the air has a great effect upon it; for the same quantity which in a dry season would discharge a bullet with the velocity of 1700 feet in one second, will not in damp weather give it a velocity of more than 12 or 1300 feet in a second, or even less, if the powder be bad, or negligently kept. *Robins's Tracts* vol. i, p. 101, &c. Further, as there is a certain quantity of water, which, when mixed with powder, will prevent its firing at all, it cannot be doubted but every degree of moisture must abate the violence of the explosion; and hence the effects of damp powder are not difficult to account for.

The velocity of expansion of the flame of gunpowder, when fired in a piece of artillery, without either bullet or other body before it, is prodigiously great, viz. 7000 feet per second. But Mr. Bernoulli and Mr. Euler think it is still much greater.

Dr. Hutton, after applying some requisite corrections to Mr. Robins's numbers, and after remarking that the powder does not all inflame at once, as well as that about $^{7}/_{10}$ths of it consist of gross matter not convertible into an elastic fluid, gives

$$v = 125 \sqrt{\left(\frac{n \cdot q}{16 + q} \times \text{log.of} \frac{b}{a}\right)}$$

for the initial velocity of any ball of given weight and magnitude, and

$$n = \frac{p + w}{3180\ ad^2} v^2 \div \text{log.} \frac{b}{a}$$

for the value of the initial force n of the powder in atmospheric pressures: when a = length of the bore occupied by this charge, b = whole length of the bore, d = diameter of the ball, w = its weight, 2 p = weight of the powder, $q = {}^{a}/_{d}$. In his experiments and results, he found n to vary between 1700 and 2300, and the velocity of the flame to vary between 3000 and 4732; specifying, however, the modification in his computations, which would give more than 7000 feet per second for that velocity. Taking 2200 for an average value of n, and substituting 47 for its square root in the above formula for v, it becomes

$$v = 5875 \sqrt{\left(\frac{q}{16 + q} \times \text{log.of} \frac{b}{a}\right)}$$

for the velocity of the ball, a theorem which agrees remarkably well with the Doctor's numerous and valuable experiments. (Tracts, [128] vol. iii, p. 290, 315.)

In a French work entitled, "*Le Mouvement Igné* considéré principalement dans la charge d'une pièce d'artillerie," published in 1809, there are advanced, among other notions which we apprehend few philosophers will be inclined to adopt, some which may demand and deserve a careful consideration. The author of this work observes, that if a fluid draws its force partly from a gaseous or aeriform matter, and partly from the action of caloric, which rarefies that aeriform matter; then its density in proportion to its dilatation, will follow the inverse ratios of the squares of the spaces described. He then investigates two classes of formulæ: the first appertains to fluids which possess simply the fluid or aeriform elasticity, which are free from all heat exceeding the temperature of the atmosphere. Whether there be one or many gaseous substances signifies not, provided their temperature agrees with that of the atmosphere; for when these dilate they conform to the inverse of the spaces described. The second relate to those which derive their elasticity as well from the aeriform fluids, as from the matter of heat which pervades them, and which are denominated *fluids of mixed elasticity*, to distinguish them from those of simple or purely *aeriform elasticity*. These fluids, in dilating, conform to the inverse ratio of the *squares* of the spaces described. Thus the celerity of action of mixed elastic fluids, is to that of simple elastic fluids as S^2 to S; whence it follows that mixed elastic fluids are more prompt and energetic in their action than others; and hence also is inferred why the fluid produced by the combustion of gunpowder, is more impetuous and more terrible in its operation than atmospheric air, however compressed it may be. The force exerted by the caloric to dissolve a quantity of powder, is regarded as equal to that possessed by the fluid which results from that dissolution, and is named the *force of dissolution* of powder by fire: and the *surface of least resistance* is that (as of the ball,) which yields to the action of the fluid. The gunpowder subjected to experiment by this author, was of seven different qualities, varying from 1000, the density of water, down to 946, the density of powder used by sportsmen. It was found by theory, and confirmed by experiment, that the real velocity with which the elastic fluid, considered under the volume of the powder, and penetrated by a degree of heat capable of quadrupling the volume, would expand, when it had only the resistance of the atmosphere to surmount, is 2546.49 feet, that is, about 2734.4 feet English.

Comparing the several forces which were calculated for the same quantity of powder, in three different circumstances: [129]

1. When the fluid has only to surmount the atmospheric pressure, it has a force of dissolution which is proper to it, and which in a charge of 8 lbs. of powder (the specific gravity 944.72, for a 24 pounder,) acts upon the surface of the least resistance with an energy equivalent to 9747.8074 lbs.

2. The fluid retarded in its expansion by a surface of least resistance, whose tenacity (occasioned by the compactness and pressure of the wadding, &c.) is t = 31, acquires by its elasticity of force = 52839.1463 lbs. at the instant when that surface yields to its action.

3. If the tenacity t = 298 lbs., the force of the fluid at the moment when the resisting surface yields to it, will be equivalent to 417371.4275 lbs. If each of these forces be divided by the surface of least resistance, the quotient will indicate the equation of each filament, namely, 1st. That of the force of dissolution = 173.63 grains; 2d. when t = 31 lbs. that of elasticity = 923.26 grains; 3d. when t = 298 lbs. force elastic equal to 7433.99 grains.

Dividing again these latter values by the length of the charges, we shall have for the mean force of each elementary fluid particle,

1. Force of dissolution, 0.14205 grains.

2. When t = 31 lbs. the force elastic = 0.75540 grains.

3. When t = 298 lbs. the force elastic = 6.08174 grains.

It appears, however, that equal charges of powder of the same quality employed in the same piece, produce very different velocities; the more considerable being the resistance to the expansion of the fluid, the less the velocity becomes. Thus, it is found, when t = 31 lbs. the velocity of the ball when expelled at the mouth of the piece, is 1563.6 feet: when t = 298 lbs. v = 1350.9 feet.

The following table will exhibit in one view the velocities with which a 24 lb. ball issues from the mouth of a gun, when propelled with the several charges expressed in the first column.

1st. According to the theory developed in the volume, from which we have made these extracts.

2d. According to the experiments of M. Lombard, at Auxerre, on guns for land service.

3d. According to the experiments of M. Teixiere de Norbec, at Toulon, on guns for sea service.

4th and 5thly. According to the determination of Mr. Robins and Dr. Hutton.

[130]

Charges of powder.	Velocity from Theory.		Mean velocity from Theory.	Velocity from experiment.		VELOCITIES.	
	When t=31	When t=298		Lombard.	Norbec.	Robins.	Hutton.
1 lb.	622	524	573	575	570	640	500
2½	980	836	908	906	940	750	730
3	1072	918	995	989	1020	969	830
4	1233	1057	1145	1132	1245	1069	940
6	1407	1216	1312	1320	1340	1215	1164
8	1564	1351	1457	1425	1560	1319	1348
10	1581	1370	1476	1475			1500
12	1631	1421	1526	1530			1600

It is the prodigious celerity of expansion of the flame of fired gunpowder, which is its peculiar excellence, and the circumstance in which it so eminently surpasses all other inventions, either ancient or modern; for as to the momentum of these projectiles only, many of the warlike machines of the ancients produced this in a degree far surpassing that of our heaviest cannon, shot or shells; but the great celerity given to them cannot be approached with facility by any other means than the explosion of powder."

Dr. Hutton, in conjunction with several able officers of the artillery and other gentlemen, made an extensive course of experiments at Woolwich, at the expense of the British government, by the direction of the then master-general of the ordnance, (the late duke of Richmond,) in the years 1783, 1784, and 1785, which demonstrated the following facts:

1. That the velocity continually increases as the gun is longer, though the increase in velocity is but very small in respect of the increase in length; the velocities being in a ratio somewhat less than that of the square roots of the length of the bores, but somewhat greater than the cube roots of the same, and nearly indeed in the middle ratio between the two.

2. That the charge being the same, very little is gained in the range of a gun, by a great increase of its length; since the range or amplitude is nearly as the fifth root of the length of the bore, and gives only about a seventh part more range with a gun of double length.

3. That with the same gun and elevation, the time of the ball's flight is nearly as the range.

4. That no sensible difference is produced in the range or velocity, by varying the weight of the gun, by the use of wads, by different degrees of ramming, or by firing the charge of powder in different parts of it.

5. That a great difference, however, in the velocity, is occasioned by a small variation in the windage; so much so, indeed, that [131] with the usual windage of one-twentieth of the caliber, no less than between one-third and one-fourth of the whole charge of the powder escapes and is entirely lost; and that as the windage is often greater, one-half the powder is unnecessarily lost.

6. That the resisting force of wood to balls fired into it, is not constant, and that the depths penetrated by different velocities, or charges, are not as the charges themselves, or, which comes to the same thing, as the squares of the velocities.

7. That balls are greatly deflected from the direction they are projected in, sometimes, indeed, so much as 300 or 400 yards in a range of a mile, or almost a fourth part of the whole range, which is nearly a deflection of an angle of 15 degrees.

The observations of Glenie, (*History of Gunnery*, 1776,) show the theory of projectiles in vacuo by plain geometry, or by means of the square and rhombus; with a method of reducing projections on inclined planes, whether elevated or depressed below the horizontal plane, to those which are made on the horizon.

This author, in his treatise, after stating in page 48, the two following positions of Mr. Robins, namely, "that till the velocity of the projectile surpasses that of 118 feet in a second; the resistance of the air may be estimated to be in the duplicate of the velocity;" that "if the velocity be greater than that of 11 or 1200 feet in a second, the absolute quantity of the resistance will be nearly three times as great as it should be by a comparison with the smaller velocities;" says, that he is certain from some experiments, which he and two other gentlemen tried with a rifle piece properly fitted for experimental purposes, that the resistance of the air to a velocity somewhat less than that mentioned in the first of these proportions, is considerably greater than in the duplicate ratio of the velocity; and that to a celerity somewhat greater than that stated in the second, the resistance is less than that which is treble the resistance of the same ratio. He observes, also, that some of Mr. Robins's own experiments come to this conclusion; since to a velocity no quicker than 200 feet in a second, he found the resistance to be somewhat greater than in that ratio, and remarks, therefore, that "after ascertaining the velocities of the bullets with as much accuracy as possible, I instituted a calculus from principles which had been laying by me for some time before, and found the resistance to approach [132] nearer to that, which exceeds the resistance in the duplicate ratio of the velocity, by that which is the ratio of the velocity, than to that, which is only in the duplicate ratio."

The experiments of Mr. Dalton, confirm the premises of Mr. Robins, that the elasticity of the gases produced from a given quantity of powder, is equally increased by heat and diminished by cold as that of atmospheric air. Hence, as we before remarked, and from direct experiments, he concludes that the elastic fluid produced by the firing of gunpowder, is nearly three-tenths of the weight of the powder itself, which, expanded to the rarity of common air, is about 244 greater than the elasticity of common air, or in other words, than the pressure of the atmosphere. To this, however, must be superadded the increase of expansive power produced by the heat generated, which is very intense. The mere conversion of confined powder into elastic vapour, would exert against the sides of the containing vessel, an expansive force 244 times greater than the elasticity of common air, or, in other words, than the pressure of the atmosphere. If the heat, for the expansion of the gases, should be equal to that of red-hot iron, this would increase the expansion of common air, (and also of all gases) about four times, which in the present instance would be as we stated in the preceding pages, 244 to nearly 1000; so that in a general way it may be assumed, that the expansive force of closely confined powder at the instant of firing, is 1000 times greater than the pressure of common air; and as this latter is known to press with the weight of $14\frac{3}{4}$ pounds on every square inch, the force of explosion of gunpowder is 1000 times this, or 14750 lbs. or about six tons and a half upon every square inch. This enormous force diminishes in proportion as the elastic fluid dilates, being only half the strength when it occupies a double space, one-third of the strength when in a triple space, and so on.

There is one more fact worthy of notice, that Mr. Robins found the strength of powder to be the same in all variations of the density of the atmosphere, but not so in every state of moisture, being much impaired by a damp air, or with powder damped by careless keeping, or any other cause; so that the same powder which will discharge a bullet at the rate of 1700 feet in a second in dry air, will only propel it about 1200 feet when the air is fully moist, and a similar difference was observed between dry and moist powder. The sum of these remarks, with the necessary illustrations, may be found in the extract we have given from Gregory's [133] Mechanics.

Before we mention the different modes of proving powder, we will offer some remarks respecting the use of sulphur in gunpowder. The conclusions on this head are drawn from the experiments made at Essonne, near Paris.

The sulphur is not (properly speaking) a necessary ingredient in gunpowder, since nitre and charcoal alone, well mixed, will explode; but the use of the sulphur seems to be to diffuse the fire instantaneously through the whole mass of powder. But, if the following experiments are correct, it should seem that the advantage gained by using sulphur in increasing the force of explosion only applies to small charges; but in quantities of a few ounces, the explosive, or at least the *projecting* force of powder without sulphur, is full as great as with sulphur.

The following are a few out of many trials made at the Royal Manufactory at Essonne, near Paris, in the year 1756, to determine the best proportions of all the ingredients. Of powder made with nitre and charcoal alone, 16 of nitre and 4 of charcoal was the strongest, and gave a power of 9 in the eprouvette. With all three ingredients, 16 of nitre, 4 of charcoal, and 1 of sulphur, raised the eprouvette to 15, and both a less and a greater quantity of sulphur produced a smaller effect. Then diminishing the charcoal, a powder of 16 of nitre, 3 of charcoal, and 1 of sulphur gave a power of 17 in the eprouvette, which was the highest produced by any mixture. This last was also tried in the mortar-eprouvette against the common proof powder, and was found to maintain a small superiority. The powder made without sulphur in the proportions above indicated was also tried in the mortar-eprouvette, and with the following singular result: when the charge was only two ounces it projected a sixty pound copper ball 213 feet, and the strongest powder with sulphur projected it 249 feet; but in a charge of three ounces, the former projected the ball 475 feet and the latter only 472 feet; and on the other hand the great inferiority of force in the smaller eprouvette of the powder without sulphur has been just noticed.

It is a fact, known from time immemorial, that by the combustion of bodies caloric is generated, or chemically speaking, is given out in a free state; but the cause was not known until the anti-phlogistic theory of chemistry was established, which abolished as untenable the old doctrine of phlogiston; The quantity of caloric, which passes from a latent to a free state in combustion, as [134] combustion is nothing more than the phenomena occasioned by this transition, is variable; and depends therefore on the substances burnt, and the nature of what is denominated the supporter of combustion.

The experiments of MM. Lavoisier and Laplace have shown the quantity of caloric produced by the combustion of different substances by the calorimeter, a table of which may be seen in Thenard. (*Traité de Chimie*, &c. t. i, p. 81). From this table it appears, that while a mixture of one pound of saltpetre with one pound of sulphur liquefied, by its combustion, thirty-two pounds of ice, one pound of hydrogen gas melted 313 lbs. phosphorus 100 lbs. and the same quantity of charcoal 96.351 lbs.; and by the detonation of a mixture of one pound of saltpetre with 0.3125 lbs. of charcoal (French weight) melted only 12 lbs. of ice.

In the table of the elevation of temperature by the combustion of different substances, the caloric being communicated to water, (Thenard, *Traité de Chimie*, vol. i, p. 82), it appears, that by the combustion of equal weights of hydrogen gas, phosphorus, charcoal, and oak, the caloric produced was as follows:

Hydrogen	23,400°
Phosphorus	7,500
Charcoal	7,226
Oak wood	3,146

The reader may find some interesting calculations on this subject in Biot's *Traité de Physique*, &c. tome iv, p. 704, and 716.

It appears also, that in the combustion of one pound of hydrogen gas, six pounds of oxygen were consumed, and according to Crawford's experiment the caloric given out melted 480 lbs. of ice. One pound of phosphorus requires for combustion one and a half pounds of oxygen gas; one pound of charcoal, 2.8; and one pound of sulphur, 1.36. See Thomson's *System of Chemistry*, vol i, p. 133.

While noticing this subject we may remark, that in combustion heat and light, according to the Lavoiserian doctrine, are given out from the oxygen gas, while the oxygen unites with the combustible body: which has since been modified by supposing, that while caloric is evolved from the gas, the light is emitted from the burning body. There are some facts contrary to the received theory of combustion; that of *gunpowder* furnishes one. We have also another instance in the combustion of oil of turpentine by nitric acid.

Gunpowder will burn with great avidity in close vessels, or under an exhausted receiver, and we know that the oxygen is already [135] combined with azote in the nitric acid of the nitrate of potassa, and consequently not in a gaseous but a solid state; yet we also know that a great quantity of caloric and light are emitted during the combustion, and nearly all the products are gaseous. The other anomaly is, that as combustion is produced by pouring nitric acid on spirit of turpentine, the oxygen being already combined with azote, caloric and light are evolved by the mixture of the two fluids, from which it is inferred, that oxygen is capable of giving out caloric and light, not only when liquid, but even after combustion. In the instance of gunpowder, in order to explain the combustion which takes place independently of atmospheric air, or any aeriform supporter, "the caloric and light," in the opinion of Dr. Thomson, (*Chemistry*, i, 128) "must be supposed to be emitted from a solid body during its conversion into gas, which ought to require more caloric and light for its existence in the gaseous state than the solid itself contained."—Mr. Lavoisier (*Elements of Chemistry*, p. 157,) observes, that he and M. De la Place deflagrated a convenient quantity of nitre and charcoal in an ice apparatus, and found that 12 lbs. of ice were melted by the deflagration of one pound of nitre. After giving the proportions of acid and alkali in nitre, and the quantity of oxygen and azote in the acid, he observes, that during the deflagration, $145\frac{1}{3}$ grains of carbon have suffered combustion along wit 3738.34 grains of oxygen; and as 12 lbs. of ice were melted, one pound of oxygen burnt in the same manner would have melted 29.5832 lbs. of ice. To which, if we add the quantity of caloric retained by a pound of oxygen, after combining with carbon to form carbonic acid gas, which was already ascertained to be capable of melting 29.13844 lbs. of ice, we shall have for the total quantity of caloric remaining in a pound of oxygen when combined with nitrous gas in the nitric acid, 58.72164; which is the number of pounds of ice, the caloric remaining in the oxygen in that state is capable of melting. In the state of oxygen gas it contains at least 66.66667. M. Lavoisier infers then, that the oxygen in combining with azote to form nitric acid, only loses 7.94502, and that "this enormous quantity of caloric, retained by oxygen in its combination into nitric acid, explains the cause of the great disengagement of caloric during the deflagration of nitre; or, more strictly speaking, upon all occasions of the decomposition of nitric acid." This view of the subject may enable us to explain the production of caloric, in those cases of combustion which cannot be explained on the ordinary principles; and, with regard to gunpowder, the accension of oil of [136] turpentine by nitric acid, and similar cases, we may conclude, as the only rationale which seems applicable, that it is nothing more than the transition of caloric from one state to another, from a latent to a free state. Be this as it may, the combustion in such instances furnishes an anomaly to the already established doctrine, of the absorption of oxygen, or the base of the supporter, and the evolution of caloric from the gas, and not from the combustible; or, in other words, the change of caloric in the supporter from a combined to an uncombined state.

The idea of *latent* heat may be had from Dr. Black's own expression (*Black's Lectures* by Robinson:) "By this discovery," says the doctor, "we now see heat susceptible of fixation—of being accumulated in bodies, and, as it were, laid by till we have occasion for it; and are as certain of getting the stored-up heat, as we are certain of getting out of our drawers the things we laid up in them." Murray's *System of Chemistry*, 2d edition, p. 398, and Watson's *Chemical Essays*, vol. iii, &c. may be consulted on this subject with advantage. See *Introduction.*

We will consider, in the next place, the subject of *gunpowder proof*. The first examination of gunpowder is by rubbing it in the hands, to find whether it contains any irregular hard lumps. If it is too black, it is a sign that it is moist, or else, that it has too much charcoal in it; so, also, if rubbed upon white paper, it blackens it more than good powder does; but, if it be of a kind of azure colour, it is a good indication. If on crushing it with the fingers, the grains break easily, and turn into dust, without feeling hard, it is a criterion, that it has too much coal; or, if in pressing it under the fingers upon a smooth hard board, some grains feel harder than the rest, it is inferred that the sulphur is not well mixed with the nitre. By blasting two drachms of each sort on a copper plate, and comparing it with approved powder. In this proof it should not emit any sparks, nor leave any beads or foulness on the copper. The method of *burning*, which is commonly employed, Mr. Robins observes, is to fire a small heap on a clean board, and to attend nicely to the flame and smoke it produces, and to the marks it leaves behind on the boards.

Another trial of powder is to expose it to the atmosphere. One pound of each sort, accurately weighed, is exposed to the atmosphere for 17 or 18 days; during which time, if the materials are pure, it will not increase any thing material in weight, by [137] attracting moisture from the air. One hundred pounds of good powder should not absorb more than twelve ounces, or somewhat less than one per cent. See Mr. Coleman's account of the manufacture of powder in England, page 110.

To determine the strength of powder in the easiest manner, is by comparing its effect with improved powder; as, for instance, by using a given weight of powder, as two ounces, and discharging a ball of a known weight, say 64 pounds, from an 8 inch mortar. The best cylinder powder generally gives about 180 feet range, and pit 180, with a ball and charge of the above weights; but the weakest powder, or powder that has been reduced, &c. only from 107 to 117 feet.

The practice adopted in England, we are told, is, that the merchant powder, before it is received into the king's service, is tried against powder of the same kind made at the king's mills, and it is received if it gives a range of $\frac{1}{20}$ less than the king's powder, with which it is compared. In this comparison, both sorts are tried on the same day, and at the same time, and under exactly the same circumstances.

James (*Mil'y Dictionary*, p. 348) remarks, that the proof of powder as practised by the board of ordnance, besides that of comparing it by combustion on paper, is that 2 drachms, when put into the eprouvette, must raise a weight of 24 pounds to the height of $3\frac{1}{2}$ inches.

According to Bottée and Riffault, before gunpowder is received into the arsenals of France, for service, it undergoes a variety of proofs; and the instructions for that purpose are contained under forty-two heads, embracing, at the same time, the specific duties of the officer employed for that service. The principal points, however, refer to a standard proof, made with the eprouvette, and differ, in no essential part, from the methods practised elsewhere. There is a uniformity in the French service, which cannot but be admired. In every thing which relates to the ordnance especially, even in the most minute details, the French, without doubt, exceed any other nation.

Having examined the different kinds of proof, not only for gunpowder, but for cannon and small arms, as established by an act of parliament, it appears, that musket powder undergoes another description of proof. A charge of four drachms of fine grain or musket powder in a musket barrel, should perforate, with a steel ball, a certain number of half inch wet elm boards, placed $\frac{3}{4}$ inch asunder, and the first 39 feet 10 inches from the barrel. The powder manufactured at the Royal Powder Mills generally passes [138] through fifteen or sixteen, and restored powder, from nine to twelve.

There are other contrivances made use of, such as *powder-triers*, acting by a spring, commonly sold at the shops, and others again that move a great weight, throwing it upwards, which is an imperfect kind of eprouvette.

Dr. Hutton is of opinion, that the best eprouvette is a small cannon, the bore of which is about one inch in diameter, and which is to be charged with two ounces of powder, and with powder only; as a ball is not necessary; and the strength of the powder is accurately shown, by the *arc of the gun's recoil*.

The whole machine is so simple, easy, and expeditious, that, as Dr. Hutton remarks, the weighing of the powder is the chief part of the trouble; and so accurate and uniform, that the successive repetition, or firings, with the same quantity of the same sort of powder, hardly ever make a difference in the recoil of the one-hundredth part of itself.

Gregory (*Treatise of Mechanics*, vol. ii, p. 178) has given a more particular description of the eprouvette of Dr. Hutton; namely, that it is a small brass gun, $2\frac{1}{2}$ feet long, suspended by a metallic stem, or rod, turning, by an axis, on a firm and strong frame, by means of which, the piece oscillates in a circular arch. A little below the axis, the stem divides into two branches, reaching down to the gun, to which the lower ends of the branches are fixed, the one near the muzzle, the other near the breech of the piece. The upper end of the stem is firmly attached to the axis, which turns very freely by its extremities in the sockets of the supporting frame; by which means, the gun and stem vibrate together in a vertical plane, with a very small degree of friction. The charge is the same we have mentioned, usually about two ounces, without any ball, and then fired; by the force of the explosion, the piece is made to recoil or vibrate, describing an arch or angle, which will be greater or less, according to the quantity or strength of the powder.

To measure the quantity of recoil, and consequently the strength of the powder, a circular brazen or silver arch of a convenient extent, and of a radius equal to its distance below the axis, is fixed against the descending two branches of the stem, and graduated into divisions, according to the purpose required by the machine: *viz.*

1st. Into equal parts, or *degrees*, for the purpose of determining the angle actually described in the vibration.

2nd. Into equal parts, according to the *chords*, being, in fact, 100 times the double sines of the half angles, and running up to [139] 100, as equivalent to 90 degrees.

3d. Into unequal parts, according to the versed sines; they are, in truth, 100 times the versed sines of our common tables, $141\frac{1}{2}$ corresponding with 90 degrees. These serve to compare the forces.

The divisions in these scales are pointed out by an index, which is carried on the arch during the oscillation, and then, stopping there, shows the actual extent of the vibration. Two ounces of powder, give, on an average, according to the experiments of professor Gregory, about 36 on the chords, or about 21° on the arch. A more detailed account, with diagrams, may be seen, by consulting Hutton's Tracts, vol. iii, p. 153.

The eprouvette constructed by the late Mr. Ramsden, differs from the preceding simply by the gun's recoiling in a direction parallel to itself, instead of its vibrating as a pendulum. The gun is suspended by two hanging frames, which serve to make it rise and fall, during its recoil and return, so as always to retain the horizontal direction. The degrees are measured upon a fixed arch, by means of a moveable index, nearly as in Dr. Hutton's eprouvette.

We remarked, that the common powder-triers are small strong barrels, in which a determinate quantity of powder is fired, and the force of expansion measured by the action excited on a strong spring, or a great weight. The French eprouvette is usually a mortar of seven inches (French) in caliber, which with three ounces of powder should throw a copper globe of sixty pounds weight to the distance of 300 feet. No powder is admitted that does not answer this trial. This eprouvette, however, has been improved, as we shall mention hereafter. These methods have been objected to, the former because the spring is moved by the instantaneous stroke of the flame, and not by its continued pressure, which is somewhat different; and the other, on account of the tediousness attending its use, when a large number of barrels of powder are to be tried.

J. Bodington of London, invented a machine to try the force of gunpowder. M. the chevalier d'Arcys made an eprouvette on the principle of Mr. Robins. M. Le Roy proposed to employ the different elastic forces of inflammable air, but his method has never been used. M. Tresnel also proposed an eprouvette, which was announced in the French journal, entitled *Nouvelles de la* [140] *République des Lettres et des Arts*, par M. de la Blancherie, for 1782, p. 190.

It is hardly necessary to observe, that the eprouvette has undergone some improvements: thus, the eprouvette of Darcy consists of a cannon suspended at the extremity of a bar of iron, and the graduated arc measures the recoil; the eprouvette of Regnier is nearly the same, and the arc determines the force of the powder.

A description of mortar-eprouvettes generally, may be seen in the work of MM. Bottée et Riffault, (*Traité sur l'art de Fabriquer la poudre à canon*,) and in the Memoirs of Proust (*Journal de Physique*, tome lxx, *et suiv.*), &c.

I saw a model of an improved eprouvette, which appeared to possess every advantage, at the Ordnance Arsenal near Albany; an index hand moved in an arc.

Quicklime is said to increase the force of powder. Dr. Baine says, that three ounces of pulverized quicklime being added to one pound of gunpowder, its force will be augmented one-third; shake the whole together, till the white colour of the lime disappears.

The preservation of gunpowder in properly constructed magazines, of which we will have occasion to speak hereafter, is a subject that should claim our attention. The greatest difficulty, if any, exists at sea, and on this head we have a variety of opinions.

Mr. James (*Military Dictionary*, p. 348) says, that it has been recommended to preserve gunpowder at sea by means of boxes lined with sheet-lead. M. D. Gentien, a naval officer, tried the experiment by lodging a quantity of gunpowder and parchment cartridges in a quarter of the ship which was sheathed in this manner. After they had been stowed for a considerable time, the gunpowder and cartridges were found to have suffered little from the moisture; whilst the same quantity, when lodged in wooden cases, became nearly half destroyed.

It has been recommended to line powder magazines with lead, as a mean for preserving the powder from dampness. The lead, it seems, so far attracts moisture, as to condense it. In the last volume of the *Transactions of the American Philosophical Society*, is a memoir on *leaden* cartridges, by Wm. Jones, Esq. the late secretary of the navy, which, besides preserving the powder, has advantages over either paper or flannel. See Magazine.

What is termed the *analysis of gunpowder*, is nothing more than the separation of its component parts, and determining the [141] relative proportions of its respective ingredients. We may indeed examine the quality of the nitrate of potassa, by dissolving a portion of powder in distilled water, and employing the reagents mentioned under the head of nitre; but for the purpose of separating, as well as determining the proportion of saline matter, charcoal and sulphur, it may be readily accomplished in the following manner: Take a given quantity of gunpowder and affuse it in distilled water sufficient to dissolve the salt; after suffering it to remain for some time, applying heat to assist the solution, decant the whole upon a filter of unsized paper. The saltpetre and other saline matter will pass through, and the sulphur and charcoal remain on the filter. By evaporating the solution to dryness, and weighing it, the quantity of saltpetre will be found; or, after drying the mass on the filter, and weighing it, by subtracting its weight from that of the original, it will give the loss sustained, which of course is the saltpetre. By exposing the mass to a heat sufficient to evaporate the sulphur, it will be expelled; the loss sustained will indicate its quantity, and the weight of the residue the proportion of charcoal. The sulphur may be even separated by subjecting gunpowder itself to the action of a well regulated heat; it will sublime, and leave the nitre and charcoal. It takes a much higher temperature to inflame gunpowder than is required to volatilize sulphur. The method of extracting the nitre from damaged powder, we have already noticed. See *nitre.* This process also depends on the solubility of the nitre, and the insolubility of the charcoal and sulphur. Bishop Watson, in his *Chemical Essays*, proposed the examination of gunpowder by solution and sublimation; a process sufficiently accurate. If it should be our object to ascertain the presence and quantity of foreign substances, in the saltpetre, this may be accomplished by following the process already given, viz: by collecting the precipitates, &c. determining their weights, and making the necessary allowance, for the new compounds, as the carbonates of lime, sulphate of barytes, muriate of silver, and the like.

Baumé proposed the analysis of powder by sublimation, in order to separate the sulphur, using however a graduated heat. Another mode consists in distilling the powder in a retort with water, and collecting the sulphur and sulphuretted hydrogen gas, and then separating the charcoal, &c. A third process was recommended by Pelletier, after the separation of the nitre, by subliming a mixture of the residue with mercury, which, however, presents no advantages. The use of nitric acid has also been [142] recommended, in order to acidify the sulphur. For this purpose nitric acid is poured on the residue, and the whole is digested for some time, renewing the acid as it is decomposed. By this means the carbon, as well as the sulphur, is acidified, and carbonic acid gas with deutoxide of azote are disengaged, leaving the sulphuric acid formed by the union of oxygen with the sulphur, in the remaining fluid, from which it is separated by nitrate of barytes, and its quantity ascertained by the sulphate of barytes produced. The proportion of sulphur, in the sulphuric acid, is then calculated.

Caustic potassa has been employed for the separation of the sulphur from the charcoal. It unites with the sulphur, forming a sulphuret; and as sulphuretted hydrogen gas is also produced, the sulphuret must likewise contain the hydroguretted sulphuret of potassa. The charcoal is not acted upon.

M. Vito Caravelli, professor of chemistry at Naples, (*Elements d'Artillerie*, 1773,) has given a more simple process for the separation of these substances, which depends on their specific gravity. When mixed with water, the sulphur will deposite, and the charcoal float on the fluid.

Vauquelin directed his attention to this subject, and has recommended various processes, not only for the separation of the sulphur and charcoal, but also the nitre.

The process of Smithson Tennant is nearly of the same nature.

The separation of sulphur from charcoal may be effected more perfectly, according to Brande, by introducing the mixture into a small retort furnished with a stop cock, exhausted, and filled with chlorine gas; the chlorine will unite with the sulphur, forming a chloride, and leave the charcoal, which may be washed, dried, and weighed.

Baumé found, that when all the sulphur is expelled which will be driven off in the heat, a certain portion will still remain, and not burn away at a lower temperature than will consume the charcoal; so that to the last the burning residue will smell strongly sulphurous. This retained portion of sulphur he finds, by the results of many other experiments, to be very uniformly about one-twenty-fourth part of the whole sulphur employed; whence, for all common purposes, an adequate correction may be made, by estimating that the slow weak combustion of the residue, after the nitre has been extracted, destroys only $^{23}/_{24}$ths of the sulphur instead of the whole. On trying to separate them by an alkaline solution, he found some of the sulphur to remain undisturbed, and still adhering to the charcoal. In consequence of this circumstance, it is recommended, to insure a perfect analysis, to separate the [143] nitre in the first place from gunpowder, by hot water, and to treat the residue with nitric acid. After the sulphur is acidified, the addition of nitrate or muriate of barytes will separate, effectually, the sulphuric acid from the fluid, and form a sulphate of barytes; this being collected, washed, dried, and weighed, will give the quantity of sulphuric acid, and of sulphur in the acid, by the well known proportion of acid in the salt, and of sulphur in the acid. One hundred parts of sulphate of barytes, when perfectly dry, indicate fourteen and a half parts of sulphur; or, which is the same, according to Chenevix, one hundred and fifty-five grains denote twenty-two and a half grains of sulphur.

The observations of M. Champy and professor Proust on *humid powder*, seem to place the quantity of water absorbed, at 8, 10, and 14 per cent. These proportions, it is evident, depend greatly on the quality of the nitre; and if deliquescent salts exist in any quantity, the absorption, and consequently the increase of weight must be greater. Chemical examination will readily determine this fact.

The different sorts of gunpowder are usually distinguished by marks on the heads of the barrels. Gunpowder marks are various. All gunpowder for service is mixed in proportions according to its strength, so as to bring it as much as possible to a mean and uniform force. This sort of powder, says Adye, (*Bombardier and Pocket Gunner*,) is marked with a blue L. G. and the figure $^1/_2$; or with F. $^1/_2$ G. and the figure 3, whose mean force is from 150 to 160 of the eprouvette. This is the powder used for practice, for experiments, and for service. The white L. G. or F. G. is a second sort of powder of this quality. It is sometimes stronger but not so uniform as the L. G. It is, therefore, generally used in filling shells, or such other things as do not require accuracy. The red L. G. F. G. denotes powder in the British service, made at the King's mills, with the coal made in cylinders, and is used at present only in particular cases, and in comparisons, and to mix with other sorts to bring them to a mean force. The figures 1, 2 or 3 denote that the powder is made from saltpetre, obtained from the rough. Other marks are also in use to designate the rifle, musket, cannon powder, and the like.

Powder merchants recover damaged gunpowder, by putting a part of the powder on a sail cloth, and adding an equal quantity of [144] good powder, which is well mixed with it, and the mixture is then dried.

Sec. VIII. Of Lampblack.

Lampblack, which is nothing more than a finer kind of coal, is so named from its being produced and originally made by the combustion of oil in lamps. It is hardly necessary to say, that it is formed in the combustion of turpentine, various species of the *pinus*, tar, pitch, rosin, &c. as all these substances yield it more or less, and of different qualities. It is the result of imperfect combustion; for, if the combustion were rapid, and the smoke itself consumed, we would then have only carbonic acid. This fact is exemplified in the argand lamp, which, on account of the glass cylinder, consumes its own smoke. The process of forming lampblack is conducted in *lampblack houses*. After the combustion has ceased, the soot or lampblack is swept down, as it collects above and on the sides of the room. When it is obtained by burning the dregs and coarser parts of tar, furnaces of a particular construction are used. The smoke is conveyed through tubes into boxes, each covered with linen, in the form of a cone. Upon this linen the soot is deposited, from which it is, from time to time, beaten off into boxes, and afterwards packed in barrels for sale. There is also a very fine black, superior in many respects to lampblack, especially in making the ink for copperplate printers, prepared by carbonizing grape stalks, &c. in close iron vessels.

There are two kinds of lampblack in common use. One is the light soot, from burning wood, of the pine and other resinous kinds, usually made in Sweden. In Sweden the impure turpentine is also burnt for this purpose. It is collected from incisions made in pine and fir-trees, and the turpentine is boiled down with a small quantity of water, and strained, while hot, through a bag; and while this part is used for another purpose, the dregs and pieces of bark remaining in the strainer, are burnt in a low oven, whence the smoke is conveyed through a long passage into a square chamber, which contains a sack, as above stated, where the greater part of the lampblack collects, and the remainder is caught in the chamber.

The other kind of lampblack is formed by carbonization, a process similar to that for preparing the black, called *blue-black*, from grape stalks, or for preparing the German black, a pigment made by charring principally the lees of wine and husks of grapes.

The lampblack made in Philadelphia, for the purpose of printers' ink, is prepared by the combustion of tar. One barrel of [145] Carolina tar will produce forty pounds of soot or lampblack.

A patent was granted 1798 to a Mr. Row, (*Repository of Arts*, vol. x.) for a newly invented mineral lampblack. It is nothing more than the smoke obtained by the combustion of pit coal. In the county of Sarrbrook on the Rhine, are some establishments for making coke and lampblack at the same time; and from 100 lbs. of coal, 33 lbs. of coke, and $3\frac{1}{2}$ of lampblack are obtained. Jeanson (*Archives des Découvertes*, &c. i, p. 21) has described a process for carbonizing oil.

Lampblack has the same chemical properties as charcoal, and being remarkably fine, and containing sometimes a portion of oil, is used on that account in the composition of some fire-works. Its quality may be known by its colour, and, when burnt, leaving no residue. It may be sufficient to remark, that like charcoal, it decomposes nitric acid; and the nitrates, when mixed with it, and projected into a red-hot crucible, will deflagrate or produce a vivid combustion. It may therefore be used in all kinds of fire-works, in which charcoal is employed. Concentrated nitric acid, when poured on lampblack, previously dried, will produce combustion. It is to the carbon, as well as the hydrogen, in oil of turpentine, that turpentine inflames when brought in contact with nitric acid; and although much charcoal is deposited, yet a considerable part passes off in the state of carbonic acid gas. By a proper treatment, lampblack like charcoal may be converted into artificial tannin by nitric acid. It has also antiseptic qualities; but to be used for this purpose it should first be exposed to heat, in order to drive off any oil which it may have contracted, or with which it might be contaminated. The quality of lampblack may, we suspect, be improved by bringing it to a state of ignition in close iron vessels. If required intensely black, as for the making of printers' ink, this process might be advantageously used. Mixed with gum water, it makes a durable writing ink, or, according to Mr. Close, by mixing it with a solution of copal in oil of lavender. This ink is not, like the common kind, acted upon by acids.

Sec. IX. Of Soot.

Soot, or that substance formed by the combustion of wood, &c. which collects in chimnies, is used in some of the pyrotechnical [146] preparations, partly to assist the flame, and partly to modify its appearance. It is found, that soot, produced by the combustion of wood, is formed by the condensation of the carbon evolved in the smoke. It also contains volatile products, the nature of which, depends on the kind of combustible. Wood-soot is considered a good manure, on account of the carbon and some volatile salts, it is said to contain. That it contains ammonia, is evident, since it may be detected by experiment; and that this alkali is combined with carbonic acid, and sometimes with muriatic acid, a number of facts prove. Soot, then, when used in fire-works, may, like sal ammoniac, but in a lesser degree, produce a particular coloured flame. When soot is well washed in water, in order to free it from saline and other soluble matter, and probably from pyroacetic acid, and then pulverized, it forms the pigment called *bistre*. It is a fact, that the excrement of some animals, the camel for instance, which feed on saline vegetables, when burnt, will yield a soot, which contains an abundance of muriate of ammonia, or sal ammoniac. Hence, by re-subliming this soot, sal ammoniac was originally prepared in Egypt. The quantity of muriate of ammonia, contained in the soot of camels' dung, is considerable. It is found that 26 lbs. of soot yield on an average 6 lbs. of that salt; See *Sal Ammoniac.* Camels' dung, and in fact the dried excrement of animals, furnish a very good fuel. In Egypt it is used with advantage. The soot of oil, &c. is of a different kind; it is the substance, which forms our lampblack.

Sec. X. Of Turpentine, Rosin, and Pitch.

All these substances enter into the composition of fire-works, either to increase the rapidity of combustion, as in incendiary fire-works, or, in some cases, as with rosin, to produce a coloured flame. That they contain carbon and hydrogen, as their principal ingredients, is well known; to which we may attribute their rapid combustion, and the facility with which they decompose nitrous salts. The Greek fire, for example, owed, it is said, its powerful effect to turpentine, which, with other substances employed, made the composition remarkably inflammable, and the decomposition of the nitre, (which some say it contained) so rapid, as even to defy the action of water.

All of the turpentines are obtained from different species of pinus. Common turpentine is the resinous juice, which exudes chiefly from the *Pinus Sylvestris*, or Scotch fir, and is obtained by boring holes into the trunks of the trees, early in the spring, and placing [147] vessels beneath for its reception. This turpentine, and in fact all others, are composed of rosin and a volatile oil. The latter is obtained by distilling the turpentine with water. It passes over with the water, from which it is afterwards separated, and is then known by the name of the essential oil, or spirit of turpentine. The substance, remaining in the still, is common rosin, or yellow rosin, known likewise by the names of *fidlers' rosin* and *colophony*. Tar is also obtained from the roots and refuse parts of the fir tree, by cutting them in billets, piling these in a proper manner, in pits or ovens, formed for the purpose, covering them partly over, and setting them on fire. During the combustion, a black and thick matter, which is tar, falls to the bottom, and is conducted into barrels.

Pitch is nothing more than tar boiled down to a solid consistence; it is usually made, however, by melting together coarse hard rosin, and an equal quantity of tar. The ancient pitch possessed a flavour and fragrance. White pitch is the same as the white turpentine.

Melted pitch, sulphur, and camphor, mixed, when nearly cold, with pulverized saltpetre, and afterwards thinned with spirit of turpentine, will form a composition, that is very inflammable, and will almost resist the action of water. A similar composition must have formed the Greek fire, of which, according to Beckman, there were several kinds.

The turpentine trees furnish various products: Thus, the Pinus Abies, or spruce fir, yields the Burgundy pitch, and its branches produce the Essence of Spruce; but other species of pinus are used for the same purpose, which are nearly allied to it, and which grow abundantly in Canada. From the *Pinus laryx*, or larch, Venice Turpentine is obtained; but that sold, is usually made by melting rosin, and adding the spirit of turpentine. From the sap of the larch, the Russians prepare a gummy substance, known in Russia by the name of *Orenburg gum*. Turpentine is extracted in France, in great quantity, from the *pinus maratima*. Gallipot, colophony, tar, pitch, &c. are likewise obtained from it.

The turpentine of cedar, according to Dr. Pocoke (*Travels through Egypt*) was employed by the Egyptians for embalming, the operation being performed in several ways. It was injected, and used with salt, nitre, &c.

Pitch, tar, and turpentine all enter into sundry compositions, used in war. The different incendiary preparations, noticed in the last part of the work, are composed, in general, of either one or all of these substances. Their use is obvious. Being very inflammable, and brought in contact with gunpowder, nitrate of potassa, &c. they burn with great rapidity, and consume every [148] thing before them. Hence the tourteaux of the French, tarred links, and fascines, carcasses, &c. owe their effect to the presence of these substances.

Rosins are considered to be volatile oils, saturated with oxygen.

Thus, or frankincense, of which there are several varieties, has been long used in fire-works; it is frequently employed in the composition of odoriferous fire. It is obtained from the pinus abies, and appears in *tears*. During winter, the wounds made in fir trees become incrusted with a brittle substance, called *barras* or *gallipot*, consisting of rosin united with a small portion of oil. All rosins, according to the experiments of Gay-Lussac, and Thenard, (*Recherches physico-chimiques*) are composed of a great quantity of carbon and hydrogen, united with a small quantity of oxygen. To this, we attribute their great inflammability, and it enables us to account for the rapid decomposition of nitre, in those preparations, in which nitre and resinous substances are employed. See *General Theory of Pyrotechny*, sec. ii.

For the accension which takes place by mixing oil of turpentine and nitric acid, see the properties of nitric acid, under the head of *nitre.*

Morey (*Silliman's Journal*, vol. ii, p. 121) observes, that a small quantity of spirit of turpentine being added to a mixture of iron-filings, sulphuric acid, and water, the hydrogen gas produced, will burn with a very pleasant white flame, and without smoke. He also observes, that, if the vapour of spirit of turpentine be made to pass through a tube, covered at the upper end with a fine wire gauze, it burns with much smoke; but, if a quantity of atmospheric air be allowed to mix with it, the smoke ceases, and the flame continues white. If more still be added, the flame lessens, and becomes partly blue. By adding still more and more, it will burn with a very small flame, entirely blue, and with a singular musical sound. If still more be added, the flame, and every ray of light cease; but that the combustion still continues, is certain, from the explosive detonating noise, continuing to be distinctly heard.

Mr. Morey further remarks, that, if tar, containing a considerable proportion of water, is dropped on brick or metal, at a temperature, which will readily evaporate them, the vapours will burn with white shooting streaks, much flame, and without smoke, while the water lasts. Inflamed drops of tar, burn, while falling, with a red flame, and much smoke; but, on reaching boiling [149] water, the smoke instantly disappears, and streaks of a white flame shoot up. He also says, that, if water in one cylinder be made to boil, and the steam be led to the bottom of another, containing rosin, or tar, at a high temperature, after passing up through it, the water, together with the vapourized portion of the rosin or tar, will, when the preparations are properly regulated, burn with an intense *white* flame, and *no smoke*; much the greater part of which appears, (by alternately shutting the steam out, or letting it in) to be derived from the water; and also, that if steam be led over the surface of tar in a cylinder, and made to force out a small stream of it through a pipe, into which a quantity of steam is also admitted, and made to mix intimately with it, they burn, with a great body of flame and intense heat, and without smoke, provided the proportions are well regulated. These facts are remarkable, and may probably lead to some useful applications. That water is decomposed, appears more than probable. If water is thrown, in considerable quantities, on oil or tar, in a state of inflammation, as Morey observes, the flame is greatly increased; and if ever so small a drop of water fall into oil at a temperature near boiling, an explosion will take place. He draws the following conclusion, from these circumstances; that we have only to pass the steam of water through oil, heated to the temperature, at which it boils, or takes fire, to produce combustion.

Sec. XI. Of Common Coal, or Pitcoal.

All the variety of coals, belonging to the coal family, are composed principally of charcoal and bitumen, with small quantities of earthy, and metallic matter. Whether we consider the formation of coal, the localities or situation in which it occurs, whether in beds or strata, accompanying other minerals, such as clay-slate, bituminous schistus, sandstone, &c. is of no moment, except so far as the situation in which it is found, indicates or determines its character and qualities. The different kinds of coal owe their variety to the presence or absence of bituminous matter, whether great or small, the quantity of the carbonaceous ingredient, and the presence or absence of anthracite, and other foreign substances. Coal, which is, or ought to be preferred in fire-works, should contain the greatest quantity of bituminous matter; and, while it contains the due proportion of carbon, should be entirely free from anthracite. Coal, and all other inflammable fossils, are characterized by their inflammability, insolubility in water, alcohol, and acids, and by their specific gravity, which scarcely exceeds 2, unless loaded with foreign matter. Coal surcharged with [150] bitumen, burns with a bright flame, and, by distillation, affords more carburetted hydrogen gas, which is used for *gas light*. Common coal, or pitcoal, burns in cakes, more or less, during combustion. Besides charcoal and bitumen, it contains sometimes pyrites, sulphate of iron, and earth. Slate-coal, however, contains more clay.

The collieries, from which pitcoal is obtained, are more or less extensive in England, and elsewhere. Immense beds of coal are found near Pittsburgh, and Richmond. The Lehigh, and other localities in the United States, produce it also in abundance, but of various qualities. Coal districts, or places in which it is found, may be considered a valuable acquisition to a country; and as coal is so essential in many manufactories, it is a satisfaction to know, that our resources in this particular, are almost inexhaustible;—a fact, which shows, that, while our national industry is the main pillar of national independence, in its true acceptation, the arts, which require a supply of coal, will, for centuries to come, be abundantly furnished with it.

When coal is exposed to the action of heat, in iron retorts or cylinders for the preparation of coal gas, or when it is exposed to heat in coke-ovens, the bitumen, &c. are disengaged, and there remains a coal called coke. Coke, therefore, is nothing more than charred pitcoal.

Mr. Mushet made some valuable experiments on the carbonization and incineration of coals. He found that the Scotch cannel-coal afforded 56.57 volatile matter, 39.43 charcoal, and 4 ashes; while the stone-coal, found under basalt, gave 16.66 volatile matter, 69.74 charcoal, and 13.6 ashes, and oak wood, 80.00 volatile matter, 19.5 charcoal, and 0.5 ashes. The quantity of gas, however, depends entirely on the quality of the coal. A temperature of about 600° to 700° is sufficient to disengage it. A pound of good cannel coal, properly treated in a small apparatus, will yield five cubic feet of gas, equivalent in illuminating power to a mould candle, six in the pound. One pound of coal, on a large scale, affords only $3^1/_2$ cubic feet of gas. A gas jet, which consumes half a cubic foot per hour, gives a steady light equal to that of a candle of the above-mentioned size.

The cannel coal, known in Scotland by the name of parrot coal, is very inflammable, takes fire immediately, and produces a brilliant flame. It is used by the poor as a substitute for candles. This coal, we have seen, furnishes an abundance of carburetted hydrogen gas. It has the appearance of jet, and admits of being turned in a lathe.

Stone coal, Kilkenny coal, Welch coal, and glance coal consist almost entirely of charcoal; and hence, when laid on burning coals, [151] they become red-hot, emit a blue lambent flame, in the same manner as charcoal, and at length are wholly consumed, leaving behind a portion of red ashes. They burn without smoke or soot.

The pitch coal, which has a brownish-black colour, and is generally found massive in plates, the bovey coal, called brown coal, and bituminous wood, with the anthracite coal, and some others of lesser note, form the remaining varieties of coal.

When coal is employed in fire-works, it is to be pulverized, and sifted in the usual way. For some purposes it is preferred to charcoal, in consequence of the bitumen it contains, which appears to contribute to the rapidity of the combustion. It is to be observed, that, as the base of coal is carbon, its action is the same as charcoal, and therefore, by producing the same effects, or nearly so, as charcoal itself, the phenomena it presents are analogous. As 12.709 parts of carbon, according to Kirwan, are required to decompose 100 parts of nitrate of potassa, we may readily ascertain the quantity of real carbon in any specimen of coal. According to Kirwan, 50 grains of Kilkenny coal will decompose 480 grains of nitrate of potassa, from which it is inferred, that ten grains would have decomposed 96 of nitrate of potassa, precisely the same quantity of charcoal, which would have produced the same effect. Therefore, Kilkenny coal is composed almost entirely of carbon. Cannel coal, when treated in the same manner with nitrate of potassa, left a residuum of 3.12 in the hundred parts of earthy ashes; and 66.5 of it were required to decompose 480 grains of nitrate of potassa, but 50 of charcoal would have been sufficient. From this experiment, it appears, that 66.5 grains of cannel coal contain 50 grains of charcoal, and 2.08 of earth; the remaining 14.42 grains must be bitumen. In a similar manner, by knowing the quantity of coal required to decompose a given quantity of nitrate of potassa, when melted in a crucible, the quantity of carbon in any variety of this substance may be ascertained.

With respect to the earthy and metallic ingredients of coal, we may ascertain them by burning the coal, with free access of air. What remains unburnt must be considered an impurity. Its weight may be ascertained, and its nature by analysis. As the object, however, is generally to determine the relative proportion of combustible matter, or carbon, which different species of coal are capable of yielding, that point may be determined in the manner already stated.

That coal originates from vegetables, whatever opinion may be formed to the contrary, we may fairly infer from a variety of [152] vegetable remains, and impressions of animals that are both found in the strata of coal, and in earthy strata above and below them. Of its submarine origin, there can also be no doubt; or why do we find in it shells, the impression of fish, and other productions of the ocean? That coals *grow like vegetables*, an opinion with the uninformed, is contrary to fact, and the nature of things.

We may notice, in this place, another substance which sometimes is found partially carbonized; we mean turf.

Turf or peat, obtained from morasses, consists of a multitude or congeries of vegetable fibres, partly in a decomposed state, and is frequently so inflammable as to inflame by a spark. Very extensive morasses are found in some countries from which the inhabitants are supplied with fuel. Some improvements in the manner of preparing turf for use, have been made; that of charring it in kilns is one. By this process it kindles sooner, burns with less air, and forms a moderate and uniform fire, without much smoke, though it is not so lasting as that produced by turf. The method of reducing turf to coal is still practised in some parts of Bohemia, Silesia, and Upper Saxony, which was first proposed in 1669, by John Joachim Becher, who also recommended, at that time, a process for depriving coals of their *sulphur*, by burning them in an oven, and the use of the oil procured from them. What are our modern patents on this subject? What are lord Dundonald's coke ovens and coal tar? Are they original? Boyle (*Usefulness of Natural Philosophy*,) speaks of Becher's invention. Anderson, (*History of Commerce*,) however, observes, that something of the kind was attempted before Becher's time; for in the year 1627, John Hacket and Octavius Strada obtained a patent for their invention of rendering coals as "useful as wood for fuel in houses, without hurting any thing by their smoke."

With respect to turf, it appears that Hans Charles von Carlowitz, to save wood, introduced the use of it in Saxony, in the smelting houses, in 1708.

Turf has been known for a long time. It was used from the earliest periods, in the greater part of Lower Saxony, and throughout the Netherlands; as is fully proved by Pliny's account of the Chauci, who inhabited that part of Germany. Pliny (*Hist. Nat. lib.* xvi, c. i.) observes, that they pressed together with their hands, a kind of mossy earth which they dried by the wind rather than by the sun, and which they used, not only for cooking their victuals, but also for warming their bodies. We also read that a morass in [153] Thessaly, having become dry, took fire, and the same thing ensued in some part of Russia, where a morass burned several days and did much damage. Very dry turf is nearly as inflammable as spunk, and when prepared with nitre, has been used for the same purpose. See *Pyrotechnical sponge.*

Ure (*Chemical Dictionary*) observes, that "turf has been charred lately in France, it is said by a peculiar process, &c." The truth is, that the *charring* of turf is by no means a recent invention, as we stated above. Sonnini (*Journal*, &c.) says, that it is superior to wood. It kindles slower than charcoal of wood, but emits more flame and burns longer. In a gold-smith's furnace, it fused eleven ounces of gold in eight minutes, while wood charcoal required sixteen.

Turf frequently contains phosphoric acid; for bogs or morasses, and bog-iron ores abound, more or less with it, in different states of combination. The *siderite* of Bergmann which he supposed to be a peculiar metal, and found in bog-ore, is a phosphate of iron. The native Prussian blue, which also occurs in such localities, is generally admitted to be a combination of phosphoric acid iron and alumina.

Sec. XII. Of Naphtha, Petroleum, and Asphaltum.

Naphtha, petroleum, and asphaltum are all modifications of bituminous oil; and as they are all inflammable, naphtha being the most so, they have been used in the preparation of fire-works.

It will be sufficient to remark, that naphtha or rock oil is a yellow or brownish bituminous fluid, of a strong, penetrating odour, and so light as to float on spirits of wine. By exposure to the air, it acquires the consistence of petroleum. It takes fire on the approach of a lighted taper, and burns with a bluish flame, yielding a thick smoke. Plutarch and Pliny both affirm, that the substance with which Medea destroyed Creusa, the daughter of Creon, was naphtha. She sent a dress to the princess, which had been immersed in, or covered over with the oil, and which burst into flames as soon as she approached the fire of the altar. Plutarch relates that Alexander the great, was amused and astonished with the effects of naphtha, which were exhibited to him at Ecbatana. On the shores of the Caspian sea, it is burnt in lamps, instead of oil. There are copious springs of this oil in that neighbourhood, and it is sometimes obtained by distilling bituminous substances.

Hanway (*Travels through Russia into Persia*, i, 263,) mentions the naphtha of Baku, and remarks that the earth is strongly [154]
impregnated with it; for, he adds, by taking up two or three inches of the surface, and applying a live coal, the part which is so uncovered, immediately takes fire, almost before the coal touches the earth. Eight horses were consumed by the fire from naphtha, being under a roof where the surface of the ground was turned up, and, by some accident took fire. A cane, or tube, even of paper, set two inches in the ground, and the top of it touched with a live coal, and blown upon, immediately emits a flame, without hurting either the cane or paper, provided the edges be covered with clay. Three or four of these lighted canes will boil water in a pot.

Pinkerton, (*Petralogia* ii, p. 148,) speaks of the naphtha of Baku, which exists on the western side of the Caspian sea, being carried to Constantinople, "where it formed the chief ingredient of the noted composition called the Grecian Fire; which, burning with increased intensity under water, became a most formidable instrument against an inimical fleet." See *Greek fire.*

Naphtha is obtained of several qualities by suffering it to remain in pits or reservoirs. The Persians, who use it in their lamps, and to boil their food, find it to burn best with a small mixture of ashes. They keep it at a small distance from their houses, in earthen vessels, under ground, to prevent any accident by fire, of which it is extremely susceptible.

Hanway speaks also of what is called the *everlasting fire*, about ten miles from Baku, which is an object of devotion to the followers of Zoroaster. Near the altar of their temple, he observes, is a large hollow cane, from the end of which issues a blue flame, which the Indians pretend has continued to burn ever since the flood, and which, they fancy, will last to the end of the world.

We have no hesitation in believing, that the ancients made use of this oil in their exhibitions; and, from its properties, that when mixed with other substances, it would make a brilliant fire-work.

Petroleum, called also mineral tar, is less fluid and less transparent than naphtha. It has an oily consistence, more or less viscid. It occurs of a black or brown colour. It burns rapidly, but not so readily as naphtha, and exhales a black smoke. By distillation, it forms a liquid like naphtha, and leaves a thick tar in the retort.

It exudes from rocks, is found in wells, &c. In Pegu, the wells furnish annually 400,000 hogsheads. It is used there in the place of [155]
oil for lamps. When boiled with rosin, it is used for painting houses, and the bottoms of vessels. In the embalming of dead bodies, it was employed by the ancient Egyptians; and, in some countries, clay, soaked in it, is used as fuel.

It is found in the United States, in Kentucky, Ohio, the western parts of Pennsylvania, in New York at the Seneca lake, &c. The Seneca or Genessee oil is the same bitumen.

When petroleum is exposed to the atmosphere, it acquires a greater degree of consistence, and passes into another bituminous substance, called maltha. This has the properties, and frequently the appearance of pitch. When burnt, it yields more smoke and soot than petroleum. According to its original meaning, it signifies a kind of cement; and the maltha mentioned by Pliny, Heineccius, Festus, and others, which was employed in the same manner as our modern sealing wax, was a mixture of pitch and wax, and was also used to make reservoirs, pipes, &c. water-tight. Maltha also sometimes resembles wax. Mr. Kirwan, however, gave it the name of mineral tallow.

Mineral or Barbadoes tar is somewhat thicker than petroleum, and nearly of the consistence of common tar. It is used for the same purposes as the ordinary petroleum. Elastic bitumen, a variety between the softer and harder bitumens, resembles caoutchouc. It burns with a bright flame, and bituminous odour.

Asphaltum, or solid bitumen, is much harder than pitch, brittle, and of a brownish-black colour. It burns freely, and leaves but little residue. In Judea, it is found on the waters of the Dead sea, or the lake of Asphaltes. It is also called *Jews' pitch*. It was employed by the Egyptians for embalming under the name of *mumia mineralis*.

Both maltha and asphaltum were used by the ancients as a cement. The walls of Babylon were cemented with these substances, as obtained from the river Is, which falls into the Euphrates. It may be observed, that those countries, which yield bitumen, contain salt springs, and it frequently accompanies pyrites. Limestone, particularly the black, contains it, and the colour is often owing to its presence. The *stink stone*, or bituminous carbonate of lime, is of this kind. The retinasphaltum, a combination of bitumen and earth, having a yellow colour, burns with a bright flame, and fragrant odour, which at last becomes bituminous. Many stones, and particularly some of the black marbles, owe their colour to bitumen; hence they burn white. The bituminous schistus, or bituminous shale, sometimes contains so much of this substance as to burn in the fire. Jet is a mineral of a black colour, and [156]
resembles the cannel coal. It is inflammable, producing a green flame, with a strong bituminous odour.

With respect to bitumens, we may observe, that they all possess one character, that of being inflammable; and that they are more or less so in proportion as they partake of the principle of naphtha; or, at least, the rapidity of their combustion depends upon the presence of this oil. The following additional facts, therefore, with respect to naphtha, may be interesting: Certain liquids have the property of uniting with naphtha, which has also the property of dissolving and combining with solid substances, of which the following examples may be stated:

At the degree of ebullition, it dissolves sulphur, which, on cooling, is in part deposited in needle-form crystals. At the same temperature, it also dissolves phosphorus, part of which is again separated.

It unites also with iodine. With camphor, it also combines, and in large quantity. It takes up a much larger proportion of pitch. In the cold, its action on wax is feeble, but assisted by heat, it unites with it in all proportions. On lac and copal, its action is feeble. In the cold, it does not dissolve caoutchouc; but when assisted by heat, it dissolves this substance, though not completely. These facts may determine its action in certain mixtures.

According to Theodore de Saussure's Analysis, (*Bibliot. Universelle*, iv, p. 116), it appears, that naphtha is composed of 87.60 carbon, and 12.78 hydrogen.

Sec. XIII. Of Oil of Spike.

This oil is principally used as a vehicle for mixing the ingredients of some kinds of fire-works; and, although it is employed in that way, yet it has also an effect in combustion, having similar properties with liquid bitumen. It enters into the composition of some of the preparations, and perhaps is equally good as liquid bitumen. Indeed, the oil of spike, as sold in the shops, and used principally by farriers as an embrocation for horses, is an artificial preparation, made by mixing together about five ounces of Barbadoes tar, with a pint of the spirit of turpentine.

Sec. XIV. Of Amber.

Amber, succinum, karabe, the electron of the ancients, which are synonimous terms, is very inflammable. A piece of it, put on [157]
the point of a knife, and set on fire, will burn entirely away, emitting, at the same time, a white smoke, and a somewhat agreeable odour. It is used in the composition of fire-works, and particularly in some kinds of rockets. All the preparation it undergoes, when thus used, is to reduce it to powder in a mortar, and to pass it through a fine sieve. It also forms a part of the composition of odoriferous fire; but the formulæ for the latter are various.

Amber is of various colours, either yellowish, white, or honey-yellow. It is translucent, and sometimes transparent. It may be turned or polished. It occurs in grains or in irregular masses. Alluvial deposites of sand, gravel, &c. frequently contain it. It is also found with bituminous wood, brittle lignite, or jet, and with other substances. It has been discovered in New-Jersey, near Trenton, in alluvial soil. Naturalists believe, that amber was once a resinous juice. Masses weighing 20 lbs. have been found. Sometimes it contains insects. It is formed into beads and the like. As amber becomes electric by friction, and the ancients called it electron, the term electricity is derived from it. By distillation, it yields both an acid, (the succinic), and an oil. Jet is usually considered black amber.

We may introduce here a few remarks respecting ambergris:

Ambergris is a substance, which has a peculiar fragrance, and for that reason is used as a perfume, and may be employed like similar substances in odoriferous fire. As to its origin, we have no certain account; but it seems, from its general properties, to be formed in the same manner as bituminous substances, although it is mostly found on the sea-shore, where it has been probably washed up from the sea.

Ambergris is found principally on the shores of Ceylon, and is known to be good, by laying some of it on a very hot knife, when, if pure, it will not only melt and run like wax, but entirely evaporate, leaving no residue.

Ambergris, on account of its price, (the retail price in London being a guinea per ounce), is frequently adulterated with various mixtures of benzoin, labdanum, meal, &c. scented with musk. But pure ambergris, when heated, has a greasy feel, and appearance, and is soluble in hot ether and alcohol.

Sec. XV. Of Camphor.

Camphor is a resinous substance, although generally called a gum, which has a peculiar, and powerful smell. It is obtained [158] principally from the *Laurus Camphora*. It is extracted from this, and other trees in the East Indies. We are informed, that, in Borneo and Sumatra, the larger pieces which contain the most camphor, are picked out with sharp instruments. The Chinese cut off the branches, chop them small, and place them in spring water. They are then boiled, and stirred with a stick. As soon as the camphor is observed to adhere to the stick, the fluid is strained. It is then poured into a basin, and the camphor separates, in Japan, the roots and the extremities of the branches are steamed. It is also obtained by sublimation. The roots, wood, and leaves are all boiled in large iron pots, and the camphor is collected on straw, placed in a tubular head.

With respect to the refining of crude camphor, in order to produce *heads*, as they are called, and to free it from impurities, the operation is nothing more than sublimation. Sublimers made of glass are used; and into each, the camphor, along with a small portion of lime, is introduced, and they are then placed in a sand bath. Heat is applied, and the pure camphor rises and attaches itself to the upper part of the vessel, forming the refined camphor.

The general properties of camphor are the following: It is not altered by the atmospheric air, but is volatilized during warm weather. It is insoluble in water; is soluble in alcohol, forming the spirit of camphor, and also in volatile and fixed oils. It is not acted upon by the alkalies. It is dissolved in acids without effervescence, and by some it is decomposed. Nitric acid converts it into a peculiar acid, called the camphoric. It melts between 300 and 400 degrees. It takes fire, and burns with a white flame, and, generally, while it presents the character of a resin, it shows, by its combustion, like other inflammable bodies, that it contains, in its composition, a large quantity of carbon and hydrogen.

There are several species of camphor, which have been examined by chemists and which differ in their properties. These are, common camphor, the camphor of volatile oils, and the artificial camphor, formed by treating oil of turpentine with muriatic acid.

The base of camphor forms a constituent part of some volatile oils, which are in a liquid state; and for its separation, it appears to require a combination with oxygen.

Camphor may be apparently set on fire by means of water, an experiment, which is nothing more than producing chemical action by it, in the following manner: Put a portion of nitrate of copper on some tin-foil, along with camphor; then by adding some water, and quickly wrapping the foil up, pressing the edges close, it will inflame, and sparks of fire be produced. [159]

Camphor has been used in the manufacture of candles. For this purpose, it is dissolved in brandy, and the wick, composed of equal parts of cotton and linen, is dipped in. It is then dried, and covered, in the usual manner, with tallow or wax. The tallow, recommended as the best for candles, is a combination of equal parts of mutton and beef suet.

Camphor is very soluble in acetic acid, which is highly inflammable. This solution is decomposed by water. When combined with essential oils, it forms aromatic vinegar. Romieu has observed that small pieces of camphor floating on water have a rotary motion.

Camphor enters into a composition, which is used to determine, like a barometer, the state of the weather, and the changes it undergoes. According to the *Journal de Pharmacie*, 1815, some experiments were made in France on the fluid taken out of one of the English weather gauges. The liquid contained water and alcohol, was strong with camphor, and reddened litmus paper. The tube contained $3\frac{1}{2}$ ounces. On analysis, its contents were found to be, 24 grains of alum, 120 grains of camphor, and enough water to dissolve the former, and alcohol to dissolve the latter. A similar composition was made, and put into a tube, which, it seems, had the same effect. The tube is hermetically sealed. M. Cadet observes, that the *prognosticator*, made in Paris many years ago, was a similar preparation.

Although, according to Cadet, this contrivance cannot be depended upon, as the appearances it presents are not regular; yet, as the effect is produced by heat, as well as light and electricity, the following summary may be added:

1. In fair weather, the composition remains at the bottom, and the liquor is clear.

2. Before rain, it will rise a little; the liquor will be clear, having merely a star floating in it.

3. Before a storm, it will rise to the surface, the liquor will appear troubled. These appearances may be seen 24 hours before the change in the weather takes place.

4. In winter, it is higher than common. During a snow, it will be very white, and pieces are seen in motion.

5. In settled weather in summer, and when warm, the composition will be low.

6. To know from what quarter wind will come, the composition will remain attached on the opposite side of the bottle to that from which it is expected.

Camphor has been burnt, like ether and alcohol, by platinum wire, previously heated. Dr. Ure observes, that a cylinder of [160] camphor may be used for both wick and spirit, in the aphlogistic lamp; and the ignition is very bright, while an odoriferous vapour is exhaled. By adding various essential oils in small quantities to the alcohol of the lamp, various *aromas* may be made to perfume the air of an apartment. See *Scented Fires for rooms.*

Camphor is employed in those fire-works chiefly, which are exhibited in rooms; its expense being an objection to its use in large exhibitions. In what are termed perfumed pastes, or mixtures, scented fire, or odoriferous fire-works, it is used in abundance: in fact, it enters into nearly all the compositions of this kind. Camphor, besides producing, alone, a white flame, gives a brilliant light, and, when mixed with other substances, adds greatly to the appearance of the flame; and, giving out a powerful odour, destroys, in a measure, the disagreeable smell arising from the combustion of the sulphur and nitre.

By referring to the article on Greek fire, and some incendiary preparations used in war, it will be seen, that camphor is an important constituent. As camphor is very combustible, and will even burn on the surface of water, it is well adapted for all those purposes. We have already spoken of the Greek fire; and it seems, that the peculiar character of that fire, of burning in water, was owing to the presence of camphor. This opinion appears plausible, when we consider, that some preparations *have been* made with camphor, which had the property of burning on water.

Camphor may be pulverized by the assistance of, and brought into intimate mixture with, nitre and sulphur; because the former, in particular, tends to divide it. But it may be pulverized separately, and afterwards added to the composition, by rubbing it in a mortar with a small quantity of alcohol, or spirit of wine; or, if this cannot be had, with fourth proof brandy. As camphor is very inflammable, its effects, when mixed with saltpetre and fired, are much the same as those produced by other resins, or concrete oils. A combustion, more or less rapid, ensues, and, while the nitre itself is decomposed, the camphor also undergoes the same change, producing both water and carbonic acid, from the union of two of its elements, the hydrogen and carbon, with the oxygen of the nitric acid. In all cases, in which camphor is employed in artificial fire-works, although its own flame is *white*, it may assist in increasing the flame, which, however, is modified, according to the substances, which enter into the composition. These may not [161] retard its combustion, but, nevertheless, may change the appearance of the flame; as is the case, when we employ the filings of iron, steel, brass, or zinc, sal ammoniac, rosin, saw-dust, and other substances, which usually form a part of such mixtures. Upon the whole, then, we may consider, that camphor acts in fire-works; 1st, as an inflammable body; 2ndly, that, besides being in a great measure decomposed, a portion of it is evaporated, and communicates, to the surrounding atmosphere, a peculiar smell, which is recognised in the odoriferous fire-works; 3rdly, that, while it acts in taking a part of the oxygen from the nitric acid of the nitre, it assists in the decomposition of this salt, more especially if it be mixed separately with the nitre; 4thly, that, in all instances of its combustion, while it acts primarily on the nitre, with the oxygen of which it forms both water and carbonic acid, it, at the same time, increases the flame, which may be either white, red, or yellow, according to the other substances employed; and, finally, it may be thrown out in the state of combustion, and receive, for the further support of its combustion, the oxygen of the air, and hence produce a white exterior flame, while that in the immediate vicinity of the composition may be more or less coloured. But its application, the proportions in which it is used, as well as the kind of fire-works to which it is applicable, will be considered at large in other parts of the work.

The great inflammability of camphor is to be ascribed to its containing a *large* quantity of carbon and hydrogen, and a *small* quantity of oxygen.

There is a preparation, called artificial camphor, that is formed by passing muriatic acid gas through spirit of turpentine. It inflames with facility, and burns, without leaving any residue. Might not this preparation be economically employed, in lieu of camphor, for incendiary fire-works?

Sect. XVI. Of Gum Benzoin, and Benzoic acid.

Gum Benzoin, or Benjamin, is considered a solid balsam, and is the production of a tree, which grows in Sumatra, &c. called the *styrax benzoe*. It is obtained from this tree by incision, a tree yielding three or four pounds. It is a brittle substance, sometimes in the form of yellowish-white tears and called, from that circumstance, almond benzoin. Besides a resinous substance, it contains an acid, called the benzoic or *flowers of benzoin*, a substance similar to balsam of Peru, being a peculiar aromatic principle, soluble in [162] alcohol and water. By heating it, or by combustion, it evolves a very agreeable smell, and is, therefore, used in those fire-works which are exhibited in rooms, theatres, &c. and also in the composition of odoriferous fire-works. Besides being in itself inflammable, it produces a peculiar smell, arising, in all probability, from an essential oil, aided, in some degree, by the separation of benzoic acid.

It has been examined by Bucholz and Brande. Its general properties are: that it is insoluble in water, although hot water takes up a part of it, said to be the benzoic acid. It is soluble in alcohol, from which it is separated by muriatic and acetic acids, but not by the alkalies. It is also soluble in ether.

The benzoic acid, or flowers of benzoin, are obtained from it by sublimation. A quantity of the powdered gum, put into an earthen basin, a thick paper cone being tied round the rim, and heat applied, the acid will leave the resin, and be condensed on the inner side of the cone. Bucholz (*Bulletin de Pharmacie*, v. p. 177) has given a process for obtaining it by means of alcohol, and some others have been adopted. By boiling four ounces of the gum in powder in a sufficient quantity of water, with three drachms of carbonate of soda, the acid will unite with the alkali, and form a benzoate of soda, which, when filtered and decomposed by sulphuric acid, will yield the benzoic acid. Five drachms of acid will be thus obtained. Lime has been used in the same manner as soda, and the acid separated by the addition of muriatic acid.

Flowers of benzoin may be used in the place of the gum; using, however, but a small quantity. They will communicate the same odour to fire as the benzoin. The flowers, or acid of benzoin, are so inflammable, as to burn, with a clear yellow flame, without the assistance of a wick. It is soluble in ardent spirits, in oils, and in melted tallow. The compounds, which it forms with them, are also inflammable. Benzoic acid is considered to be an oily acid, and contains, no doubt, a very large proportion of hydrogen.

Sect. XVII. Of Storax Calamite.

Storax is the most fragrant of all the balsams. It is afforded by the *styrax officinalis*, a tree which grows in the Levant. It is sometimes in red tears. Common storax is in large cakes, and brittle and soft to the touch. This is more fragrant than the other [163] sort, but is frequently adulterated with saw-dust. It is soluble in alcohol, and is said to yield some benzoic acid.

Styrax is a different substance; a semi-liquid juice obtained from the *liquidambar styraciflua*. Its odour is less agreeable than that of storax calamite. It is used in odoriferous fire, in *pastes*, in the composition for *scented vases*, and the like.

Sect. XVIII. Of Essential Oils.

Essential or volatile oils, as well as the raspings of red cedar, dried rosemary, and other fragrant plants, are all used in the preparation of odoriferous fire. In some preparations, the *oil of roses* is employed; in others, the essence of bergamot, of lemon, &c. which, being very volatile, evaporate in a moderate heat, and, being also inflammable, may assist in the combustion. In the case of the raspings of cedar in particular, it also communicates a peculiar appearance to the flame.

Oils, whether essential or fixed, when passed through ignited tubes, are decomposed, and furnish an inflammable gas called olefiant gas. Wax, tallow, &c. produce the same gas, the hydroguret of carbon. Messrs. Taylor and Martineau contrived an ingenious apparatus for generating gas from oil on the great scale, as a substitute for candles, lamps, and coal gas, it being much preferable for burning, as it contains no sulphur, and does not injure furniture, books, plate, paint, &c. Oil gas contains more hydroguret of carbon than coal gas, which is a great advantage, enabling one cubic foot of oil gas to go as far as four of coal gas. An elegant apparatus was erected by Taylor and Martineau at the Apothecaries' Hall, London, a drawing of which may be seen in the 15th number of the "*Journal of Science and the Arts*."

It is to be observed, that odoriferous fire-works are intended for exhibition in close apartments; so that the smell of certain gases, produced by the nitre, charcoal, and sulphur, according to the preparation used, will be more or less destroyed. Such preparations are, nevertheless, expensive, and for that reason seldom used.

Sect. XIX. Of Mastich.

This resin, obtained, from the *pistacia lentiscus*, by making transverse incisions in the tree, is first in a fluid state, and gradually concretes into yellowish semi-transparent brittle grains. In Turkey, great quantities of it are used for sweetening the breath, and [164] strengthening the gums. It is from the use of the resin as a *masticatory*, that its name is said to be derived. It is not completely soluble in alcohol, a soft elastic substance separating from the solution. When exposed to heat, it melts, and exhales a fragrant odour: for which reason, principally, it enters into the composition of some fire-works, as the *scented paste*. In ordinary fumigations, mastich is commonly used.

Sect. XX. Of Copal.

Gum copal, by which name it is known, is a resin, obtained from a tree, called *thus copallinum*. It is often in the form of a beautiful white resin; but sometimes it is more or less coloured. It is frequently opaque. It may be dissolved in alcohol, spirit of turpentine, and oils, by a peculiar management, (by using camphor, previously melting it, and the like,) and then it forms the various copal varnishes, which are more or less perfect, as the copal is transparent, and the solution properly formed. When heated, it melts like other resins, and in this, and many other properties, it partakes of the character of resins in general. It is used in some of the formulæ for fire-works.

Sect. XXI. Of Myrrh.

Myrrh is obtained from a plant, supposed to belong to the genus *mimosa*, which, as Bruce informs us, (*Travels, &c.*) grows in Abyssinia and Arabia. It is in the form of tears, of a reddish-yellow colour; sometimes transparent, and at other times opaque. It possesses a peculiar odour, and a bitter and aromatic taste. It burns with difficulty, and does not melt when heated. With water, it forms a yellow opaque mixture. It dissolves in alcohol, and the solution is decomposed by the addition of water, the whole becoming opaque. According to Braconnot, myrrh is composed of 23 resin, and 77 gum, in the 100 parts. Pelletier, whose analysis differs from Braconnot's, observes, that, besides resin, it contains some volatile oil, to which, no doubt, its fragrance is owing. The gum, extracted from it, had the character common to all gums, with the exception, that, instead of forming the mucous or saclactic acid, by the action of nitric acid, it produced only oxalic acid.

That myrrh burns with difficulty, is owing entirely to the presence of so much gum, and, comparatively speaking, the small [165] quantity of resin, which enters into its composition. But, notwithstanding this property, as it partakes of a fragrant oil, it is used in some compositions for fire-works. The gummy part may retard, as is sometimes required in particular preparations, the rapidity of the combustion, and therefore have a two-fold effect when employed in fire-works.

Sect. XXII. Of Sugar.

Refined sugar is sometimes used in pyrotechno-mixtures. As it is a vegetable oxide, (composed of carbon, hydrogen, and oxygen), which is decomposed by heat, and has the property of decomposing nitric acid, and some of its combinations; its operation in such mixtures may be readily perceived. We have seen, when treating of chlorate of potassa, that, when this salt and sugar are mixed together, and sulphuric acid poured on the mixture, a rapid combustion ensues, which is owing as well to the decomposition of the sugar, as to that of the salt. The matches, likewise, which inflame by immersion in sulphuric acid, are covered with a similar mixture. That sugar, therefore, has the property of decomposing those salts, which are composed of acids, that have their oxygen but feebly combined, and thereby producing combustion, according to the temperature employed, or other agents made use of, is evident from a variety of experiments. By its action, then, in such cases, the products of combustion, arising from the elementary parts of the sugar alone, uniting with oxygen, must be carbonic acid and water. Sugar, submitted to destructive distillation, affords a variety of new substances; among which we may notice *caromel*, or that peculiar odour, which is recognised in the burning of sugar. Sugar may, therefore, besides assisting in part in the decomposition of saline bodies, and particularly nitre, and perhaps giving rise to new products, with which we are unacquainted, have another effect, that of destroying the offensive smell of other substances, by means of the caromel formed. Sugar, also, when mixed with various bodies, and struck with a hammer, will produce detonations.

Sugar, when used in compositions of fire, should be pure; and it may be known to be so, by producing invariably a phosphorescence in the dark, when two pieces are rubbed together. At a red heat, it bursts into flame with a kind of explosion. This flame is white, with blue edges.

Sugar is obtained from the sugar-cane; from the sap of the sugar-maple; from beets and grapes; and from various other [166] saccharine bodies. It is formed also artificially, by the action of sulphuric acid on starch.

Mr. Kirchoff, a Russian chemist, accidentally discovered that starch may be changed into sugar by diluted sulphuric acid. One hundred parts of starch yield one hundred and ten of sugar. It appears, that, by the abstraction of a little hydrogen and carbon, starch will be converted into sugar. Potatoes, digested with diluted sulphuric acid, Dr. Ure found, would also form sugar, and very abundantly. The sulphuric acid may be removed by the addition of chalk, and, as the sulphate of lime is but slightly soluble, the pure saccharine fluid may be obtained by filtration. The sugar is procured in a solid state by evaporation, and may be clarified like other sugar. Dr. Ure observes, that good beer has been made from starch-sugar, but recommends potato-sugar. To obtain the latter, the potatoes are washed, grated down, and treated with the dilute acid for a day or two, at a temperature of 212°.

The observations of Braconnot are interesting. He has succeeded in converting a variety of vegetable substances into gum and sugar. The conversion of wood into sugar, however remarkable it may seem, has been effected; and a pound weight of rags will, by the same process, make more than a pound weight of sugar. Rice, as it contains a large quantity of fecula, may, we have no doubt, be converted, in the same manner, into saccharine matter.

When sugar is first obtained, it is impure, containing a variety of foreign substances, and more or less brown, as the Muscovado of the West India islands. It is refined, and formed into loaves, by treating its solution in water with bullocks' blood, the serum of which coagulates by heat; and, finally, by pouring the sugar, when sufficiently boiled, into conical earthen moulds, where it concretes. It is clayed, by putting a mixture of white clay and water on the sugar in each of the cones; the water from which passes through, and renders it beautifully white. The same process may be repeated; hence the single and double refined sugar. The molasses passes out from the sugar at the apex of the cone, and is received in vessels.

From twenty to thirty-five per cent. of molasses are separated in the refining of raw sugars; and it is supposed, that a considerable part of it, probably two-thirds, are formed by the high heat used in the concentration of the sirup. In order to prevent so great a quantity of molasses, different plans have been recommended. That of Howard is highly spoken of. It consists in [167] surrounding the sugar-boiler with oil or steam at a high temperature, instead of exposing it, as heretofore, or the mode usually adopted, to the naked fire. The boiler is covered at top, and, by means of an air-pump, the air is exhausted, and the pressure of the atmosphere being removed, ebullition takes place at a lower temperature. No blood is used in Mr. H.'s process, instead of which, the clarification is performed by means of canvass filters, adding previously a pasty mixture of gypsum and alumina, made by saturating a solution of alum with quicklime. He does not employ clay, as is done in whitening the sugar; but, in its place, makes use of very pure saturated sirup. He uses animal charcoal, (bone black), which has the property of destroying vegetable colouring matter. Wilson's process for refining sugar possesses some advantages. It will be found in the 34th volume of the *Repertory of Arts*. The patent filtering apparatus of Sutherland is highly approved.

The chemical properties of sugar are the following: It is very soluble in water, both hot and cold; it forms with water a sirup, which on standing will crystallize, forming the candied sugar. It is not acted upon by oxygen gas. It is capable of combining with, and, according to some chemists, of neutralizing acids and alkalies. It is decomposed by nitric acid with effervescence, being converted into oxalic and malic acids. Tartaric, acetic, and oxalic acids prevent it from crystallizing. It unites with lime and strontian, but is partially decomposed by barytes. It combines also with oxide of lead, which it precipitates from its solution, forming, as it is called, a saccharate of lead. Alcohol has some action on it, and also hydrosulphurets, sulphurets, and phosphurets of alkalies and alkaline earths. On the application of heat, it melts, swells, becomes brownish-black, and exhales a peculiar odour, which we have mentioned, and, at a red heat, takes fire. Lastly, though possessed of some general and specific characters, it differs, in some of its properties, according to the substance from which it is obtained.

Sect. XXIII. Of Sal Prunelle.

This salt is nothing more than nitrate of potassa, melted in a crucible, and poured into moulds, whence it receives the form under which it is found in the shops. The saltpetre, when merely fused, is not decomposed, as it is when exposed to a red heat in an iron retort. In the former case, the water only which it contains is separated; but, in the latter, the salt itself is decomposed, and [168] oxygen gas evolved. Sal prunelle, therefore, is fused saltpetre. Combustible bodies, as charcoal, sulphur, phosphorus, oils, resins, &c. have the same effect on it as on ordinary nitre. The only advantage it has over the common refined saltpetre, in the preparation of some fire-works, is, that it is free from water, and more readily acted on by combustible substances. In preparing it, care must be taken in the application of the heat; which, if too powerful, would, besides fusing it, decompose, and convert it into nitrite of potassa. It may be readily pulverized and sifted. For the properties of *nitre*, see that article.

Sect. XXIV. Of Alcohol.

Alcohol, or rectified spirit of wine, is used for a variety of purposes in pyrotechny, and, when it cannot be procured, strong brandy is substituted. In assisting the pulverization of some substances, as camphor, in forming the mixture of certain pastes, and in acting as a vehicle for the intimate union of some bodies, it is considered a necessary article. Alcohol may be made to form variously coloured flames, by mixing with it certain saline substances. Thus, boracic acid will form a green flame; muriate of strontian, a carmine red; muriate of lime, an orange; nitrate of copper, an emerald green; nitre, common salt, and corrosive sublimate, a yellow, &c. As alcohol has the property of dissolving essential oils, camphor, &c. it may be used as a menstruum for certain oils in the preparation of odoriferous fire-works. See *Articles on coloured flame, and odoriferous fire*.

Alcohol constitutes a part of all ardent spirits, wine, cider, beer, &c. in which it is combined with water, or with water and mucilaginous and colouring matter. It is formed in the vinous fermentation, and always results from the union of carbon and hydrogen. During the process, carbonic acid gas is liberated. Fermented liquors, therefore, or those which have passed through the vinous fermentation, always contain alcohol in more or less abundance, but mixed with water in many instances. In some it is accompanied with water, and saccharine, mucilaginous, and extractive matter. The different kinds of beer is an example of this fact. When liquors, which contain spirit, are submitted to distillation, the product is alcohol and water; for the volatile parts evaporate, and the fixed substances remain in the still. The spirit partakes, more or less, of a peculiar taste and flavour, by which [169] liquors are distinguished from each other. On this subject, however, it will be sufficient to add, that brandy is procured by the distillation of wine; rum, from the fermented juice of the sugar-cane; gin, from fermented grain and juniper-berry; whiskey, from the fermented mash of grain, cider, &c. and, generally, the ardent liquors, from pears, peaches, and other substances, by the same process.

Alcohol, therefore, exists in all these distilled liquors, in a greater or smaller quantity, combined with water; and the proportion it bears to the water is known by a standard, as either proof, above proof, or under proof, according as its strength is shown by the hydrometer.

The process of obtaining alcohol in a pure state, (usually called rectified spirit of wine), by which the water is separated from the alcohol, consists in repeated distillations, either alone, or mixed with certain substances, which have the property of uniting with, and keeping down the water, in the act of distillation. These substances are usually potash, and dry muriate of lime, both of which substances have a great affinity for water. The specific gravity of highly concentrated alcohol, at 60° is .820, but that of common alcohol, only .837, at the same temperature.

The properties of alcohol are the following: It is a transparent liquor of an agreeable flavour, and may be changed in this particular, by essential oils. It may be exposed to a low temperature without freezing. It boils at 106°, when of the specific gravity

.820, and in a vacuum at 56°. It has a strong affinity for water, with which it combines in any proportion; and the specific gravity varies according to the proportion of the mixture and the temperature, on which are founded the tables of Blagden, Gilpin, and others.

Neither common air, nor oxygen, has any action on alcohol at moderate temperatures, whether in a liquid or aeriform state. On hydrogen, carbon, and charcoal, it has little or no action, but on phosphorus it acts, a portion of which it dissolves. With sulphur, it may be made to unite, as also with the alkalies, but not with the earths, except strontian and barytes. It is decomposed by sulphuric and nitric acids, with both of which it forms ether. It dissolves some salts, and has scarcely any effect upon others. Lastly, it dissolves resins and essential oils; but it neither acts upon gums, properly so called, nor on fixed oils. It is a compound of hydrogen, carbon, and a small proportion of oxygen, and may be decomposed, by passing its vapour through an ignited porcelain tube.

Alcohol, by its combustion, as it is used in spirit-lamps for chemical and other purposes, produces no smoke, in consequence of [170] the carbon it contains being totally converted, during that process, into carbonic acid; and its hydrogen, uniting with another portion of the oxygen of the atmospheric air, passes off in the form of aqueous vapour. Alcohol, used in this way, is preferable to oil; for the latter produces a large quantity of smoke, unless it is burnt in the Argand lamp. Alcohol is inflamed, when it is brought in contact with an ignited body. The combustion is rapid without any residue, and the flame white.

As to the strength of alcohol, the best means of determining it, is with the hydrometer; but usually its *proof* is ascertained by means of gunpowder. A portion of powder, put into a cup, and alcohol poured on it and inflamed, will, if the latter be strong, be set on fire; if, however, the powder should not take fire, but the flame of the alcohol be extinguished, we infer the existence of water, and that the alcohol is not of the proper strength. This experiment is founded on this circumstance, that, if the alcohol contains water, after the alcoholic portion is all consumed, the water will not only extinguish the flame, but also prevent the inflammation of the powder. The hydrometer, however, is the best experiment, as it determines at once the fact of the *strength* of the liquor.

Alcohol is used in the preparation of certain fulminating substances, as fulminating mercury and silver in particular; the preparation of which, we will give in the two next sections.

It may not be improper to mention another application of alcohol, that of forming the *aphlogistic lamp*, or lamp that burns without flame. The following description of it, is given by Accum, in his *Chemical Amusements*, Am. Ed. p. 355. "In a common lamp, with a wick of about half a dozen common threads of cotton wick, used for lamps, put some good spirit of wine. Dispose the threads of wick, not intertwined, but straight and parallel to each other. Take platina wire of the thickness of $^{1}/_{100}$th part of an inch; coil it round the wick, about nine coils below, and six coils standing above the top of the wick; the diameter or width of the coils should not be more than $^{3}/_{20}$th, or $^{1}/_{7}$th of an inch wide. Light the wick; and, when the coil of platina above the wick is red-hot, blow out the flame. There will then be a current of pure alcohol, gradually rising from the reservoir below, through the wick, sufficient to keep the upper coil of platina red-hot, until the whole of the alcohol is consumed. This lamp has kept constantly lighted during [171] sixty hours. By means of it, a match, a bit of spunk, or candle may be lighted when wanted. The quantity of alcohol consumed is not much: about an ounce, or an ounce and a half during the night, from bed-time until morning will suffice." This article was added to Accum by Dr. Cooper. A figure of the lamp is in Brande's Chemistry. Dr. Comstock has a paper on the aphlogistic or flameless lamp, in Vol. IV. p. 328, of Silliman's *Journal of Science and Arts*, which contains some judicious and useful remarks. Sir H. Davy (*Journal of the Royal Institution*) has discovered, that the vapour of camphor answers the same purpose as alcohol. If a platinum wire be heated and laid upon camphor, it will continue to glow as long as any remains, and the wire will frequently light it up into flame. Davy found, that, in the slow combustion of alcohol, &c. an acid was generated, to which he gave the name of Lampic acid. Faraday and Daniel (*Journal of Science and the Arts*) have confirmed his conclusions.

Dr. Marcet has proposed a method of producing an intense heat, by causing a current of oxygen gas to pass through the flame of alcohol. The construction of the lamp and gas-holder may be found in the *Archives des Découvertes*, Vol. vii, p. 61.

Sect. XXV. Of Fulminating Mercury.

As the fulminating mercury of Howard consists principally of the oxalate of mercury, the oxalate of this metal may be employed for the same purpose. Oxalic acid does not act on mercury, but dissolves its oxide, and forms with it a white powder. I formed various fulminating metallic powders, (*See Coxe's Medical Museum*), and prepared one in particular by merely digesting a solution of the salt of sorrel (superoxalate of potassa) on red precipitate. The effect is that the oxalic acid unites with the oxide of mercury, and forms an oxalate of mercury, which, when struck with a hammer, produces a detonation. Oxalate of mercury, possessing the same effects, may be formed, very expeditiously, by pouring the oxalate, or the superoxalate of potassa into a solution of nitrate of mercury. The oxalate of mercury will be precipitated, which is to be caught on a filter, washed, and dried in a gentle heat.

Howard's fulminating mercury is less dangerous than either fulminating silver, or fulminating gold. The extreme force of detonation which it possesses is remarkable. The temperature required for its explosion is 360 degrees. Friction, percussion, [172] electricity, and the flint and steel will produce this effect. It gives rise to a stunning disagreeable report, and its force is sufficient to indent both the hammer and the anvil. Four or six grains are sufficient for an experiment. It is rather singular, as Mr. Cruikshank first observed, that this powder will not inflame gunpowder; as may be shown by spreading some of the former on paper, and shaking gunpowder over it, and then firing the mercurial powder. The grains of the gunpowder may be collected entire after the explosion.

From the experiments of Howard, it appears, that this powder is composed of oxalate of mercury, and nitrous etherised gas. Fourcroy, however, has shown, that it varies in its nature, according to the mode of its preparation.

There is also a preparation of mercury, which is likewise explosive, discovered by Fourcroy. This compound may be formed by digesting the red oxide of mercury in liquid ammonia for the space of eight or ten days. The oxide assumes a white colour, and at last appears in crystalline scales. Upon ignited coals, it detonates loudly like fulminating gold, which see below. In a few days, however, it loses its fulminating property, and undergoes spontaneous decomposition. Exposed to a low heat, the ammonia is disengaged, and an oxide of mercury remains.

As ammonia forms several detonating compounds with metallic oxides, the theory of their explosive effects is the same; viz. that, while the hydrogen of the ammonia unites with the oxygen of the oxide, forming water, the azote is disengaged in the state of gas.

The process for preparing Howard's fulminating mercury is the following, dissolve one hundred grains of mercury in an ounce and a half (by measure) of common nitric acid, assisting the solution by heat. When cold, pour the solution upon two ounces (by measure) of strong alcohol, and apply a moderate heat, until the mixture begins to effervesce. A white fume then begins to undulate on the surface of the liquor, and a white powder precipitates, which is the fulminating mercury. This powder is to be immediately washed with cold water, and dried at a heat, not much exceeding that of boiling water. One hundred grains of mercury, will give, on an average, one hundred and twenty-five grains of the powder.

The products of its combustion are carbonic acid gas, azotic gas, water, and mercury. Besides by percussion, it is inflammable when brought in contact with sulphuric acid. It is supposed, that fulminating mercury sometimes contains ammonia, and that the [173] products of combustion, according to the mode of preparation, are therefore different. The reader may consult some interesting observations on this powder in the *Journal de l'Ecole Polytechnique*.

M. Bayen, an apothecary, in 1779, (*Journal de Physique*), announced a process for preparing fulminating mercury. His process, however, is different from that described. A solution of mercury is made in nitric acid, and precipitated by caustic alkali. The precipitate (oxide of mercury) is then caught on a filter, washed, and dried. Thirty grains of this powder, mixed with four or five grains of sulphur, and struck with a heavy hammer, or heated on an iron, will explode with violence. The oxide of mercury, obtained from its solution by lime-water, has the same effect, when treated in the same manner. Another process recommended is, to precipitate a solution of the perchloride of mercury (corrosive sublimate) by lime-water, and treat the precipitate with sulphur, as above described.

Sect. XXVI. Of Fulminating Silver.

This compound, which is more powerful than fulminating mercury, is prepared also with alcohol. Descostils (*Annales de Chimie*, LXII. p. 198,) Cruikshank, and Brugnatelli, have all written upon it.

Fulminating silver explodes without much heat. By the slightest friction it is inflamed, and detonation follows. Hence it is used in the form of toys, in fulminating balls, bombs, crackers, &c. which explode by falling on the ground. Torpedoes, pulling crackers, &c. are formed of this powder. The fulminating balls are made of glass, and contain a grain or two of fulminating silver, mixed with sand. The same mixture, put on the ends of two strips of paper, and the ends pasted, forms the pulling crackers; for the moment they are pulled asunder, the friction produced sets the fulminating silver on fire, and causes a detonation.

The same preparation placed on a wafer, and the wafer put between paper, as in the sealing of a letter, will explode, when the paper or the wafer is broken. Fulminating bombs are balls of the size of a hazle nut, containing about three grains of the fulminating silver. Their explosive effects are said to be violent. See *Detonating Works.*

This powder, in consequence of its powerful action, is dangerous; and, as it explodes so readily, it should never be put into a [174] phial, nor should it be touched or handled in any way that can produce friction. Even when made to approach the flame of a candle, it will explode with extreme violence.

The preparation of Brugnatelli's fulminating silver consists in reducing 100 grains of nitrate of silver (lunar caustic) to powder; and, when put into a basin, pouring over it one ounce of alcohol, and the same quantity of nitric acid. The mixture will become hot, effervescence will ensue, while the whole will assume an opaque or milky appearance.

When the gray powder of the nitrate has become white, and the mixture acquires consistency, distilled water is to be added, to suspend the action. The white precipitate is then to be washed by repeated affusions of cold water, and dried in the open air, but in a dark place, so as to seclude it from the light.

In fact, this process is similar to that for preparing fulminating mercury; for it is nothing more than treating silver with nitric acid and alcohol. Cruikshank employs forty parts of silver, sixty parts of nitric acid, and sixty parts of alcohol, from which sixty parts of the powder are obtained.

Berthollet considers this powder to be composed of ammonia, and oxide of silver, and the theory of its detonation to be the same as that of fulminating gold. In its explosion, the oxygen of the oxide of silver unites with the hydrogen of the ammonia, and the nitrogen is disengaged.

Berthollet's fulminating silver, which he discovered in 1788, is another preparation, which fulminates powerfully. It is prepared by precipitating nitrate of silver by lime-water. The precipitate is placed on filtering paper, which absorbs the water, and the nitrate of lime. Pure caustic ammonia is then added, which produces an effect somewhat similar to that attending the slaking of lime. The ammonia dissolves only a part of this precipitate. It is left at rest for ten or twelve hours, and at the expiration of this time, there is formed, on the surface, a shining pellicle, which is re-dissolved with a new portion of ammonia, but which does not appear, if a sufficient quantity of ammonia has been added at the first. The liquid is then separated, and the black precipitate, found at the bottom, is put, in small quantities, on separate papers. This powder explodes even when moist, if struck with a hard body. When dry, the slightest friction will explode it. Its detonation is owing to the same cause as that producing the explosion of the other preparation of this metal, as it is also composed of oxide of silver and ammonia.

The fulminating silver of Chenevix explodes only by a slight friction in contact with combustible substances. It is nothing more [175] than chlorate of silver. It is formed by passing chlorine gas through alumina, diffused in water, and afterwards digesting, in the liquor, some phosphate of silver. The whole is to be evaporated slowly. A single grain of this powder, with three grains of sulphur, will explode by the slightest friction.

For the preparation of fulminating silver, the formula given by professor Silliman of Yale College, appears to possess some advantages. To an ounce of alcohol and as much nitric acid, he adds 100 grains of pulverized lunar caustic. A gentle heat is applied to excite the action between them, which must be removed, the moment they begin to act. When a thick white precipitate appears, cold water must be added to check the action. The precipitate is then to be collected, washed, and carefully dried. A grain or two will explode over a candle.

Sect. XXVII. Of Fulminating Gold.

The preparation, called by some aurate of ammonia, is formed by dissolving gold in nitromuriatic acid, diluting the solution with water, and adding gradually liquid ammonia, until the precipitation ceases. The precipitate is then to be caught on a filter, well washed with water, and dried in the air. The fulminating gold, thus produced, exceeds the weight of the original gold employed by thirty-three per cent.

Three or four grains of this powder, heated on a knife, will explode with a loud report. The temperature required for its explosion is between 230° and 300°. Ten or twelve grains will penetrate a copper-plate, of the thickness of a playing card. The facility with which this powder explodes, is increased by drying. If it be heated until it becomes black, the slightest touch will cause a detonation. This powder is composed of oxide of gold, ammonia, and a portion of chlorine; and, during its detonation, water, nitrogen and chlorine are evolved, the gold being revived.

The presence of ammonia is necessary to give to gold the property of fulminating. Fulminating gold accordingly loses this property, the moment the ammonia is separated. Concentrated sulphuric acid, melted sulphur, fat oils, and ether have this effect.

The discoverer of fulminating gold was a German Benedictine Monk, who lived about the year 1413. Basil Valentine has described the preparation of it very accurately. He recommends, however, mixing sal ammoniac with aqua fortis, the old mode of [176] making aqua regia, and distilling the mixture; then putting in the gold in leaf. After the acid is saturated, he adds *oleum tartari*, or *sal tartari* (carbonate of potassa) dissolved in water; and the precipitated *calx*, thus obtained, when collected, washed, and dried in the open air, will fulminate. In this process, it is evident, that the aqua regia, prepared with sal ammoniac, contains ammonia, and, when the gold is dissolved, and the potash added, the oxide of gold separates, and, from the composition of the powder, must combine with a portion of ammonia, and hence produce fulminating gold. He remarks, that distilled vinegar digested on fulminating gold, destroys its fulminating properties, and observes also, that care must be taken to prevent its explosion. He also knew that sulphur would have the same effect.

Bergman (*Treatise on Pulvis Fulminans*) describes the process employed by Valentine; and Beckman (*History of Inventions*, v. iii. p. 132,) observes, that, after the time of Valentine, Crollius, who lived in the last half of the 16th century, was well acquainted with fulminating gold, and made its preparation more generally known. In the *Oswaldi Crollii Basilica Chymica*, 4to, p. 211, published at Frankfort, in 1609, the process is also to be found. He calls it *aurum volatile*, and speaks of its being useful in medicine. Beguin, however, appears to have given it the appellation of *aurum fulminans*, if we judge from his *Tyrocinium Chymicum*, 12mo, printed in 1608.

Sect. XXVIII. Of Fulminating Platinum.

While noticing explosive compounds, it may not be improper to mention that of platinum, lately discovered by Mr. E. Davy. It explodes, when heated to 400 degrees, with a sharp report, similar to that produced by fulminating gold; but neither friction nor percussion will decompose it. It is formed by making a solution of platinum in nitromuriatic acid, and passing through it, sulphuretted hydrogen gas, until no further precipitation ensues. This precipitate, when collected, and digested in nitric acid, is converted into sulphate of platinum. This is dissolved in water, and liquid ammonia then added. The precipitate, now formed, is washed, and boiled in a solution of potassa, and, after having freed it from the adhering potassa, is suffered to dry. All fulminating ammoniacal compounds are analogous; and fulminating platinum, being composed of oxide of platinum, ammonia, and water, is [177] decomposed in the same manner as these compounds.

Fulminating platinum is composed as follows:

Peroxide of platinum	82.5	*nearly* 2 primes.
Ammonia	9.0	1 ——
Water	8.5	2 ——

Sect. XXIX. Of Detonating Powder from Indigo.

That indigo produces a detonating powder by treating it with nitric acid, is evident from experiment. As it produces a *purple* light, it might, perhaps, be used advantageously in small fire-works.

The process described by Dr. Thomson, (*System of Chemistry*, VOL. IV. p. 80, *Amer. edit.*) is to boil one part of indigo in four parts of nitric acid. The solution will become yellow, and a resinous matter appear upon its surface. The boiling is to be stopt, and the liquor cooled. The resinous matter is then to be separated; and the solution evaporated to the consistence of honey. This is to be re-dissolved in hot water, and filtered, and a solution of potassa added, which will throw down yellow spicular crystals, consisting of *bitter principle*, combined with potassa. When the resin is again treated with nitric acid, the same bitter principle is produced. The spicular crystals, when wrapped up in paper, and struck with a hammer, detonate with a purple light.

Sect. XXX. Of the Fulminating Compound, called Iodide of Azote.

Iodine is a particular substance, which has the property not only of combining with oxygen and hydrogen, forming iodic and hydriodic acid, but also with various bases constituting a class of bodies, called iodides. Its union with azote produces a singular substance, which detonates with great violence, when slightly touched or heated. It may be formed, by putting a quantity of iodine into the water of ammonia. It will be gradually converted into a brownish-black matter, which is the iodide of azote. It is formed in this process by the iodine, in the first instance, decomposing a part of the ammonia; the hydrogen of which combines with a portion of the iodine, and produces hydriodic acid, which then unites with the undecomposed part of the ammonia, and forms the [178] hydriodate of ammonia; whilst the azote the other constituent of the ammonia, unites with another portion of the iodine, and forms the compound in question.

When exposed to the air, iodide of azote gradually flies off in vapour, without leaving any residue. The products of its detonation are iodine and azotic gas.

The iodide of azote was discovered by M. Courtois, and subsequently examined by M. Colin. Iodine, brought in contact with ammoniacal gas, a combination taking place, produces a viscid shining liquid of a brownish-black colour, which, as the saturation goes on, loses its lustre.

This liquid does not detonate, and is considered to be an iodide of ammonia; but, when it is added to water, it is decomposed, as well as the water, and we obtain two new compounds, as before observed, the hydriodate of ammonia, and iodide of azote. This iodide detonates. Hence it is evident, that hydrogen united with azote, in ammonia, prevents explosion; for the moment it is taken away, by the formation of hydriodic acid, and the azote itself combines with the iodine, a fulminating compound is formed. The elements of this powder are feebly united.

It is found, that hydriodate of ammonia has the property of dissolving a large quantity of iodine, and, if suffered to remain with the iodide of azote, of decomposing it also, and setting the azote at liberty. Water is said to have the same effect, although feebly.

Iodate of potassa, a salt composed of iodic acid and potassa, when mixed with sulphur, and struck with a hammer, will detonate, in consequence of the decomposition of the iodic acid. The iodate of potassa may be formed very readily by agitating iodine with a solution of caustic potassa. The water is decomposed, and the hydriodate of potassa is also formed, which, being very soluble, remains in solution, whilst the iodate separates, on concentrating the liquor, and suffering it to stand.

Chlorate, as well as nitrate of silver, form with sulphur fulminating powders.

Iodic acid, called also oxy-iodine, (prepared by exposing iodine to the action of euchlorine,) when heated in contact with inflammable substances, and the more combustible metals, will produce detonations.

It appears, however, that sulphur has a stronger affinity for oxygen than iodine has, and iodine a stronger affinity than chlorine for the same element. Hence chloric acid is more readily decomposed by inflammable bodies than iodic acid, and iodic acid, sooner [179] than sulphuric acid.

The acids, which chlorine, iodine, and sulphur form respectively with oxygen, Gay-Lussac remarks, have their elements more strongly *condensed*, than the same substances united with hydrogen.

Sect. XXXI. Of Detonating Oil, or Chloride of Azote.

This oil is produced by the action of chlorine on ammonia, by using some of the salts of this alkali. A small jar of chlorine gas is transferred into a basin, containing a solution of nitrate or muriate of ammonia, a little heated: an absorption will gradually take place, and the gas be condensed. An *oily film* will now appear on the surface of the ammoniacal solution, which, as it increases, will form globules and fall through the liquor. This substance is the detonating oil, composed, according to analysis, of chlorine, azote, and hydrogen. It is supposed by Messrs. Wilson, Porret, and Kirk, that the hydrogen serves as a medium of union between the chlorine and azote, and that, in detonation, the powerful effect is owing to the chlorine.

Detonating oil explodes violently at 212 degrees; and even when touched with cold inflammable substances, as a portion of olive oil, about the size of a pin's head, the detonation is also violent, and the vessel, in which the experiment is made, will, in most cases, be broken into fragments.

Detonating oil is considered, however, a chloride of azote. In order to prevent the decomposition of the chloride by the ammoniacal salt, a thin stratum of muriate of soda, put into the bottom of the vessel, is recommended. Its specific gravity is 1.653. Warm water, put into a vessel containing it, will change it to an aeriform fluid of an orange colour. "I attempted," says Sir H. Davy, "to collect the products of the new substances, by applying the heat of a spirit-lamp to a globule of it, confined in a curved glass tube over water: a little gas was at first extricated; but, long before the water had attained the temperature of ebullition, a violent flash of light was perceived, with a sharp report; the tube and glass were broken into small fragments, and I received a severe wound in the transparent cornea of the eye, which has produced a considerable inflammation of the eye, and obliges me to make this communication by an amanuensis. This experiment proves what *extreme* caution is necessary in operating on this substance; for the quantity I used was scarcely as large as a grain of mustard seed." *Phil. Trans.* 1813, Part I.

In *vacuo*, it expands into vapour, which still possesses the power of exploding by heat. In water, it gradually disappears, the [180] water becoming acid, and azote being evolved. Mercury decomposes it, and a white powder (calomel) is formed, while the azote is set at liberty.

Dr. Ure (*Chemical Dictionary*, Art. *Nitrogen*,) observes, that the mechanical force of this compound, seems superior to that of any other known substance, not even excepting the ammoniacal fulminating silver. The velocity of its action appears to be likewise greater.

The Doctor touched a minute globule of it, in a platina spoon, resting on a table, with a fragment of phosphorus at the point of a pen-knife, and the blade was instantly shivered into fragments by the explosion.

Messrs. Porret, Wilson, and Kirk (*Nicholson's Journal*, Vol. XXXIV,) employed 125 different substances, by bringing them in contact; and out of that number the following caused it to explode:

Supersulphuretted hydrogen,	Sulphuretted oil,
Phosphorus,	Oil of Turpentine,
Phosphuret of lime,	---- Tar,
Phosphuretted camphor,	---- Amber,
Camphoretted oil,	---- Petroleum,
Phosphuretted hydrogen gas,	---- Orange peel,
Caoutchouc,	Naphtha,
Myrrh,	Soap of silver,
Palm oil,	---- Mercury,
Ambergris,	---- Copper,
Whale oil,	---- Lead,
Linseed oil,	---- Manganese,
Aqueous ammonia,	Fused Potassa,
Olive oil,	Nitrous gas.

See *Detonating Works.*

According to Mr. Davy, chloride of azote contains

4 vols. of chlorine	= 10 +	or	4 primes	= 18.0 +
1 —— azote	= 0.9722		1 ——	= 1.75,

or very nearly 10 by weight of chlorine to 1 of azote.

Sect. XXXII. Of Pyrophorus.

Pyrophorus is a black substance, which takes fire spontaneously, when brought into contact with air. It is the luft-zunder, or air-tinder of the Germans. It first emits sulphuretted hydrogen gas, and in a few seconds becomes red-hot, burning with a bluish flame. Pyrophorus consists of alumina, charcoal, and sulphuret of potassa, and also, according to some, of potassium, which is [181] alleged to be formed in its preparation. Be this as it may, it seems, that water is decomposed in its combustion, that sulphuretted hydrogen gas is emitted, which is inflamed by the oxygen gas of the atmosphere, and that, during the combination of oxygen, a degree of heat is produced, which causes the ignition of the charcoal, as well as the inflammation of the remaining sulphur.

Pyrophorus may be formed in several ways, all of which produce the same result. The usual process is the following: Take equal parts of brown sugar and alum, and melt them in a ladle. Continue the heat, stirring them constantly until a spongy black mass is formed. Let this mass be reduced at once to powder, and introduced into a common green glass phial, of the capacity of about six ounces, previously coated outside with a mixture of pipe-clay and solution of borax. Immerse the phial in a crucible, filled with sand, closing the mouth of the former with a piece of charcoal, or a glass tube inserted in it. Upon the crucible being exposed to a red heat, an inflammable gas will escape, which will take fire.[21] When this effect ensues, the heat must be continued for about twenty minutes longer, at the expiration of which time, the crucible must be removed from the fire, and the phial taken out and closely stopt. The pyrophorus is to be preserved in a ground stoppered bottle. The addition of one-sixteenth part of sulphate of soda, or Glauber's salt, to the alum and sugar, is said to make the pyrophorus with more certainty. Various vegetable substances, besides sugar, as flour, starch, &c. may be used. Three parts of alum, and one part of wheat flour will make a good pyrophorus.

Homberg discovered this substance, in the year 1680. Hence it is sometimes called Homberg's pyrophorus. He was operating upon a mixture of human excrement and alum; and, when he examined the contents of his vessel, in three or four days after, he was surprised to see it take fire spontaneously, when brought to the air. Soon after Lemery, the younger, discovered, that honey, sugar, flour, or almost any animal or vegetable matter, could be used in lieu of human fæces; and, as Macquer informs us, M. Lejoy de Suvigny showed, that other salts, containing sulphuric acid, may be substituted for alum. Mr. Scheele (*Treatise on fire*, &c.) found by experiment, that, when alum was deprived of potassa, it was incapable of forming pyrophorus, and that vitriolated [182]
tartar (sulphate of potassa) may be used in the place of alum. The experiments of Mr. Proust prove, that a number of neutral salts, composed of vegetable acids and earths, when submitted to heat, leave a residuum that inflames spontaneously. This statement agrees with the experiments of M. Chenevix. From the experiments and observations of sir H. Davy, and Dr. J. R. Coxe, late professor of chemistry, but now of materia medica, &c. in the University of Pennsylvania, it is rendered very probable, that pyrophorus owes its property of inflaming spontaneously to a small portion of potassium, which is formed in the process.

The preparation of pyrophorus is explained on the principle, that the vegetable matter is first decomposed; that the hydrogen and a part of the carbon decompose the sulphuric acid of the alum, by uniting with its oxygen; that water, carbonic oxide, and carburetted hydrogen are disengaged, along with a part of the sulphur; and that, while the excess of charcoal remains intimately mixed or divided with the alumina, the sulphur and the sulphuret of potassa, form together a compound, which has the property of inflaming spontaneously in the open air. Some suppose, as alum is a triple salt, having potassa, as well as alumina, for its base, that the potassa is decomposed in the process, and potassium, as we remarked, produced; to the presence of which they ascribe the singular property of inflaming in the open air.

The spontaneous combustion of charcoal, in several instances, is supposed by some to have been owing to the presence of pyrophorus, by others to phosphorus, and by others again to nascent hydrogen. To the presence of this substance, is attributed the explosion of gunpowder mills. (See *Gunpowder.*)

Several different mixtures, and torrefied substances, form a kind of imperfect pyrophori, and have more than once occasioned fires, from no suspicion of their properties being entertained.

Besides pyrophorus, other compositions, which, in like manner, take fire on exposure to the open air, have been by degrees made known to us: 1. The scoria of the martial regulus of antimony, or antimony freed from sulphur by the intervention of iron and nitre, as well crude as also after being dissolved, have been observed to take fire spontaneously, when laid upon a hot stone, or in the sun. Of the truth of the latter case, Wiegleb says, he is assured by his own experience. 2. The residuum of the acetate of copper is another pyrophorus. 3. Some assert, that they have observed an inflammation ensue from honey and flour, calcined [183]
according to the rules laid down. 4. According to Geoffroy, a calcined mass of three parts of black soap, and one of diaphoretic antimony, has been known to take fire spontaneously. 5. Meuder has observed, that a pyrophorus is obtained, when equal parts of orpiment and iron-filings are sublimed together, and ten parts of this sublimate are triturated in a mortar along with twelve of nitrate of silver. 6. A pyrophorus is produced, according to Penzky, when two drachms of white sand, three of common salt, one of sulphur, two of sulphuric acid, and half an ounce of muriatic, are mixed together and distilled in a glass retort. In this operation, a sublimate is said to be obtained, which bursts out in flames, as soon as it comes into contact with the air. 7. The spontaneous precipitate of osteocolla, from a solution of it in sulphuric acid, after having been separated by means of a filter, and dried, took fire in a warm place. S. Pott observed the same phenomenon in the earth of the residuum, after the distillation of urine, that had been putrid for a considerable time. 9. To these may also be referred, a mass composed of equal parts of sulphur and iron-filings; which, when thoroughly moistened with water, after some time, grows hot, swells, and at last breaks out into vapour, smoke, and flame. (See *Artificial Volcano.*)

Cadet's fuming liquor, prepared by distilling equal parts of acetate of potassa, and arsenious acid, emits a very dense, heavy, fetid, noxious vapour, which inflames spontaneously in the open air. Black wadd, an ore of manganese, when dried by the fire, and mixed with linseed oil, gradually becomes hot, swells, and then bursts into flame.

M. Chenevix (*Annales de Chimie*, tom. LXIX,) remarks that almost all the metallic residuums, which are formed by the distillation of acetates *per se*, are pyrophoric, after cooling; which Mr. C. attributes to the presence of finely divided charcoal, mixed with the metallic part. He experimented on several acetates, with the view of ascertaining the quantity of pyroacetic spirit they would yield, and found, in every instance, that charcoal existed in the residue, sometimes with reduced metal, and at other times with metallic oxide. A table of these experiments may be seen in Ure's *Chemical Dictionary*. The residuum of acetate of copper has long been known to possess pyrophoric properties.

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Sect. XXXIII. Of Sal Ammoniac.

This salt enters into the composition of fire-works, to give, more particularly, a peculiar colour to flame, which is that of green, or yellowish-green. Sal ammoniac is a salt, composed of muriatic acid and ammonia, and, when pure, is white, and capable of being sublimed without decomposition. Its purity may be known by its complete volatilization. It is readily pulverized.

The experiment, showing the formation of sal ammoniac by a direct union of its component parts, may be made by bringing in contact, in a glass receiver, muriatic acid gas and ammoniacal gas. White clouds will form, a condensation take place, and muriate of ammonia be deposited on the sides of the vessel.

Sal ammoniac was altogether made, at one period, from the soot of camels' dung, or of other animals, which feed on saline plants. The excrement was burnt, the soot collected, and sublimed. This was the process practised in Egypt. The composition of sal ammoniac being known, the process for obtaining it was improved; so that, instead of using the soot of dung, it is now formed by the distillation of bones. The impure ammoniacal liquor, thus obtained, is combined with sulphuric acid, by an easy process, and the resulting sulphate of ammonia is then decomposed by muriate of soda, by which sulphate of soda and muriate of ammonia are produced. They are separated, and the latter is formed into heads by sublimation. In this state, it occurs in commerce. It was made in great quantity in the vicinity of the temple of Jupiter Ammon; and hence its name.

Mr. Minish, according to the English writers, is entitled to this method of converting impure liquid ammonia into sal ammoniac. The following is an outline of his process. He suffered the impure ammoniacal liquor to percolate through a stratum of bruised gypsum, and as carbonate of ammonia is contained in the liquor, the fluid, which filters, would contain sulphate of ammonia, the carbonate of lime being insoluble. This sulphate he evaporated, and the dry mass, mixed with muriate of soda, was sublimed. If I am not greatly mistaken, however, although I have not the work to refer to, this process is described in Dr. John Pennington's *Chemical Essays*, a work published in Philadelphia, about 1792. Dr. Pennington's work, we may observe, is the first chemical book which was published in the United States, and contains numerous important facts and observations. That this process was known [185]
in Philadelphia, and used at the *Globe works*, or rather *Glaub works*, (from the circumstance that Glauber's salt was made there,) is within the recollection of many. I heard the late professor Wistar speak of this process, and of the economy in using gypsum.

Mr. Lebanc (*Annales de Chimie*, vol. XIX.) invented a process, by which he brought the ammoniacal gas and muriatic acid gas in contact, in a chamber lined with lead. In one pot, he put common salt and oil of vitriol; in another pot, animal matter. Being conducted by pipes into the chamber, the gases united, and sal ammoniac was formed. Other improvements have been made, as obtaining ammonia from coal soot, &c.

Ammonia is generated in artificial nitre beds, and is at first united with nitric acid; which compound is subsequently decomposed, as the process of putrefaction goes on, by the potassa, calcareous earth, &c. present in nitre beds. *See Nitrate of Potassa.*

Sal ammoniac is ready formed in the soot of animal feces, twenty-six pounds of which yield six of the salt. According to Siccard, who published, in 1716, an account of the fabrication of sal ammoniac in Egypt, which Geoffroy, in the same year, proved to be a compound of the spirit of sea salt and volatile alkali, sea salt and urine were used in that country. The account, however, given by Lemery, in 1719, makes no mention of either sea salt or urine.

Sal ammoniac is found native. It occurs in the vicinity of burning beds of coal, both in Scotland and England, and is met with in volcanic countries. When triturated with quicklime, it exhales ammonia, which is a characteristic of all ammoniacal salts.

Sal ammoniac is often found in crusts of lava. Sir William Hamilton observes, that, in the fissures formed by the lava, this salt sublimes. He found, in the same locality, common salt.

Sal ammoniac is decomposed by a variety of substances. Sulphuric acid will disengage the muriatic acid from it, while lime, potassa, &c. liberates the ammoniacal gas, which, when combined with water by distillation or other means, forms the common spirit of sal ammoniac, or water of ammonia. Mixed with carbonate of lime and sublimed, it produces the carbonate of ammonia, usually called mild volatile alkali, or pungent smelling salts. Ammonia, in a separate state, unites with some metallic oxides, giving rise to certain fulminating powders, which have been already noticed. That iodine decomposes ammonia, we have shown, when on [186]
the preparation of iodide of azote, or fulminating powder.

Sal ammoniac enters into the composition of candles, to prolong their duration. The process recommended in the *Archives des Découvertes* is the following: Dissolve, in half a pint of water, a quarter of an ounce of sal ammoniac, two ounces of common salt, and half an ounce of saltpetre, and add the solution to three pounds of mutton tallow, and eight pounds of beef tallow, previously melted. Continue the heat until all the water is evaporated. It is then suffered to cool, and, when used, is to be melted with a quarter of an ounce of nitre, and formed into candles in the usual manner. This preparation of tallow is highly recommended on account of its economy, as well as the improvement itself. A candle, made of this tallow, will burn two hours longer than one of the ordinary kind.

Another process for making candles, in which sal ammoniac is used, is mentioned in the *Annales des Arts et Manufactures, Nos. 142 and 146*. Eight pounds of suet are melted, and a pint of water is added. The tallow is again submitted to heat, and the same quantity of water, holding in solution half an ounce of saltpetre, half an ounce of sal ammoniac, and one ounce of alum, is added. It is then suffered to stand, and when used is re-melted. The wick is first dipped in a mixture of camphor and wax. Care must be taken, before the tallow is used, to evaporate the water. Equal parts of beef and mutton tallow are recommended.

Sect. XXXIV. Of Corrosive Sublimate.

Corrosive sublimate, known in chemistry by the names of corrosive muriate, and perchloride of mercury, is made use of in some preparations of fire-works, and particularly in the composition of stars, in which it is mixed with a variety of substances, such as steel filings and antimony, in order to vary the appearance of the flame, and to communicate to it particular colours. Corrosive sublimate is formed by various processes, among which we may enumerate the following: Take five parts of sulphuric acid, four parts of mercury, four parts of muriate of soda, and one part of black oxide of manganese. Boil the mercury in the sulphuric acid, until it forms a dry sulphate, which is to be reduced to five parts. Mix the sulphate thus formed, with the muriate of soda, previously dried, and the oxide of manganese, and sublime the mixture. By this process the sulphuric acid of the sulphate unites with the soda, and forms sulphate of soda; while the muriatic acid of the muriate of soda combines with the oxide of mercury, [187]
(which receives an addition of oxygen from the oxide of manganese,) and forms the perchloride, called by Thenard the deutochloride of mercury. The same process is used without the addition of manganese. By exposure to heat, the sublimate sublimes, and the sulphate of soda forms the residuum. The same salt, if re-sublimed with an addition of crude mercury, will be changed into the protochloride of mercury, or calomel. Or, if the sulphate of mercury and muriate of soda be mixed with crude mercury, and sublimed, calomel will be formed at one operation. It is sufficient to observe, that corrosive sublimate is one of the most virulent of poisons when swallowed; and therefore should be used with caution.

It is soluble in water, and capable of crystallizing. It is also soluble in alcohol, to the flame of which it communicates a yellow colour, and in sulphuric, nitric, and muriatic acids. It is decomposed by alkalies, forming with ammonia a triple salt, (*Sal Alembroth*,) by the alkaline earths, and the metals or their sulphurets; and, when distilled with arsenic, bismuth, antimony, or tin, the mercury is separated.

The proper antidote for corrosive sublimate, is the white of egg or albumen, which converts it into calomel. Sulphuretted hydrogen water may also be employed along with emetics. The effect of albumen, in this way, may be relied on.

Sect. XXXV. Of Orpiment.

Orpiment, or the yellow sulphuret of arsenic, which is either native or artificial, is principally used in fire-works for the composition of stars. Orpiment is divided by some into two kinds; viz. the red, called realgar, and the yellow, called yellow arsenic.

Arsenic combines readily with sulphur. When they are mixed together, and put into a crucible and fused, the product will be a red vitreous mass. This red sulphuret may also be formed, by melting sulphur with arsenious, or arsenic acid. Sulphurous acid gas will be evolved, evidently showing that a portion of the sulphur unites with the oxygen of acid employed.

When arsenious acid, known in commerce by the name of white arsenic, and called by some oxide of arsenic, is dissolved in muriatic acid, and a solution of sulphuretted hydrogen in water is added, a yellow precipitate will be obtained which is orpiment. [188]
The hydrogen, in this case, unites with the oxygen of the arsenious acid, by which the metal is reduced, and the sulphur then combines with it. A mixture of sulphur and arsenic, exposed to a heat not sufficient to melt them, will sublime into a yellow sulphuret.

Both the yellow and red sulphurets are employed in fire-works. They are not, however, required, except in particular cases. In the composition of Bengal lights, given in the Bombardier or Pocket Gunner, by R. W. Adye, orpiment is used. According to the same author, it is also used in Chinese white lights. Both the yellow and red sulphuret of arsenic will detonate with chlorate of potassa.

Sect. XXXVI. Of Antimony.

The antimony, which enters into the composition of many fire-works, is not to be understood to be the metallic, or regulus of, antimony, unless so expressed; but the crude antimony of the shops. Crude antimony is a combination of antimony and sulphur, and is usually met with in fine powder. That both antimony and its sulphuret have a powerful effect in modifying the flame of gunpowder, and all compositions, in which nitre and inflammable substances form a part, is evident from the many cases, in which it is employed, and from the effects that thereby result.

The different substances in any inflammable compound, intended to produce particular colours, should be so mixed, as that, from a knowledge of the proportions which produce such colours, the *effect* may be retained, even when it is mixed with other bodies. For this reason, the artist should know the different effect of each ingredient. Some may show themselves in the flame, some in sparks, some in stars, others in fire-rain, and the like, as the case may be. Antimony, for instance, produces a reddish flame, if it be in a proper proportion, and not altered by the presence of other substances. Hence, when antimony is mixed with nitre, the flame will be more or less a *whitish-green*.

This modification, or change in the appearance of flame, is apparent in certain compounds, of which antimony constitutes a part. Thus, antimony is used in the preparation of the common rocket stars, in drove stars, in the fixed pointed stars, in some of the gold and silver rains, in the slow and dead fire for wheels, in tourbillons for crowns or globes, in the composition of serpents, lances for illumination, Bengal lights, and many other kinds of fire-works. According to Adye, (Pocket Gunner,) it enters into the composition [189]
of carcasses, Chinese lights, &c.

When it is as one to sixteen of nitre, the gunpowder being as four, and the sulphur, eight, the composition will produce a white flame; but when it is in the proportion of eight to sixteen of nitre, without any addition, the flame will be blue. By substituting, in its place, eight of amber to sixteen of nitre, with sixteen of sulphur, and eight of meal powder, this change will produce a yellow flame. It is obvious, however, that these and similar changes are owing to the proportions, as well as to the substances used.

Antimony, in the state of a sulphuret, when mixed with chlorate of potassa, &c. will form detonating compounds.

Antimony is a grayish-white metal, more or less brilliant and laminated. It is brittle, and may be easily reduced to powder. It melts at a red heat, and evaporates at a higher temperature: on cooling, it crystallizes. It undergoes no change by exposure to the air, except the loss of its lustre. When steam is made to pass over ignited antimony, the decomposition of the water is so rapid, as to produce a violent detonation. At a white heat, it burns, and forms a white coloured oxide, called the *argentine flowers of antimony*. Its oxides are various, some of which, possessing acid properties, are called acids. The protoxide is gray, the antimonious acid, white, and antimonic acid, of a straw colour. The crocus of antimony, and the glass of antimony are oxides of this metal, but in particular states of combination. It unites with several of the acids. Its oxide, with tartaric acid, and tartrate of potassa, forms *tartar emetic*. With chlorine, it constitutes the butter of antimony.

The artificial sulphuret may be formed, by melting sulphur and antimony together. The native sulphuret is almost the only ore of antimony, and is the mineral from which the regulus is obtained. It unites with the metals, forming alloys of different kinds.

Sect. XXXVII. Of Carbonate of Potassa.

Potassa, either pure or carbonated, retards the progress of combustion; and, therefore, may prevent, according to the proportion employed, the action of combustible bodies on nitre. Combustion may be retarded by using those substances, which are not in themselves inflammable, and which, if used in too large a quantity, would effectually prevent it. Clay, wood ashes, &c. as in the [190] blind fuse, act on this principle; and serve, also, in particular cases, to produce that succession of explosions, which renders the effect of some fire-works, more grand and impressive. Rope, soaked in a solution of saltpetre and dried, would burn rapidly, were it not for the after immersion in potash ley, or urine, either of which acts by retarding the progress of combustion. The same thing may be said of other bodies, the use of which will claim our attention hereafter. Potassa, although not generally used for the purposes mentioned, as it is apt to deliquesce, or absorb water, and thus destroy the effect altogether, may be more advantageously employed in a liquid state, as in the preparation of slow match in the way stated under that head. But as match rope is now generally superseded by the port-fire, as a more certain method of firing cannon, it would be unnecessary, as it is irrelevant, to enlarge on this head. The use, also, of the priming fuse, which conveys the fire to the powder in the gun, with certainty and with rapidity, is an improvement of no small moment.

Alum has also been used for the purpose of checking the rapidity of combustion, in some particular fire-works. In one of the formulæ for the preparation of *fire-balls*, to be thrown with the hand, or fired from a gun, given in the *Memoir on Military Fire-works*, as taught at Strasburg, in 1764, there is, besides sulphur, mutton suet, saltpetre, and antimony, *nitre of alum*, equal to one-fourth of the weight of the compound. That this salt, the supersulphate of alumina and potassa, is used to make paper, as cartridge paper, &c. incombustible, is a fact, with which every one is acquainted.

We might, also, enumerate the uses of glue, isinglass, gum arabic, &c. for similar purposes; and also of wood-ashes, in the composition of the, so called, blind fuse. Light twisted white rope, when soaked in strong ley, or a strong solution of potash, we are informed, will form a slow match that will burn only three feet in six hours.

Potash is obtained from wood-ashes, by lixiviation with water, and evaporation. It contains more or less impurities; and always carbonic acid, from which it is separated by quicklime, the alkali being rendered caustic. Some of the foreign ingredients are burnt off by exposing it to heat in an oven. It then assumes a white, somewhat *pearly* appearance, and takes the name of pearl-ash, but is still the same alkali.

Wood-ashes, when mixed with quicklime, and lixiviated, produce caustic ley, the strength of which depends on the quantity of [191]
alkali held in solution. It is this ley, when boiled with oils, fat, &c. that produces soft soap. Hard soap is a combination of oil or fat, and soda. The quantity of real alkali in potash may be known by the proportion of acid required to saturate a given weight of it. Potash, pearl-ash, salt of tartar, and salt of wormwood are all carbonates of potassa. This alkali is called the vegetable alkali, because it is obtained from vegetables. It is considered to be the hydrated deutoxide of potassium, and when decomposed will furnish potassium.

Table of the saline or soluble products of one thousand pounds of ashes of the following vegetables.

	SALINE PRODUCTS.	
Stalks of Turkey wheat,	198 lbs.	
Stalks of sun-flower,	349	
Vine branches	162.6	
Elm	166	
Box	78	
Sallow	102	
Oak	111	
Aspen	61	
Beach	219	
Fern, cut in August,	116,	or 125 according to Wildenheim.
Wormwood	748	
Fumitory	360	
Heath	115	

The observations of Mr. Kirwan on potash may be seen in *Aikin's Chemical Dictionary*.

When a piece of hydrated potassa is placed between two disks of platinum, which are brought in contact with the poles of a galvanic battery, consisting of upwards of 200 pairs of plates, four inches square, the oxygen will separate at the positive surface, and small metallic globules of potassium will be formed at the negative surface. The potassa, in the mean time, will undergo fusion.

Sir H. Davy discovered potassium, in 1807. It may be obtained by means of iron turnings, in the following manner: Heat the iron turnings to whiteness in a curved gun barrel, and suffer potassa, in a state of fusion, to fall upon them very gradually, air being excluded: potassium will form, and collect in the cool part of the tube. For the different facts respecting this metal, consult Sir H.
Davy's communications on the subject, and the memoirs of Gay-Lussac and Thenard, Curadeau, &c. See also, Davy's *Chemical* [192]
Philosophy, and Thenard's *Traité de Chimie*.

Potassa unites with, and neutralizes, acids, and forms salts; the principal of which are the sulphate, muriate, and nitrate of potassa. It unites also with sulphur, phosphorus, &c.

Potassa, in the state of carbonate, is very soluble in water, for which it has so strong an affinity, that, when exposed to the atmosphere, it deliquesces and becomes fluid. Caustic potassa undergoes the same change, in a more remarkable degree. It is on account of its great avidity for water, that the carbonate is used in the preparation of alcohol from spirituous liquors; it retaining the water, while the alcohol may be distilled over.

Potassa has a stronger affinity for the acids, than either the earths or metals; hence it decomposes earthy and metallic salts, the earth or metallic oxide being precipitated, while it unites with the acid of the salt. It is on the same principle, that earthy and metallic salts decompose soap; and waters which are hard, and owe that property to the presence of earthy salts, will curdle, or, in other words, decompose soap. Such waters, for this reason, are called hard. Acids have the same effect in decomposing soap.

The use of potassa is very apparent in the manufacture of saltpetre. When the nitric acid is combined with an earthy base, as in the calcareous nitre of the nitre caves of the western country, potassa from wood-ashes will decompose it, on the principle already stated; and, by combining with the nitric acid, form nitrate of potassa. It is used also in refining saltpetre, where earthy salts are present, besides common salt. The effect of this alkali, for that purpose, will be more obvious, by referring to the processes for the extraction and refining of saltpetre, in the article on that subject.

Potassa acts as a flux for siliceous substances and forms glass. These are its prominent characters.

Sect. XXXVIII. Of Wood-Ashes.

Wood-ashes, the product of the combustion of wood, contain potassa, some foreign salts, and earthy and sometimes metallic substances, insoluble in water. The quantity of alkali, which ashes, obtained from different woods, furnish, is greater or less, according to the nature of the wood. The ashes of the oak are generally used in pyrotechny; but it seems to us, that ashes in common will have the same effect.

The ashes, for this purpose, should be dry, and passed through a fine sieve. They enter into the composition of blind fuse. [193]

In some instances, the *leached*, or lixiviated ashes might be used. The residue, after the separation of alkali and saline matter by the action of water, is nothing more than the insoluble part of the ashes. Caustic ley is always obtained from wood-ashes, by mixing them with about a fiftieth part of quicklime, and putting them into a barrel or tub, and adding water. The lime takes up the carbonic acid, and the ley comes off in a caustic state. If the solution should not contain a sufficient quantity of potassa, or not bear an egg, as that is the usual criterion of its strength, (which depends on its specific gravity,) its strength may be increased by evaporation; and, if too strong, simple dilution with water, is all that is necessary.

While the ashes of some plants, as the upland plants, generally yield potassa; others, as many marine plants, the *salicornia europea*, *salsola tragus*, *salsola kali*, *&c.* afford soda by incineration. It will be sufficient, however, to observe, that the ashes of all plants contain alkali, in more or less quantity, which depends on various circumstances; and that the alkali may be extracted by lixiviation, and, in some instances, may even be seen among the ashes, in a semivitrified mass. The white ashes, which are formed by the combustion of animal matter, as osseous or bony substances, we may remark, do not afford potassa or soda, but only phosphate of lime, and some uncombined earths. Bones, nevertheless, may, like wood, be carbonized, although the charcoal formed is of a different nature. For the preparation of phosphorus from bone-ash, see the article Phosphorus.

Sec. XXXIX. Of Clay.

Clay is an argillo-siliceous substance, of a colour more or less yellow, and containing a variable quantity of silica and alumina, with oxide of iron. There are a variety of clays; the common potter's clay, pipe clay, porcelain clay, &c. Some contain, and others are free from iron. Those that contain this metal burn *red*; while those which remain, or become white in the process of burning, are free from it.

The use of clay in fire-works is confined nearly altogether to rockets. In the driving of sky-rockets, &c. the *charge* must always be driven one diameter above the piercer, and on it there is sometimes rammed one-third of a diameter of clay, through the middle [194] of which a hole is bored to the composition, so that, when the charge is burnt to the top, it may communicate its fire through the hole, to the stars in the head. This, however, is not always the case. See *Rockets.*

The clay for fire-works, is usually prepared of the common kind, which contains neither stones nor sand. It must be first baked in an oven, until perfectly dry, and then pulverized, and sifted through a common hair sieve. In China, the Chinese mostly employ, for this purpose, their white porcelain clay.

Sec. XL. Of Quicklime.

Lime, as it is found in nature, is combined with carbonic and sulphuric acids, and less frequently with some of the other acids, as the nitric, fluoric and phosphoric. Calcareous carbonates are the most abundant; in which we include marble, limestone, and chalk; and the sulphate, or gypsum, may be considered the next. Lime constitutes the basis of marine shells; for, when burnt, they furnish quicklime. Its union with nitric acid is well known, forming the calcareous nitre of the saltpetre caves of Kentucky, &c. We have mentioned this combination under the head of nitre.

Without enumerating all the chemical properties of lime, it will be sufficient to remark, that it is composed of calcium and oxygen, and, when slaked with water, will evolve caloric in a free state, while the water solidifies or combines with the lime; that it forms with water, a solid hydrate, an example of which combination is afforded by the preparation of mortar; that it dissolves in water, and forms lime-water, and is slaked by exposure to the air, absorbing, at the same time, carbonic acid; that it unites with acids, like other salifiable bases, and forms salts, some of which are soluble in water, and others not; that it deprives the alkalies of carbonic acid, and renders them caustic, being itself changed into a carbonate; and, that it unites with sulphur and phosphorus, forming a sulphuret and phosphuret, and, also, with hydroguretted sulphur, and sulphuretted hydrogen, forming a hydroguretted sulphuret, and a hydro-sulphuret.

When limestone, marble, &c. are burnt in a kiln, the carbonic acid is expelled, and quicklime formed. Quicklime and lime, chemically speaking, are synonimous terms.

The fluor, or Derbyshire spar, is a fluate of lime. When this substance is distilled in a leaden retort, with sulphuric acid, we have sulphate of lime, and fluoric acid gas, called by some hydro-fluoric acid. This acid, when received in water, is used to etch on glass, [195] in the same manner as nitric acid on copper; and while applied in a liquid state, or in that of gas, it acts on the glass, by combining with the silicon, and is changed from the hydrofluoric, into the silicated fluoric acid. If, instead of employing a leaden vessel, we make use of a glass retort, or introduce powdered glass or silica, into the leaden vessel, in either case, we obtain another acid, which we have just mentioned, the silicated fluoric acid; in consequence of the union of silicon with the supposed radical of the fluoric acid, known by the name of fluorine.

Quicklime is occasionally, though but rarely, employed in fire-works. That it increases the strength of powder, is asserted by Dr. Bayne. See Gunpowder. Its use in making slow match, along with other substances, is given in the article on that subject.

Sec. XLI. Of Lapis Calaminaris.

That some of the ores of zinc are employed in fire-works, is evident from the use of lapis calaminaris, or calamine stone, which is an impure carbonate of zinc. Calamine should be finely pulverized and sifted. As zinc gives a particular colour to flame, (see *zinc*), its carbonate may also communicate a colour, and, under particular circumstances, may produce a great variety, and, therefore, in such cases, be preferable to the zinc itself. It is one of the ingredients in the *dead fire* for wheels, which is composed of lapis calaminaris, saltpetre, brimstone, and antimony.

The modifications, to which particular bodies are subject, as to their respective effects, depend very greatly on the presence of other bodies, and frequently on the chemical action, which ensues throughout; so that, as we had occasion to observe, the *effect* which one body would produce on the flame, maybe completely changed, modified, or varied by the presence of a second, third, or fourth substance. The art, therefore, of uniting various bodies, in kind, as well as in proportion, so as to produce a given effect, can be acquired only by a series of experiments. Zinc, as a metal, when finely divided, produces a peculiar effect; when mixed with other metals, and with certain salts, as sal ammoniac, another; and, when combined with some acids, as the carbonic in lapis calaminaris, a third effect; and these effects may be governed, as it appears, by the presence or absence of certain bodies. This fact will appear more striking, when we consider the various mixtures, and their respective properties. For the uses of zinc, see [196] that article.

Sec. XLII. Of Zinc.

Zinc, commonly called spelter, is a metal, obtained from blende, or sulphuret of zinc, and calamine, or carbonate of zinc. The ore is first roasted, and then mixed with some carbonaceous flux, and submitted to the action of heat in close vessels. The metal is volatilized, and passes over, and is usually caught in water. It is then fused, and cast in moulds.

Zinc possesses many remarkable properties, some of which are the following. It is of a brilliant white colour, with a shade of blue, and is composed of a number of thin plates, adhering together. Its specific gravity is more than six times that of water. It is brittle, but, when heated to 212 degrees, may be hammered out, or made into sheets. At 400° it becomes very brittle. Its tenacity is so feeble, that a wire of $^1/_{10}$th of an inch in diameter, will support a weight of only 26 pounds. At 680° it melts, and above that temperature, evaporates. It soon oxidizes, and its lustre is therefore tarnished. At common temperatures, it soon decomposes water; and, when the vapour of water is passed over it at a high temperature, the decomposition is very rapid, the oxygen of the water being absorbed. Zinc is soon oxidized when melted and exposed to the air, forming a gray oxide.

At a red heat, zinc inflames, and the product of combustion is the white oxide of zinc, or flowers. The oxide of zinc is reduced by mixing it with charcoal, and exposing the mixture to a strong heat in close vessels.

Zinc will burn in chlorine gas, and forms a chloride of zinc. If the perchloride of mercury and zinc-filings be heated together, the same compound will result. This chloride melts at 212°, and rises, in the gaseous form, at a heat much below ignition. It was formerly called the *butter of zinc*, and muriate of zinc. With iodine, zinc forms a compound, called iodide of zinc.

With phosphorus and sulphur, zinc also combines, and with the latter, it forms the native sulphuret, known by the name of blende. It unites, also, with acids, and forms salts. Of these, the sulphate of zinc, or white vitriol, is the most common. It unites with various metals, forming alloys. Of these, that with copper, called brass, is the most known. Zinc, with copper, forms galvanic batteries. With tin and mercury, it constitutes amalgam for electrical machines. It forms, besides brass, the yellow copper, or [197] laiton; commonly called pinchbeck.

Acetic acid readily dissolves zinc. The acetate formed is not altered by exposure to the air, is soluble in water, and burns with a *blue* flame. It may be used, therefore, in fire-works, to communicate that colour to flame. It may be formed very expeditiously, by mixing about equal parts of sulphate of zinc, and acetate of lead, both being in solution. The sulphate of lead, which is formed, will precipitate, and acetate of zinc remain in solution. By evaporation, it is obtained in crystals. This salt cannot injure any composition of fire-work, in which it enters; as it does not deliquesce, and, for that reason, may be advantageously employed.

When zinc is used in fire-works, it should be remarkably fine. The powder may be very readily formed, by heating it, until it is about to fuse, and pulverizing it while hot, in a warm mortar. It is generally considered, however, that the best method of obtaining the powder of zinc, although a longer time is required, is by filing it; but the filings are more or less coarse, according to the file which is used. They may be sifted, and thus obtained of any degree of fineness. In various blue lights, in the blue flame of the parasol and cascades, and other descriptions of fire-works, it is used. It gives a more brilliant light than any other substance used for this purpose. It is frequently mixed with other substances; but, as to its peculiar properties, they remain the same. By the combustion of zinc, which follows in fire-works, it always produces an oxide. In this state, it is expelled, or thrown off.

Acetate of zinc appears to possess advantages over zinc-filing, especially as it produces the same colour, may be more readily mixed, and with more accuracy, and does not deliquesce or absorb moisture, a circumstance which must always be guarded against in artificial fire-works.

Sec. XLIII. Of Brass.

This is a mixed metal, composed of copper and zinc. This alloy, according to the proportion of the metals, is more or less yellow, or reddish-yellow. The yellow copper, or *laiton* of the French, the similor, Manheim gold, prince Rupert's metal, &c. are alloys of the same metals.

Zinc readily unites with copper; and the usual manner of forming brass by brass-founders, is to make a direct union between the two metals. The process, however, generally consists in mixing together granulated copper, calamine, or carbonated oxide of zinc, [198] and charcoal in powder, and melting them in a crucible. The charcoal reduces the zinc, which then unites with the copper. The heat is kept up for five or six hours, and towards the last of the process, is raised. Zinc, in small proportion, renders copper pale, and in the proportion of one-twelfth, inclines its colour to yellow. The yellow colour increases in intensity with the zinc, until the weight of this metal in the alloy equals that of the copper. An increase of zinc, afterwards makes the alloy white. English brass contains one-third of its weight of zinc. In Germany and Sweden, the proportion of zinc varies from one-fifth to one-fourth of the copper. Twenty to forty parts of zinc, with eighty to sixty parts of copper form the *cuivre jaune*, laiton, or yellow copper of the French.

Dutch metal, or Dutch gold, is a fine kind of brass, and comes in leaf, which is about five times as thick as gold leaf. This brass is made by the cementation of copper plates with calamine, and hammered out into leaves.

According to Thenard (*Traité de Chimie*, tome i, p. 478), the French use 50 parts of calamine, mixed intimately with 20 parts of charcoal, and stratified in a crucible with 30 parts of laminated, or granulated copper. British brass consists of two parts of copper, and $1\frac{1}{8}$ parts of zinc, by weight.

The filings of brass are much employed in fire-works. They communicate to stars, rains, &c. a flame between a blue and green. In some, the filings of copper alone are used. A beautiful green fire, for instance, is produced by 16 ounces of gunpowder, and $3\frac{1}{4}$ ounces of copper-filings. Verdigris is also employed for the same purpose; but the effect is not so striking, as in that preparation, the copper is already oxidized. The effect of copper in fire-works, it is to be recollected, depends, like that of other metals, on its combustion, and consequent oxidizement. The product of the combustion of brass, is oxide of copper, and oxide of zinc.

Sec. XLIV. Of Bronze.

The union of copper with tin, in various proportions, forms gun-metal, bell-metal, the mirrors of telescopes, and bronze.

The ductility of the copper is diminished by the tin; but its hardness, and tenacity, as well as its fusibility and sonorousness are increased.

To form a complete union of the two metals, they should be continued in fusion for some time, and constantly stirred. The tin is [199] apt to rise to the surface, unless this precaution is used.

Bronze is usually composed of 100 parts of copper, and 8 to 12 parts of tin. It is yellow, brittle, heavier than copper, and has more tenacity.

The same metals, and in the same proportion, constitute gun-metal. In the brass ordnance made at Woolwich, the proportion of tin varies from 8 to 12, to the 100 parts of copper. The purest copper requires the most. That the alloy is more sonorous than iron, is evident from the report of brass pieces, being louder than that occasioned by iron guns.

When the alloy is 78 of copper and 22 of tin, it is chiefly used for clocks. There is, in the English metal, about five per cent. of zinc, and four per cent. of lead. The proportion of tin, in bell-metal, varies. In church bells, less tin is used than for small bells. In the latter, zinc is sometimes added.

The *Tam-tam*, or *gong* of the Chinese, used for cymbals, clocks, mirrors, &c. contains, according to analysis, 80 parts of copper, and 20 parts of tin. The proportions, however, are not always the same.

The ancients made cutting instruments of an alloy of copper and tin. A dagger, analyzed by Mr. Hielm, consisted of $83\frac{7}{8}$ copper, and $16\frac{1}{8}$ tin. Vessels of bronze were frequently covered with silver. Some of this kind were found in the ruins of Herculaneum.

Pliny observes, that ancient mirrors were made with a mixture of copper and tin; but that, in his time, those of silver were so common, that they were even used by the maid servants. The quantity of tin, to make the most perfect speculum, depends on the quality of the copper. If the proportion of tin be too small, the composition will be yellowish; if it be too great, the composition will be of a grayish-blue colour. Mr. Edwards casts the speculum in sand with its face downwards; takes it out while red-hot, and places it in hot wood-ashes to cool, otherwise it would break in cooling. The mixture is first granulated, by pouring it into water, and then fused a second time for casting. Mr. Little recommends the following proportions: 32 parts of the best bar copper, 4 parts of brass, or pin wire, $16\frac{1}{2}$ of tin, and $1\frac{1}{4}$ of arsenic.

Whether for speculum metal, bronze, or gun-metal, the metals must be mixed exactly, and for this purpose be kept a long time in fusion, and constantly stirred; otherwise, the alloy will not be of a uniform quality, as the greater part of the copper will sink to the [200] bottom, and the greater part of the tin rise to the surface. When we speak of *brass guns*, as that name is generally applied to them, we are to understand, that they are not made, like brass, of an alloy of copper and zinc.

The ancient metallic mirrors, which were in use before the present mirrors, or the discovery of glass, and the mode of applying to its surface an amalgam of tin, were composed of two parts of copper and one part of tin. Mr. Mudge asserts, that the best proportion for mirrors is 32 parts of copper and 14.5 parts of tin. Klaproth found a specimen of ancient mirror to consist of 32 of tin, 8 of lead, and 62 of copper. The alloys of copper and tin may be decomposed by dissolving them in an acid, the muriatic for instance, and immersing a sheet of iron, which will precipitate the copper. The tin may then be separated by immersing a plate of lead, or zinc, by either of which metals, it will be precipitated.

Bronze, being a mixed metal, in which the copper forms the principal ingredient, is sometimes used in fire-works, in lieu of copper or brass; for its effects are similar. By the combustion of bronze filings, we have an oxide of copper and an oxide of tin.

Sec. XLV. Of Mosaic Gold.

This name, or *aurum musivum*, was given to a preparation of tin, composed of tin and sulphur. It is considered to be a persulphuret of tin.

Several methods are recommended for preparing this substance. The oldest process is to sublime a mixture of 12 parts of tin, 7 parts of sulphur, 3 parts of mercury, and 3 parts of sal ammoniac. It may be formed by heating together in a retort, a mixture of equal parts of sulphur and oxide of tin.

It is used principally for rubbing the cushions of electrical machines, and for bronzing wood. In fire-works, it is sometimes employed under the name of *gold-powder*.

It was supposed to be a combination of sulphur with the oxide of tin. Dr. J. Davy (*Phil. Trans.* 1812, p. 199) and Berzelius, (*Nich. Jour.* xxxv, 165), have proved, however, that it is nothing more than metallic tin and sulphur; the proportions of which, according to the former, are 100 of tin + 56.25 of sulphur.

Mosaic gold is of a yellow colour, resembling that of gold. It is insoluble in water, and is not acted upon by muriatic or nitric acid. The nitromuriatic, however, decomposes it. A solution of caustic potassa dissolves it, forming a green solution, which is [201] decomposed by acids, letting fall a hydrosulphuret of tin. It deflagrates with nitre.

When it is used in fire-works, it is pulverized, and sifted. It is more generally employed as a pigment to impart a golden colour to small statues of plaster-paris. When mixed with melted glass, it is said to imitate lapis lazuli.

Sec. XLVI. Of Iron and Steel.

Both iron and steel are used abundantly in fire-works. It would be unnecessary to detail the preparations, in which they are employed, which may be seen by a reference to the different kinds of fire, and to their respective formulæ.

Cast iron is more employed in artificial fire than forged iron or steel, at least in the preparation of some, as gerbes, white fountains, and Chinese fire.

The filings of iron and steel may be sifted through sieves. A fine hair sieve will answer for common purposes. Their fineness depends, in the first instance, on the file, which is used. Steel or iron filings are more commonly employed in the compositions for brilliant fire.

The sparks produced by cast-iron are very brilliant; but the reduction of the iron to powder, or to a degree of fineness sufficient for use, is a difficult operation. It is of too hard a nature to be cut by a file.

This operation is generally performed in the following manner: Procure from an iron foundry, some thin pieces of cast iron, such as generally run over the mould at the time of casting, and pound them on a block, made of cast iron, with an iron hammer of four pounds weight, putting, under the block, a cloth to catch the pieces of iron, which fly off. They are beaten with the hammer in this manner, until the whole is reduced to grains, which are more or less small. It is then thrown into a sieve, which should be fine, and the dust separated. This is used, in the place of steel dust, in small cases of brilliant fire. The remainder is then put into a sieve, a little coarser, and again sifted. This portion is preserved separately. The same operation is repeated, but with sieves of different sizes, till the iron passes through about the bigness of small bird shot.

The pulverization may be effected in an iron mortar, with a steel pestle, having the mortar covered in the usual manner, to prevent the escape of the finer particles of the iron.

According to a writer in the *Dictionnaire de l'Industrie*, vol. iii, p. 34, the Chinese prepare their iron-sand for fire-works by [202] igniting iron, and plunging it in cold water. They then pulverize the scales thus formed, and pass the powder obtained, through different sized sieves, which is then called No. 1, 2, 3, 4, &c. as it is very fine or coarse. This cannot be a good method, and we doubt whether it is at present employed; because it is obvious, that the scales, in this case, consist of the metal in the state of protoxide. D'Incarville, a missionary at Pekin, obtained the process for making Chinese fire; and observes, that the pulverized cast iron they employ is called *iron-sand*, of which they have six numbers or varieties.

As the goodness of iron or steel dust, in fire-works, depends greatly on its being dry, and not oxidized or rusted; its preservation must be accordingly attended to. The usual preservative is to put it in a box, lined with oiled paper, and covered with the same, or in tin cannisters, with their mouths well closed.

When it is to be used, it is taken according to its size, and in proportion to the cases, for which the charge is intended. Large gerbes, of 6 or 8 lbs. require only the coarse sort.

As the brilliancy of the sparks, produced by the iron and steel dust, is a desideratum in the formation of some fire-works, and as this brilliancy depends upon the nature and quality of the metal, it may not be improper to offer some remarks on these subjects.

That iron, when finely divided is capable of producing sparks of fire, is a well known fact; and we see it daily in the operations of the smith, when ignited iron is hammered on the anvil. The scintillation produced by the steel, when struck with a flint, is of the same character. In the latter case, the metal is actually fused, and, when caught on a paper, and examined with a microscope, will appear globular, and partly oxidized. Hence it is, that gunpowder is inflamed by this spark, which is nothing more than highly ignited, and inflamed iron, possessing a temperature more than sufficient to inflame gunpowder.

The effect, therefore, that results from the inflammation of fire-works, in which iron or steel forms a constituent part, is nothing more than a vivid combustion of the metal; and during that process it becomes oxidized, as it does not form an acid with oxygen, like arsenic, antimony, and some other metals.

The combustion of iron or steel may be shown by a very brilliant experiment, that of burning it in oxygen gas. A steel wire, [203] harpsichord wire for instance, formed into a spiral, with a small piece of wood dipped in sulphur, stuck on its end and then set on fire, upon being immediately introduced into a bottle, containing pure oxygen gas, will burn with great brilliancy, emitting a number of sparks or scintillations, which fall like rain. In making the experiment, some sand should be put into the bottle to prevent the sparks from breaking it. This experiment illustrates the rapid combustion of iron, or steel. For the oxygen gas supports the combustion; and while the oxygen is actually taken up by the metal, which becomes oxidized, and therefore increased in weight, in the same manner as it does when inflamed in fire-works, the caloric, the other constituent of oxygen gas, is given out in a free state, and, with the light at the same time evolved, produces the phenomena of combustion.

Many other experiments might be mentioned, in which the same effects take place, and from which the same conclusions may be drawn. But with respect to the *effect*, whether it be dull, brilliant, or very brilliant, depends more on the quality of the metal, than perhaps, on its subsequent mixture with the other materials. Crude iron, usually called cast iron, seems to possess this property in an eminent degree; but in the experiment with oxygen gas, steel is always preferable, as the combustion is more rapid, and the effect more striking. The difference, which we will not attempt to explain, may depend on the *state*, as well as the *proportion* of carbon, which enters into crude iron, as well as steel. In one case, the combustion ensues in contact with nitre, and in atmospheric air; in the other, in contact only with oxygen gas. Be this as it may, this inference is conclusive, that, in all cases of the combustion of iron in fire-works, the metal itself unites with oxygen, and the result of the combustion is an oxide of iron; and with respect to the carbon, in both instances, it is converted alike into carbonic acid. So that whether the iron receives its oxygen from the nitre, or from the air, or from both, is immaterial, as the products are the same.

When iron is exposed to the atmosphere, it tarnishes, and is gradually changed into a brown or yellow powder, called rust. This change is owing to its combination with oxygen; and its affinity for oxygen is such, that, when the vapour of water is made to pass through an ignited gun-barrel, it is decomposed, the metal becoming oxidized, and the hydrogen, the other constituent of the water, being liberated in the form of gas.

Gun barrels are browned by a process of oxidizement. There are several processes recommended. One of which is, to rub the [204] barrel over with diluted nitric or muriatic acid, and then, to lay it by for a week or two, until a complete coat of rust is formed. A brush, made of iron wire, is then applied; afterwards, oil and wax, and the barrel is finished by rubbing it with a cloth. The gunsmiths in Philadelphia use a mixed solution of sulphate of copper, tincture of the muriate of iron, and sweet spirit of nitre. This they apply by means of a cloth. The object is to form a rust, and to render it permanent on the barrel by hard friction along with wax. When sulphate of copper is employed, metallic copper is precipitated on the barrel. A coat of rust, put on in this manner, prevents effectually the oxidizement of the iron; and in point of utility, and the saving of labour in polishing and keeping muskets in order, the browning of barrels is certainly advantageous in the land service. At sea, in particular, where iron is more readily oxidized, this plan ought always to be adopted. With regard to the use of dragon's blood, it is entirely too temporary in its effect to be depended on. I was informed by an intelligent gunsmith, who followed the practice of browning barrels in Europe, that he has known the *browning* to remain very perfect for years, and that the best mode of insuring its durability is to use the *steel brush*, which *carries in*, as he expressed it, the rust.

The oxides, which are formed by the union of oxygen with iron, are two; namely, the black and the red; the first being the protoxide, and the last the peroxide. The black oxide, which is formed by the combustion of iron, and by other processes, contains 56 iron + 16 oxygen. The common rust of iron is the peroxide of this metal, combined with carbonic acid. It may be formed by exposing the protosulphate of iron, or green vitriol, in solution, to the atmosphere, and then adding an alkali. This oxide contains more oxygen than the preceding; it consisting of 56 iron + 24 oxygen.

The tempering of cutting instruments, an operation which requires great delicacy and exactness, after that of hardening, is intended to obtain a fine and durable edge; and as this subject may be interesting in a military point of view, we deem the following remarks of use.

The hardening of steel instruments is performed by heating them to a cherry-red, and then immersing them in cold water. The tempering is another process, calculated, as we observed, to obtain a fine and durable edge. This is performed by heating oil to a [205] certain temperature, and plunging the instrument into it, where it remains until the colour appears, indicative of the particular kind of temper which is intended to be given. The experiments of Stoddart, (*Nicholson's Quarto Journal*, iv, 129,) are conclusive on this subject; for his experiments prove, that, between 430° and 450° the instrument assumes a pale yellowish tinge: at 460° the colour is a straw-yellow, and the instrument has the usual temper of pen-knives, razors, and other fine edge tools. The colour gradually deepens as the temperature rises, and at 500° becomes a bright brownish metallic yellow. As the heat increases, the surface is successively yellow, brown, red, and purple, to 580°, when it becomes of a uniform deep blue, like that of watch springs. Before the instrument becomes red-hot, the blue changes to a water colour, which is the last distinguishable colour. These different shades are owing to the oxidizement of the surface of the metal; and the art of ornamenting *sword-blades*, knives, &c. long practised in Sheffield, depends on this principle. The general process is, that an oily composition is used, with which flowers and various ornaments are painted. On the application of the heat required for tempering it, that part which was covered with the composition, is not altered, whereas, the uncovered parts of the blade are changed. These ornaments, when the paint is removed, have the natural colour of polished steel. When steel is heated in hydrogen gas, no appearance of the kind takes place, a fact which shows, that it is owing to the oxidizement of the metal.

Iron is soluble in the acids. By the assistance of water, it is acted upon by sulphuric acid; the metal being oxidized, and the oxide dissolved, while hydrogen gas is evolved. The salt, formed in this case, is the sulphate of iron, green vitriol, or copperas. With muriatic, nitric, acetic and other acids, it forms various salts; and with gallic acid, when the iron is peroxidized, it forms the pergallate of iron, or common writing ink, and also the bases of black dye.

Iron unites with carbon, sulphur and phosphorus. Of the sulphurets, there are two kinds, the protosulphuret and persulphuret. The former is the magnetic pyrites, and the latter, cubic pyrites, from both of which, green vitriol is obtained by decomposition. Pyrites, we may observe, was the original fire-stone, or the *feuer-stein* of the Germans, which was used in the place of flint. See *Beckman's History of Invention*. Iron also unites with some of the metals, forming alloys. The white iron of the French, (*Fer blanc,*) [206] or tin plate of the English, is found to be any alloy of tin with iron, as well as a covering of tin on iron.

Sheet tin, or tinplate which is necessary in the construction of the apparatus for some fire-works, for canister shot, &c. is made by immersing sheets of iron, previously freed from rust, into melted tin. The number of dippings it undergoes, determines, in some measure, its quality and character.

The union of carbon and iron, forming very important modifications of this metal, is not only interesting in the military art, as concerns the metal for cannon, small arms, and fire-works, but also in relation to the many and highly useful compounds which result.

All the varieties of iron, which are distinguished by artists, under particular names, we may consider under the following heads: namely; cast iron, wrought or soft iron, and steel.

Cast or pig iron is the name of this metal, when first obtained from the ore. The ores of iron are various, and contain a greater or less quantity of iron, which is either combined with oxygen, or found with clay, giving rise to two important classes of iron ore, the calciform and the argillaceous. The reduction of the ore merely requires the presence of charcoal, and occasionally some addition, as limestone, when the clay iron ores are to be reduced. On the application of heat in furnaces, constructed for the purpose, the charcoal unites with the oxygen of the oxide, reducing it to the metallic state, and escapes in the form of carbonic acid; and the lime, if the ore be argillaceous, unites with the clay, forming a kind of glass, which floats on the melted metal. When the iron is suffered to run into moulds, prepared for its reception, it usually takes the name of pig iron.

Manufacturers distinguish cast iron by its colour and other qualities. The *white cast iron* is hard and brittle, and can neither be filed, bored, nor bent. Gray mottled iron, so called from its colour, is of a granulated texture, softer, and may be cut, bored and turned on the lathe. Cannon are made of this iron. *Black cast iron* is the most unequal in its texture, but the most fusible.

Cast iron melts at 130° of Wedgwood. Its specific gravity varies from 7.2 to 7.6. It is converted into malleable, usually called soft iron, by a process called refinement. Several modes have been adopted for this purpose. It was formerly done by keeping it in fusion in a bed of charcoal and ashes, and afterwards forging it. The hammering makes the particles of iron approach each other, [207]
and expels some impurities.

Among the various improvements for expeditiously and effectually converting crude into malleable iron, the process of Mr. Cort seems to possess advantages. The cast iron is melted in a reverberatory furnace, and the flame of the combustible is made to act upon the melted matter. It is stirred during this operation, by which means, every part is exposed to the air. A lambent blue flame begins to appear in about an hour, and the mass swells. The heat is continued about an hour longer; and, by this time, the iron acquires more consistency, and finally congeals. While still hot, it is next hammered by powerful tilt-hammers. This is called the *puddling* process.

Iron, obtained in this way, is not however pure; for it contains either some of the other metals, or oxygen, carbon, silicon, or phosphorus.

When small pieces of iron are stratified in a crucible with charcoal powder, and exposed to a strong heat for eight or ten hours, they are converted into steel. Steel is brittle, resists the file, cuts glass, and affords sparks with flint. It loses its hardness by ignition and cooling. It is malleable at a red heat. It melts at 130 degrees of Wedgwood. By being repeatedly ignited in an open vessel, it becomes, by hammering, wrought iron.

Natural steel is that which is formed, by converting the ore first into cast-iron, and exposing it to the action of a strong heat, while the melted scoriæ float on its surface. This steel is inferior to the others. Steel of cementation is formed, on a large scale, by stratifying bars of iron with charcoal, in large earthen troughs or crucibles, the mouths of which are closed with clay. These troughs are put in furnaces, and, in eight or ten days, the process is finished. This is also called blistered steel, on account of the appearance of its surface. The tilted steel is that which is beaten out into small bars by the hammer. When broken, and the pieces again united by welding in a furnace, and made into bars, it is then called German or shear steel.

Cast steel is considered the most valuable of all the varieties; and is used for the manufacture of razors, surgeons' instruments, &c. It is, besides, more fusible than common steel, and for that reason, cannot be welded with iron. It is made by melting the blistered steel, in a close crucible, along with pounded glass, and charcoal powder. It may also be formed by melting together 30 parts of iron, 1 part of charcoal, and 1 part of glass. Equal parts of chalk and clay, put with iron in a crucible, will also produce it. [208]

The Celtiberians in Spain had a singular mode of preparing steel. Diodorus and Plutarch both say, that the iron was buried in the earth, and left in that situation, till the greater part of it was converted into rust. What remained, without being oxidized, was afterwards forged and made into weapons, and particularly swords, with which they could cut asunder bones, shields, and helmets. This process is used in Japan, however improbable it may seem; and Swedenbourg, among the different methods of making steel, has introduced it. Bishop Watson, (*Chemical Essays* 8vo. i, p. 220,) speaks of the same process. The fact has been verified at Gottingen; for an anvil, which had been buried in the ground for many years, was found to be extremely soft; and a part of it, which appeared in steel-like grains, possessed the properties of steel.

The sabres made in Japan, according to Thunberg, are incomparable. Without hurting the edge, they can be made to cut through a nail at one blow.

The art of hardening steel by immersion in cold water is very old. Homer (*Odyssia* ix, 301,) says, that, when Ulysses bored out the eye of Polyphemus with a burning stake, it hissed in the same manner as water, when the smith immerses in it a piece of red-hot iron, in order to harden it. Sophocles, Salmasius, Pliny, Justin and others mention the use of water in hardening iron; but the most delicate articles of that metal were not quenched in water, but in oil. As to the opinion of the peculiar virtue of any particular water, for the purpose of hardening iron, which many have believed, it is altogether fallacious, although Vasari asserts, that the archduke Cosmo, in 1555, discovered a water, that would harden instruments, to cut, like the ancient tools, the hardest porphyry. The art of working porphyry, however, was known in every age. Beckman assures us, when treating of the processes of making steel, that the invention and art of converting bar iron into steel, by dipping it into other fused iron, and suffering it to remain there several hours, although ascribed to Reaumur, (*Art de Convertir le Fer en Acier*, p. 145), are mentioned by Agricola, Imperati, and others, as a thing well known and practised in their time.

Pliny, Diamachus, and other ancient writers mention various countries and places, which, in their time, produced excellent steel. The *ferrum Indicum* and *Sericum* were the dearest kinds. The former is the same as the *ferrum candidum*, a hundred talents of which were given, as a present, to Alexander in India.

Beckman thinks, that the ancient *ferrum candidum* is the same kind of steel still common in India, and known under the name of [209]
wootz; some pieces of which were sent from Bombay in 1795 to the Royal Society. Its silver coloured appearance, when polished, he thinks, may have given rise to the epithet of *candidum*.

Mr. Faraday of the Royal Institution has lately examined wootz, and imitated it very accurately. The experiments may be seen in *Ure's Chemical Dictionary*, article *Iron*. It appears that the presence of silex and alumina distinguishes this kind of steel from the English. Four hundred and sixty grains of wootz gave 0.3 of a grain of silex, and 0.6 of a grain of alumina. It is highly probable, that the much admired sabres of Damascus, are made from this steel.

A small portion of silver, melted with steel, improves the latter very considerably. One part of silver and five hundred parts of steel were melted together, and every part of the alloy formed, when tested, indicated silver. The alloy forged remarkably well, although very hard, and was pronounced to be superior to the very best steel. This excellence is undoubtedly owing to its combination with the silver, however small. The alloy has been repeatedly made, and with the same success. Various cutting tools have been made from it of the best quality. The silver is found to give a mechanical toughness to the steel.

Platinum and steel, equal parts by weight, form a beautiful alloy, which takes a fine polish, and does not tarnish. This alloy is said to make the best speculum. Steel, for edge tools, is improved by this metal. The proportions, which appear to be most proper, are from one to three per cent. An alloy of 10 platinum with 80 of steel, after exposure for many months, had not a speck on its surface. Would not this alloy, as it is not oxidized, be very useful for making points for lightning rods, in lieu of iron, gold, silver, or platinum alone? The experiment is worth a trial; for nothing adds more to the safety of a magazine, or building, against the effect of lightning, than a conductor.

Iron and carbon, it appears, are capable of uniting in different proportions; hence the variety of crude iron, and the different kinds of steel. When the carbon exceeds the iron, as in plumbago, or black lead, it forms a carburet. When the iron exceeds, such compounds are properly speaking sub-carburets; under which name, we may rank all the varieties of cast iron and steel.

The hardness of iron, according to the experiments of Mushet, (*Phil. Mag.* xiii, p. 138), increases with the proportion of charcoal, [210]
with which it combines, until the carbon amounts to about $^1/_{60}$th of the whole mass. This is the maximum, the metal acquiring the colour of silver. More carbon diminishes the hardness, according to its quantity. The difference in iron, whether it be the *cold-short*, or *hot-short* iron, a matter of some consequence to the workers in this metal, was found to be owing to phosphoric acid in the cold-short, which exists with the iron. But the substance, called *siderum* by Bergman, is a phosphuret, and not a phosphate of

iron.

We have gone into this subject more fully, on account of its importance, and intimate connection with the casting of guns, and the different qualities of iron. In fire-works, it will appear obvious, that the various properties exhibited by iron are owing to the iron and carbon, to the changes which they undergo, to the combustion which necessarily ensues, and to the production of oxide of iron, and carbonic acid gas; effects that invariably take place, whether cast iron or steel be used, provided it is exposed to the action of agents, under the same circumstances and conditions.

Sec. XLVII. Of Glass.

Glass, in the form of powder or dust, is used in fire-works. The pulverization of glass is easily performed. It may be done in an iron mortar, and passed though fine wire or brass sieves. It is used in the composition for wheels, in water balloons, cones, fire-pumps, slow white fire, &c.

Glass is nothing more than fused silica, made by exposing a mixture of silica and other substances to the action of a violent heat.

The quality of the glass depends on the proportion of silica, and the fluxes which are used in promoting its fusion; for the various kinds of glass, as white glass, green glass, bottle glass, &c. are all, in one respect, the same, though they differ in these particulars.

The glass of Saint-Gobin in France is made by fusing white sand, lime, soda, and broken inferior glass. The white goblet-glass is made of sand, potash, lime, and old glass; the quantity of potash is about fifty per cent. If green, or yellow, the colour is destroyed by the addition of black oxide of manganese; and hence that oxide is named *glass makers' soap*.

The common plate glass, for electrical machines, &c. is formed of sand, crude soda, old glass, and oxide of manganese. The bottle glass, made with the soda of marine plants, consists of sand, soda, common ashes, and old glass. Another bottle glass is made by melting common sand, black or yellow, with soda, wood-ashes, clay, and broken glass. It appears from the use of the substances which enter into, and compose, glass, that its quality is owing to the materials employed. The crystal or flint glass is a finer kind. The substances, with the proportions in which they are used, are the following: [211]

	Parts.
White sand,	100
Red lead,	80 to 85
Calcined potash (pearl-ash,)	35 to 40
Refined nitre,	2 to 3
Black manganese,	0.06

To this composition, there are sometimes added:

	Parts.
White arsenic,	0.05 to 0.1
Crude antimony,	0.05 to 0.1

The specific gravity of this glass is 3.2. Goblets, lustres, &c. are made of it.

Flint glass, according to the English formula, is made of

Purified Lynn sand	100 parts.
Litharge or red lead	60
Purified pearlash	30

To this is added black manganese, to correct the colour, and sometimes nitre and arsenic.

Plate glass is formed of

Pure sand,	43.0 parts.
Dry carbonate of soda,	26.5
Pure quicklime,	4.0
Nitre,	1.5
Broken plate glass,	25.0
	———
	100.

Crown, or fine window glass, is composed of

Fine sand,	200 lbs.
Best kelp, ground,	330 lbs.

To this is added, if the vitrification is not complete, some muriate of soda. Good glass, according to Pajot des Charmes, may be made by fusing equal parts of carbonate of lime, sand, and sulphate of soda. The glass is clear, solid, and of a pale yellow. Professor Scheweigger found, that the following proportions were the best:

Sand,	100
Dry sulphate of soda,	50
Dry quicklime in powder,	17 to 20 [212]
Charcoal,	4

Broad glass is made of a mixture of soap-boilers' waste, kelp, and sand. Two of waste, one of kelp, and one of sand are the proportions generally employed. Common bottle glass is usually made of waste and river sand, to which lime, and clay, and common salt are occasionally added.

The coloured glasses are produced by various metallic oxides. The colour and beauty of precious stones are thus imitated. These colours are communicated by sundry metallic preparations, as the following: The purple powder of Cassius, with oxide of manganese, will give a red or purple according to the proportions used; zaffre, an oxide of cobalt, a blue; a mixture of oxide of cobalt, muriate of silver, or glass of antimony, a green; and oxide of manganese, a violet, &c.

The basis of all artificial precious stones, is composed of what is called glass-paste, a compound of silica, potash, borax, red lead, and sometimes arsenic. These substances are melted together. The glass, which forms the body of the artificial gem, is pulverized, and the colouring substances are blended with it by sifting; and then the whole must be carefully fused, being left on the fire for from 24 to 30 hours, and cooled very slowly. The following proportions are used for this purpose:

Pastes.	1.	2.	3.	4.
Rock crystal,	4056	gr. ——	3456	360
Minium,	6300	——	5328	——
Potash,	2154	1260	1944	1260
Borax,	276	360	216	360
Arsenic,	12	12	6	——
Ceruse of clichy,	—	8508	——	8508
Sand,	—	3600	——	——

Topaz.	No. 1,	No. 2.
Very white paste,	1008	3456
Glass of antimony,	43	——
Cassius purple,	1	——
Peroxide of iron, (saffron of Mars,)	—	36.

Ruby. Paste 2880, oxide of manganese 72.

Emerald. Paste 4608, green oxide of copper 42, oxide of chrome 2.

Sapphire. Paste 4608, oxide of cobalt 68, fused for 30 hours.

Amethyst. Paste 4608, oxide of manganese 36, oxide of cobalt 24, purple of Cassius 1.

Beryl. Paste 3456, glass of antimony 24, oxide of cobalt $1\frac{1}{2}$.

Styrian garnet, or ancient carbuncle. Paste 512, glass of antimony 256, Cassius purple 2, oxide of manganese 2. [213]

The following recipes are given by M. Lancon:

Paste. Litharge 100, white sand 75, potash 10.

Emerald. Paste 9216, acetate of copper 72, peroxide of iron 1.5.

Amethyst. Paste 9216, oxide of manganese from 15 to 24, oxide of cobalt 1.

The ancient coloured glass has been much admired. The art was carried to a very great extent. Even in Pliny's time, the highest price was set upon glass entirely free from colour. He, as well as others, mentions that hyacinths and sapphires were imitated very exactly.

The emperor Adrian received as a present from an Egyptian priest, several glass cups richly ornamented with various coloured glass. Seneca speaks of the knowledge of Democritus in this art. Porta, Neri, and others, in modern times, have treated the subject in a more enlarged manner. Coloured glass was used for ornament; but Pollio relates, that Gallenius punished an impostor for selling to his wife a piece of glass for a jewel. In the *Museum Victorium* at Rome, are several ancient artificial gems, such as the chrysolite and emerald. What materials the ancients used for colouring glass is not known. Gmelin, however, observes, that it is probable they made use of iron, by which, he adds, not only all the shades of red, violet and yellow, but even a blue colour might be communicated. Cassius discovered the powder which bears his name. He was a physician, and resided at Lubec.[22] This powder was employed by the German artists. While noticing this subject, it may be proper to state, that Libavius (*Alchemy*, 1606,) gives a process for making ruby glass. Neri, (*ars vitraria* by Kunkel,) was acquainted with the gold-purple and its use. Glauber (*Furnus Philosophicus*, 1648) mentions the use, and gives the preparation of the powder. Kunkel made artificial rubies in great abundance, and a cup of ruby glass for the elector of Cologne. In 1679, he was inspector of the glass houses at Potsdam; and, in perfecting the art, he expended 1600 ducats, which the elector of Brandenburgh gave him for the purpose. [214]

M. Brongniart has lately made many experiments on the subject of staining glass. The colours, however, are the same as we noticed. A green glass may be made by putting on one side of the glass a blue, and on the other a yellow. A black glass may be made by a mixture of blue with the oxides of manganese and iron. Painting on glass is an ancient art. When pieces of old painted glass are examined, they have always on one side a transparent red *varnish* burnt into them. The moderns, however, excel in this art.

Glass is not acted upon by the acids, except the fluoric or hydrofluoric. Hence the acid of Derbyshire spar, which is a fluate of lime, is used for etching on glass, in the same manner as nitric acid is, on copper. Fluoric acid, a compound of fluorine and hydrogen, is decomposed during this action, and is changed, by the union of its fluorine with silicon, into the silicated fluoric acid.

When a quantity of alkali is used just sufficient to fuse silica, glass is the result; but when the quantity is greater, as three or four to one, the fused mass is soluble in water, and then forms the silicated alkali, or liquor of flints. From this the silica is obtained in a pure state, by the addition of an acid.

Glass, when melted and dropped into water, assumes an oval form, with a slender projection, called a tail. This is called Prince Rupert's drop. If a small part of this tail be broken off, the whole bursts into powder, with a kind of explosion. The Bologna, or philosophical phial, is a small cylindrical vessel of glass, rounded at the bottom, but open at the upper end. It is made thick at the bottom, so as not to be easily broken; but if a pebble be dropped into it, it immediately cracks, and the whole falls into pieces. In both these, (the drop and the bottle,) the glass is unannealed. When the external part of glass is suddenly cooled, the inner part is kept, as it were, contracted. Now annealing, the process of tempering glass in an oven, renders the glass uniformly alike, and capable of sustaining the variations of temperature, without breaking. By a crack or fissure, the internal parts which remained in a state of tension, endeavour to recover the full state of expansion, and consequently the glass is rent asunder.

Sec. XLVIII. Glue and Isinglass.

Both glue and isinglass are animal products. They are used in fire-works, but always in the state of solution, as vehicles to mix up [215] compositions in order to make them unite, and to preserve them from falling to powder. The quantity, however, is never large, or either would destroy the effect. The proportions are generally prescribed. A solution of glue is employed in the old process for refining saltpetre. See *Nitre.* In making priming paste, isinglass dissolved in brandy is sometimes used.

Glue and isinglass owe their adhesive quality to the presence of gelatin; the most remarkable property of which is, that it unites with, and precipitates the tanning principle from its solution in water. For this reason, the use of oak bark and other astringent substances, in the tanning of leather, is obvious, the gelatin of the hide or skin, uniting with the tannin and forming tanned leather. Gelatin exists in bones, muscles, tendons, ligaments, membranes and skins. Skins, especially those of old animals, furnish the best and strongest glue.

For the preparation of glue, the parings and offals of hides, pelts, and the hoofs and ears of horses, oxen, calves, sheep, &c. are first digested in lime-water to clean them; then steeped in fresh water, which is suffered to run off; and being previously inclosed in a strong linen bag, are boiled in a copper cauldron with pure water. The impurities are removed as they rise. To the solution, alum, or finely powdered lime, is added. It is then strained through baskets and allowed to settle; after which, the clear fluid is again boiled. When it becomes thick, or of a proper consistence, it is poured into moulds or frames, when it concretes into jelly. It is cut into pieces by a spade, and then into thin slices by means of wire, and finally dried on coarse net-work.

The goodness of glue is known by its brittleness, and equal degree of transparency, without black spots. It swells up in cold water, and becomes gelatinous, but does not dissolve. It is a mark of want of *strength*, when glue dissolves in cold water.

Size is also a gelatinous substance, and is colourless and transparent. Eel skins, vellum, parchment, &c. are used in its preparation. They are treated in the same manner as hides. Isinglass, or fish glue, is a finer kind of gelatin, obtained from the air bladder and sounds of different kinds of fish of the *accipenser* genus; as the *sturio stellatus*, *huso ruthenses*, *&c.* The bladder, when taken from the fish, is washed and stripped of its exterior membrane, and then cut lengthwise and formed into rolls, or cut into strips. Isinglass dissolves in water with more difficulty than glue. A coarser kind of fish glue is made from sea wolves, [216] porpoises, sharks, cuttle fish, the sturgeon, &c. The head, tail, fins, &c. are boiled in water, and the solution evaporated. Isinglass is used for a variety of purposes, as the making of court plaster and size, the clarification of liquors, &c.

Isinglass is almost wholly gelatin. One hundred grains give ninety-eight of soluble matter.

Gelatin constitutes the greater part of the solid parts of animals, such as bone, ligament, muscle, membrane, skin, &c. and is always extracted by boiling them in water. We need hardly remark, that it constitutes the chief part of soup, which owes its nutritive qualities principally to its presence. The portable soup is nothing more than concrete gelatin, with other substances, as spices, salt, &c.; for it contains, in a small compass, the nutritive parts of beef, veal, and other animal substances, from which it may have been prepared.

Besides the use of water for extracting, or otherwise separating, the gelatin from bone, we may separate the phosphate of lime entirely from the latter, (as these two substances constitute the greater part of bone), by the action of dilute muriatic acid, which will dissolve the phosphate of lime, and leave the gelatin.

Sect. XLIX. Of Wood.

Of the kinds of wood, used for the preparation of coal, for the purpose of gunpowder, those should be preferred, which are light, and will give a tender charcoal. This subject was fully considered under that head.

But our intention, in noticing wood at this time, is, that it is employed in the composition of some fire-works in the form of saw-dusts, or raspings. Its use in fire-works may be considered, 1st, as producing a particular coloured flame: 2dly, as varying the character of the flame, and likewise the degree of the combustion; and 3dly, as communicating an agreeable odour along with other substances; as in odoriferous fire-works. To this, we may add its use in smoke-balls along with nitre and sulphur.

The raspings of wood are sometimes required to be extremely fine. This can only be done by employing sieves of different degrees of fineness. They should be preserved from the action of moisture.

In the composition of the new priming powder, of which chlorate of potassa is the basis, very fine raspings of a particular kind of [217] wood are employed. So is also lycopodium for the same purpose.

By the distillation of wood, as in the process of carbonization in iron cylinders, we obtain some volatile products, the chief of which is the pyroligneous, now called the pyroacetic acid, while the ligneous fibre is converted into coal; but, in the combustion of wood, all the volatile products are expelled, some being consumed in the flame, and others, with some carbon, condensed in the form of soot, while the residue is an ash which furnishes common potash.

Ovid in his Metamorphoses, fable xvi, says—"Adomitis Athamanis aquis accendere lignum narratur; minimos cum luna recessit in orbes." This idea we know is groundless; for it is impossible, that wood, sprinkled with water, whether the waters of Athamanis, or any other, should be kindled when the moon is in the decrease, or at any time of the moon's age.

To prevent the action of fire on wood, marine salt, vitriol, and alum have all been used. Various ways of employing them have been adopted; but they do not absolutely prevent wood taking fire in an active heat. For the same purpose, (*Coll. Academ.* tome xi, p. 487,) a mixture of green vitriol, and quicklime is recommended, by which we form sulphate of lime and oxide of iron. The *Journal de Paris* of 1781 contains various processes. At Vienna, saline substances are employed.

The combustion of wood is the same, in all cases, in which oxygen is concerned; but the products in some particulars may vary. Hence saw-dust, when mixed with nitrate of potassa, and inflamed, will burn, and produce little or no smoke, because the combustion is rapid and perfect; but when employed with sulphur and nitre, it produces much smoke. Here the oxygen is furnished by the nitre, and carbonic acid gas is formed. The same thing takes place, when a mixture of saw-dust and nitre is used in artificial fire; and, according as the decomposition is more or less rapid, the combustion will be so likewise. The particular applications of saw-dust will be noticed hereafter.

With respect to *lycopodium* or puff ball and various species of agaric, or the medullary excrescences of trees, which are used in some preparations of artificial fire, we may observe, that the first is confined principally to theatrical fire-works, and the second to the preparation of spunk, or tinder, called also pyrotechnical sponge. See *Pyrotechnical Sponge.*

As to the substance usually called *lightning wood*, found in the hollow of the stumps of trees, and sometimes on the surface, [218] which, from having lost its compactness and other characters of ligneous fibre, is called *rotten* wood, it is in fact the solid part of the wood in a state of decomposition, in consequence of which, it becomes a *solar phosphorus*. It appears to owe its phosphorescent property, i. e. its power of shining in the dark, to the previous absorption of light, and not, as some have suggested, to the presence of phosphorus, or the emission of any gaseous compound, which contains it. The process of animal putrefaction will produce such appearances, but, in this case, the cause is different.

Turf or peat, a substance found, and employed as fuel, in some countries, and found in boggy situations, is partially decomposed vegetable matter, consisting of a congeries of fibres or roots. But black mould is the result of a decomposition of vegetable substances, in which the ligneous fibre is carbonized, and mixed with earth. The formation of mould, however, is owing more to the decay of leaves &c. (See *Coal.*)

Dr. Shaw (*Travels to the Holy Land*) observes, that when they were either to boil or bake, camel's dung was their common fuel; which, after being exposed a day or two in the sun, catches fire like touch-wood; and burns as light as charcoal.

Sec. L. Of Linseed Oil.

Linseed, or flaxseed, oil is obtained by expression from flaxseed. It is a thick mucilaginous oil, when first extracted, called *raw* oil, and in this state, is seldom used. The preparation, it undergoes before it is used as drying oil for mixing with paints, is nothing more than boiling it with litharge, or some oxide of lead, which separates the mucilage, and unites with the oil. By this treatment, it acquires the property of drying with facility, when exposed to the atmosphere.

Linseed oil unites with great ease with oils, tallow, fat, wax, &c. Some of these compositions are used in fire-works. A preparation of pitch, mutton suet, and linseed oil is used, for instance, in preventing the access of moisture to fuses; and in military fire-works, it is employed in combination with pitch, rosin, mutton suet and turpentine for incendiary works. Wax, and tallow, we may here add, are also used in the preparations of similar works.

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Sec. LI. Of Gum arabic, and Gum Tragacanth.

Gum arabic, which exudes from a tree that grows in Egypt and Arabia (*Mimosa nilotica*) when pure is transparent, and nearly colourless. There are several varieties of this gum; the *gum senegal*, for instance, which is of a reddish colour, and occurs in larger pieces. Other mucilaginous substances, the peach tree gum, the cherry tree gum, &c. which exist only in small quantities, are analogous to the gum of the Mimosa.

Gum arabic is brittle, and for that reason may be easily reduced to powder. It is readily dissolved in water, with which it forms mucilage. In this state, it is employed in fire-works, chiefly as a vehicle for the mixing of pastes, matches, &c.

Gum is a vegetable oxide, composed of carbon, hydrogen, and oxygen. It does not crystallize. It is precipitated by some metallic salts, as acetate of lead. It is insoluble in alcohol, which distinguishes it from resins. Nitric acid decomposes it, and changes it into the saclactic or mucous acid. With sugar, the same acid produces oxalic acid.

Gum tragacanth, or gum dragon, is the produce of a thorny shrub, which grows in Candia, and other islands of the Levant, called *astragalus tragacantha*. The gum obtained from this shrub has many properties in common with gum arabic, and is, therefore, used as a paste. It dissolves readily in boiling water; but is insoluble in alcohol, or ether.

It consists, almost entirely, of a peculiar vegetable principle, which is called *cerasin* by Dr. John. Cerasin has the adhesive qualities of gum arabic, but in a greater degree. It is said to constitute a part of the gummy matter, that exudes from the *prunus cerasus*, *prunus avies*, *prunus domestica*, &c.

Sec. LII. Of Cotton.

The soft down, which envelopes the seeds of different species of *gossypium*, or cotton plant, is the cotton of commerce. These plants are natives of warm climates. Cotton when bleached is perfectly white. It is extremely combustible, and burns with a clear lively flame. The ashes left behind contain potash.

Cotton is the substance, usually employed in making match rope, for the communication of fire. It has also other uses in pyrotechny. Cotton match is much used in fire-works for exhibition, not only for single cases, but also for a series of cases of artificial fire, either for fixed or moveable pieces; and serves to communicate fire, either singly, or from one case to another, or to [220] the whole piece at one time. Matches, so used, are called leaders, and are generally confined in paper tubes.

Cotton is one of the best applications to recent burns. Applied to the part, it will, in a surprising manner, abate the violence of the pain, and remove the inflammation.

Cotton is soluble in alkaline ley. For some of the earths, it has a strong affinity, particularly alumina; as also for several metallic oxides, and tannin. The action of mordants, in dying of cotton-goods, depends on these affinities. Nitric acid converts it into oxalic acid.

Cotton wick for lamps, candles, &c. is rendered very inflammable by spirit of turpentine. By dipping the end of the wick in turpentine, the candle will inflame at once, the moment flame is applied. For candle-making, the wick is sometimes dipped in a solution of camphor in spirits, or in a melted mixture of camphor and wax. See *Candle.*

Sec. LIII. Of Bone and Ivory.

Bone, which is considered to be a combination of phosphate of lime, gelatinous matter, animal oil, &c. is used occasionally in fire-works. By destructive distillation, bones, or osseous matter, afford ammonia, Dippel's animal oil, &c.; and, when consumed by fire, leave a white ash, which is composed principally of phosphate of lime. Bone-ash is the result of the combustion of bone; for, while all the gelatinous substance, oil, &c. are burnt off, that, which composes the basis of bone, and which distinguishes it from *gristle*, remains in the form of ash. Bone-ash furnishes phosphorus by a certain process. See *Phosphorus.* Diluted muriatic acid will take up the phosphate of lime of bone and leave the gelatin. This mode is recommended for the separation of gelatin from bone.

Bones, when carbonized in the same manner as wood, furnish what is called *bone-black*, but commonly known by the name of *ivory-black*. It is nothing more than animal charcoal.

In Pyrotechny, bone, in the form of raspings, is employed to communicate a *lustre* to the flame of gunpowder; but, for this purpose, the most compact, and that, which contains the least gelatin, is usually employed. Hence *ivory* is preferred. Ivory, in the form of raspings, communicates to flame a bright silver colour; and, on that account, is preferred to all other kinds of bone. The compositions, into which it enters, will be mentioned in a subsequent part of the work.

Ivory is the tusk, or tooth of defence, of the male elephant, and is an intermediate substance between bone and horn, not capable of being softened by fire. The finest and whitest ivory comes from the island of Ceylon. The tooth of the sea-horse is said to approach to ivory, properly so called. It is, however, harder, and, for that reason, preferred by dentists for making artificial teeth. The coal of ivory is remarkably black; but the so called ivory-black, sold in the shops, is nothing else than bone-black. [221]

Bone and ivory may be stained of various colours. One hundred parts of ivory contain,

Gelatin,	24
Phosphate of lime,	64
Carbonate of lime,	0.1

One hundred parts of ox-bone gave

Gelatin,	51
Phosphate of lime,	37.7
Carbonate of lime,	10
Phosphate of magnesia,	1.3

Berzelius, however, detected in bone-fluate of lime, muriate of soda, and uncombined soda. Albumen is most generally present. One hundred parts of bone are reduced by calcination to sixty-three. One hundred parts of human bone afforded Berzelius 81.9 phosphate of lime, 3 fluate of lime, 10 lime, 1.1 phosphate of magnesia, 2 soda, and 2 carbonic acid.

Sec. LIV. Of Galbanum.

Galbanum is a gum-resin, obtained from the *bubon galbanum*, a plant peculiar to Africa. It is at first a juicy fluid, which exudes when the plant is cut above the root, and hardens by exposure to the air. Alcohol dissolves about three-fifths of it. It contains some volatile oil.

The only instance we know of, in which galbanum has been used in fire-works, is in the composition of rain-fire, employed as an incendiary, before the present *fire-stones* were invented. The rain-fire, which may be found in the fourth part of this work, it is said, gave rise to the composition of fire-stone. There is no advantage, however, in using galbanum for this purpose; since pitch, tar, turpentine, and many other substances are more inflammable, and, therefore, better adapted for such compositions. We mention it merely because it was one of the ingredients in that once celebrated incendiary preparation, the fire-rain of Siemienowicz.

Sec. LV. Of Tow and Hemp. [222]

In military fire-works, tow and hemp are much used, and principally for the preparation of incendiary works. Both tow and hemp are employed in forming match. Although old rope, &c. are used for immersion in the tourteaux, carcass, or fire-stone composition, which is readily imbibed, if the rope is untwisted and beaten; yet tow or hemp is a better material, and receives more of the composition. The manner of using it may be seen by referring to the composition for fire-stone. For very nice purposes, the tow or hemp should be well dressed. Flax is, therefore, to be preferred in such cases.

Sec. LVI. Of Blue Vitriol.

Different preparations of copper are used in fire-works, to communicate colour to the flame; and besides copper filings, brass filings, verdigris, and the oxides of copper, the sulphate of copper, or blue vitriol, has been employed. We may observe here, that there are three sub-species of this salt; the bisulphate, sulphate, and sub-sulphate, the first properly speaking being the blue vitriol of commerce.

The sulphate, although recommended in some of the old formulæ for coloured fire, is not, however, preferable to some other preparations of copper. The use and application of copper, and its preparations, will be seen in the article on coloured fire.

When sulphate of copper is heated, it is converted into a bluish-white powder. If the heat be increased, the acid is expelled, and the black oxide of copper remains. Before it is used, it is exposed to heat to expel the water of crystallization. It ought to be in the state of impalpable powder. It is composed of 33 acid, 32 oxide, and 35 water. It is decomposed by the alkalies and earths, the alkaline carbonates, borates, and phosphates, and several metallic salts.

The oxide may be obtained very readily from this salt, for the purpose of fire-works, by dissolving it in water, and adding a solution of caustic potassa; collecting the precipitate, and drying it in a moderate heat. This will expel the water that may be contained in it; as metallic precipitates, made in this way, are more or less in the state of hydrates.

When metallic copper is required, it may be obtained in fine powder, and very expeditiously, by immersing a plate of iron in a solution of any of the salts of copper, as the sulphate. It will precipitate on the iron, and gradually fall to the bottom of the vessel. [223] This metallic copper will be found to be much more impalpable than the filings, however fine, and, for that reason, may be mixed more accurately with different substances.

Copper burns with a beautiful green flame, and deposites a loose greenish-gray oxide. The ammonia-oxalate of copper, of which there are three sub-species, burns with flame.

Sec. LVII. Of Nitrate of Copper.

This preparation of copper is used in some fire-works. It communicates a green colour to flame. When combined with carbonaceous substances, the combustion is vivid. This is owing to the decomposition of the nitric acid, (in the same manner as the acid of nitrate of potassa and other nitrates is decomposed), during which carbonic acid and deutoxide of azote are produced. Nitrate of copper has been more particularly recommended for the preparation of match stick, similar to that of M. Cadet, and of match rope. It is used in the same manner as the nitrate of lead. M. Proust used it in lieu of nitrate of lead when repeating some experiments of M. Born. It is more expensive than the acetate, or even the nitrate of lead. Its effect, however, is the same.

Nitrate of copper attracts the moisture of the atmosphere, and deliquesces. Acetate of lead, on the contrary, by exposure to the air gradually effloresces, and in time is decomposed. The preparations of lead, for that reason, are preferable to the nitrate of copper.

Nitrate of copper is formed by dissolving copper in nitric acid; and, when the acid is saturated, the requisite quantity of water may be added. The salt may be obtained in a dry state by evaporation; and, after being dissolved in water, the wood or rope may be soaked in it.

Dry nitrate of copper, wrapped up in tin-foil, will produce no action; but, if water be added, sufficient to moisten it, and then the foil closed tightly, combustion will take place. The water promotes chemical action by dissolving the nitrate of copper, which is then decomposed by the tin, and the quantity of caloric, put in a distributable state, is sufficient to inflame the tin. The details of the rationale will be given hereafter.

The ammonia-nitrate of copper is fulminating copper. The chlorate of copper is a deflagrating salt. Ammonia added to nitrate of copper, first separates an oxide, and then dissolves it. It is more than probable, that nitrate of ammonia causes the ammonia-nitrate to explode. [224]

Sec. LVIII. Of Strontia.

The earth called strontia or strontian, is found abundantly in different parts of the world, in combination with carbonic and sulphuric acids. The carbonate of strontia or strontianite, effervesces with acids, and burns with a purple flame. It contains about 60 or 70 per cent. of earth. The sulphate of strontia, or celestine, contains about 57 of strontia.

When carbonate of strontia is mixed with charcoal powder, and exposed to a heat of 140° of Wedgwood's pyrometer, the carbonic acid will be expelled, and pure strontia remain. The earth may be obtained in a pure state, by dissolving the carbonate in nitric acid, and evaporating the solution until it crystallizes, and exposing the crystals, in a crucible, to a red heat, until the nitric acid is driven off. If the carbonate cannot be had, the sulphate may be employed. For this purpose, it is to be pulverized and mixed with an equal weight of carbonate of potassa, and boiled in water. The carbonate of strontia, thus obtained, which exists in the form of a powder, is to be treated with nitric acid as already described.

Strontia, like the other earths, is a compound body, having a metallic basis, called *strontium*, which, united with oxygen, forms the earth.

The specific gravity of strontia approaches that of barytes. Like pure barytes, it is soluble in water, forming strontia water. It requires rather more than 160 parts of water at 60° to dissolve it; but much less of boiling water.

The solution of strontia in water, when evaporated, will crystallize in thin, transparent, quadrangular plates, generally parallelograms, seldom exceeding a quarter of an inch in length. These crystals contain about 68 per cent. of water; and are soluble in little more than twice their weight of boiling water, and in 54.4 times their weight of water at 60°. When dissolved in alcohol, they give a blood-red colour to its flame. The solution of strontia changes vegetable blues to green. Strontia differs from barytes in being infusible, much less soluble, of a different form, weaker in its affinities, and not poisonous.

The metallic base of strontia, which was discovered by Sir H. Davy, in 1808, when exposed to the air, or when thrown into water, [225] rapidly absorbs oxygen, and is converted into strontia.

As strontia communicates a red colour to flame, it has been used in certain compositions of artificial fire. The brilliant red fire, sometimes used in theatres, owes its colour to this earth. See *Theatrical fire-works.* Muriate and nitrate of strontia will give a red or purple colour to the flame of alcohol. See *coloured flame of alcohol.*

If a piece of cloth be dipped in a solution of muriate, nitrate, or acetate of strontia, or in strontia water, and then immersed in alcohol, it will burn with a red flame.

M. Fourcroy, (*Système des Connaissances Chimiques, &c.* tome iii,) mentions the use of nitrate and muriate of strontia, in artificial fire-works, for the purpose of communicating a red colour to the flame of combustible bodies. Since that time, the nitrate, in particular, has been recommended and used.

One of the characters of the salts of strontia, is, that they give a red flame to burning bodies; whereas the salts of barytes or of lime, used in the same manner, communicate a yellow flame.

The saline combinations of strontia were examined with particular attention by Dr. Hope. See *Edinburg Philosoph. Transactions* for 1790.

Nitrate of strontia may be formed by dissolving carbonate of strontia, or the sulphuret obtained by decomposing the sulphate by charcoal, in nitric acid, filtering the solution, evaporating it, and suffering it to crystallize.

Nitrate of strontia deflagrates on ignited coals. Dr. Hope pointed out, that if nitrate of strontia be exposed to a red heat, and a combustible substance be, at this time, brought in contact with it, a deflagration, with a very vivid red flame, will be produced. When a crystal of this salt is put into the wick of a candle, it communicates a beautiful purple flame. It does not deliquesce in the air, and, therefore, the compositions, into which it enters, cannot spoil on that account. Nicholson (*Chemical Dictionary,*) observes, that nitrate of strontia may be used in the art of pyrotechny. For this purpose, however, it is mixed with sulphur, chlorate of potassa, and sulphuret of antimony; and sometimes with the addition of sulphuret of arsenic and charcoal, as in the *red fire* for theatrical uses.

The muriate of strontia has similar properties. Davy first observed, that when strontia was heated in chlorine gas, it gave out oxygen gas, and a chloride of strontium was formed.

Muriate of strontia is formed very readily, by dissolving the carbonate or sulphuret of strontia in muriatic acid, and evaporating [226] the solution in order to obtain crystals. These crystals are very soluble in water. They are soluble, also, in twenty-four times their weight of pure alcohol, at the temperature of 60°. This alcoholic solution, we remarked, burns with a fine purple colour. These crystals suffer no change when exposed to the air, except they be very moist; in which case, they deliquesce. When heated, they first undergo the watery fusion, and are then reduced to a white powder. Fourcroy recommends the muriate of strontia for fire-works.

Carbonate of strontia, when thrown in powder on burning coals, produces red sparks.

Acetate of strontia, another salt used in fire-works, is formed by dissolving strontia, or its carbonate, in acetic acid. It will crystallize. The crystals are not affected by exposure to the air. When heated, its acid is decomposed, as happens to all the other acetates.

Sec. LIX. Of Boracic Acid.

Borate of soda, or borax, is a salt, which has long been known, and is used chiefly in the arts as a flux for the fusion of bodies, and for soldering. Boracic acid is a compound body, consisting of a newly discovered substance, called boron, and oxygen. Homberg obtained the acid from borax in 1702, by distilling a mixture of borax, and sulphate of iron. He supposed that it was a product of the latter; and hence it was called the *volatile narcotic salt of vitriol*, or *sedative salt*.

Boracic acid forms two salts with soda; the borate, properly so called, and borax. It is supposed to be our borax, that Pliny mentions under the name *crysocolla*, so called by the ancients. Others, however, assert, that their crysocolla was nothing more than the rust of copper, triturated with urine. The impure borax in the East Indies, is called *tincal*. When borax is melted, and exposed for some time to heat, it loses its water, and is changed into what is known by the name of *calcined borax*.

The easiest process for obtaining boracic acid is to make a concentrated solution of borax in hot water, and add by degrees, sulphuric acid, which will unite with the soda; and, as the fluid cools, the boracic acid will separate in shining laminated crystals. No more acid should be added than is sufficient to make the solution slightly sour. The crystals are to be washed with cold water, [227] and drained upon brown paper.

One of the principal characters of boracic acid is, that it is very soluble in alcohol, to the flame of which it communicates a green colour. Paper dipped in this solution, burns in the same manner.

In consequence of this property of imparting a green colour to flame, I made some experiments with it, for the purpose of preparing *green fire*; and found, that, by employing it in the proportion of one-eighth, the flame was always green, provided that the flame of the combustible used, was not tinged of any other colour. Nitre, charcoal, and boracic acid will give a green; also nitre, lamp oil, and boracic acid; nitre, alcohol, and boracic acid, along with charcoal; and chlorate of potassa, charcoal, and boracic acid, with or without the addition of alcohol. But, although boracic acid communicates a lively green, its expense will prevent its use in that way, especially as many other preparations, as those of copper, will have the same effect, and are more economical on account of their price. See the *Coloured Flame of Alcohol, and Coloured Fire.*

Oils, when assisted by heat, will dissolve boracic acid. In naphtha, it is very soluble. With oils, it yields fluid and solid products, which give a green colour to the flame of alcohol. It is not a combustible acid, but only imparts colour to the flame of combustible bodies.

Boron will unite with fluorine, the radical of fluoric acid. When one part of vitrified boracic acid, two of fluate of lime or fluor spar, and twelve of sulphuric acid are distilled, an acid gas will be obtained, called fluo-boric gas. For the properties of boron, consult Thenard's *Traité de Chimie*.

PART II. [228]

INSTRUMENTS, TOOLS, AND UTENSILS.

CHAPTER I.

OF THE LABORATORY.

The laboratory for pyrotechny may consist of a building, furnished with furnaces, boilers, &c. for the preparation or refining of saltpetre, and other substances for use; but according to its present acceptation, it is a place where all kinds of fire-works are prepared, both for actual service and for exhibition; such as, besides the ordinary works for show, quick matches, fuses, port-fire, grape-shot, case-shot, carcasses, hand granades, cartridges, &c. It should have tables, benches, and closets, where the tools, paper, thread, &c. may be commodiously placed, and an adjoining room to contain a supply of materials for two days' work.

The chief artificer takes the weight of the materials made use of, attends to the weighing of the different substances, and sees that the mixtures are made properly, &c. He also keeps an account of the number and kinds of fire-works. The prepared fire-works ought to be removed daily to the magazine. If they are made up in the field, under a tent, (denominated the *Laboratory tent,*) they should be packed in barrels or in caissons.

Sec. I. Of Laboratory Tools and Utensils.

The following constitute the furniture and equipments of a laboratory:

Copper rods, to load port fires, and the fuses of shells, howitzers, &c.
Wooden formers, on which to roll the paper cases of the port fires.
Wooden formers, to roll the cases of rockets.
Balances, large and small, with weights, &c.
Buckets to carry water.
Boxes for loading priming tubes.
Barrels with leather tops, that draw, in order to keep grained and meal gunpowder.
Rods, or rammers for charging rockets.
Brushes to wipe the tables and sweep the compositions together. [229]
Frames to dry priming tubes.
Copper calibers to regulate the size of priming tubes.
Penknives.
Needles for piercing priming tubes in the direction of their length.
Fuse drivers.
Coopers' adzes.
A copper kettle.
Scissors for cloth and paper.
Paper cutters.
Priming wires.
Skimmers for skimming the froth of boiling saltpetre.
Funnels for charging port-fires, howitzers, shells, &c.
Square ruler.
Fuses for shells, &c. (or a lathe to make them.)
Large and small wooden bowls.
Small axes.
Ladles for charging the fuses of shells, port-fires, &c.
Mallets to hammer the fuses.
Glue pots and brushes.
Heavy mallets to beat the powder.
Tin measures, of different sizes.
Hand mortar.
Foot rules.
Rat-tail files to cleanse the interior of the reeds of priming tubes.
Wooden rasps.
Iron rulers, $^1/_2$ foot long.
Leather bags, in which gunpowder and charcoal are reduced to powder.
Pocket saws.
Pallet knives for saltpetre.
Tables, small ones to mix the composition; large ones with a ledge to meal the powder on.
Sieves, fine and common; of silk, and of hair.
Fuse drawers.
Tools for rolling cartridges.
Gimblets of different sizes.

The materials required more particularly for military fire-works, are:

Gunpowder.
Saltpetre.
Sulphur.
Charcoal.
Camphor. [230]
Beeswax.
Glue, rosin.
Cotton yarn for quick match.
Brandy or other spirits.
Gum arabic.
Linseed oil.
Spirits of turpentine.
Pitch.
Reeds or quills for priming fuses.
Mutton tallow.
Vinegar.
Thread for tying quick match.
Cartridge paper.
Thread, tow and spun yarn, to make match rope.
Cordage, to make tourteaux.
Flour to make paste.

The characters used to express certain substances employed in fire-works, are the following: (*James's Mil. Dict.* p. 101.)

M. means meal powder,
⊖. Saltpetre.
C. Z. Crude sulphur.
C. S. Sea coal.
S. x Steel or iron filings.
G. x Glass dust.
C. I. Cast iron.
X. Camphor.
B. L. Lampblack.
L. S. Lapis Calaminaris.
W. Spirits of wine.
P. O. Oil of spike.
∍. Corn powder.
Z. Brimstone.
C. + Charcoal.
B. R. Beech raspings.
B. x Brass dust.
T. x Tanners' dust.
C. A. Crude antimony.
A. Y. Yellow amber.
G. I. Isinglass.
. Gum.
S. T. Spirits of turpentine.

Sec. II. Of Mandrils and Cylinders for forming Cartridges and Cases.

The rollers or rods, on which cartridges are formed, ought to be solid, and perfectly straight and round. Very dry, sound wood should be selected, and when turned, the rod should be perfectly cylindrical; one extremity being concave, and the other convex.

Mandrils may be made of copper, which is preferable to wood, as this is apt to warp and crack; and in both cases, should be longer than the cartridge, so as to be drawn out easily. They are of different lengths and diameters, according to their respective uses.

Sec. III. Of Rammers, Chargers, and Mallets. [231]

The rammers which are used for compression, are cylindrical like the preceding. They have a head much larger in dimensions than the part that enters the tube. (See A, B, C, D, and E of Fig. 1. in the Plate). Besides being made of wood, which should be of the hardest kind, as *lignum vitæ*, they may be formed of copper or brass. In this case, they are first cast of the requisite size and shape, and finished in a lathe. Wooden heads are sometimes put to them, but with little advantage; as they frequently split and require to be renewed.

The wooden rammer may be struck with metal; but when the rammer is of copper or brass, wooden mallets must be always employed.

We may here remark, that in charging rockets, it has been customary to employ several rammers. The first *drift* must be six diameters from the handle, and this, as well as all other rammers, ought to be a little thinner than the former, to prevent the tearing of the paper, when the charge is driven in. In the end of this rammer is a hole to fit over the piercer. (See B. Fig. 1.) The line marked on this rammer, as will be explained hereafter, when it appears at the top of the case, indicates that a second rammer must be used. This second rammer, from the handle, is four diameters, having a hole for the piercer, $1\frac{1}{2}$ diameters long. (C. Fig. 1.) When the case is filled as high as the top of the piercer, a short and solid drift is used. (E. Fig. 1.).

Rammers must have a ferrule, or collar of brass at the bottom, to keep the wood from spreading, or splitting. With regard to the handles of the rammers, if their diameter be equal to the bore of the mould, and two diameters long, the proportion is a good one. The shorter they can be used, the better. The longer the drift, the less of course, will be the pressure on the composition, by the blow given by the mallet.

We may observe here, that rockets may either be driven over a piercer, or driven solid, and afterwards bored.

As much of the effect of rockets depends upon the manner they are driven, whether lightly or compactly, or uniformly throughout, circumstances which affect their quality; it is necessary, in using the rammer, to employ an equal force for driving the composition. The mallet, therefore, should be of a given weight; and a certain number of strokes with the same force, on each new charge, must be accurately followed, until the driving is completed; taking care, at the same time, that the rocket stands firm on a [232] solid body.

Dry beech is the best wood for mallets. A writer very judiciously observes, in the *Encyclopedia Britannica*, (vol. xv, 695), that, if a person uses a mallet of a moderate size, in proportion to the rocket, according to his judgment, and if the rocket succeeds, he may depend on the rest, by *using the same mallet*; yet it will be necessary, that cases of different sorts, be driven with mallets of different sizes. In all cases, under one ounce, the charge may be rammed with an ounce mallet.

There is an advantage, also, by having the handle of the mallet turned out of the same piece as the head, and made in a cylindrical form. If their dimensions are regulated by the diameters of the rockets; then, for example, if the thickness of the head be three diameters, and its length four, the length of the handle will be five diameters, whose thickness must be in proportion to the hand.

Bigot (*Artifice de Guerre*, p. 118) speaking of the flying fuses, or sky-rockets, observes, that the mallet used for driving the composition, is proportionably large, according to the rockets, and that it is five inches in length, and four in breadth, when the diameter of the rocket is from 12 to 18 lines. The mallets for larger rockets are stronger and heavier, and, in some instances, where a great force is required, as in driving war-rockets, a machine similar to the pile-engine, is used. See *Congreve Rockets.*

Sec. IV. Of Utensils necessary for constructing of Signal Rockets.

A detailed account of the tools used in making signal rockets, may be seen in Ruggeri, *Pyrotechny*, p. 143; but M. Bigot has enumerated them as follows:

One mandril for forming the cartridge, or case.
One pair of curved compasses to determine the exterior diameter.
Three conical mandrils. (See fig. 3, plate.)
One solid, or massive cylinder.
One mould for garnishing.
Two moulds for the capitals, or heads, one of which is for the rockets with, and the other for the rockets without, the *garnish*, or furniture.
One piercer and block (See plate, fig. 1, I & H.)
One scoop. [233]
One punch.
One mallet.
One press.
One large knife.
One pair of scissors.

All the wooden utensils ought to be made of hard and sound wood, without knots. The rammers should be furnished with rings or ferrules, and the first bored with a hole of sufficient length to receive the piercer. The second should be bored deep enough to receive two-thirds of the piercer, and the third, to receive one-third, while the fourth should be solid. These rammers are all furnished with heads. (See section iii.)

Sec. V. Of the Rolling, or Plane Board.

This board is furnished with a handle, and is used for rolling rocket cases, &c. and is of different dimensions, according to its application. It is made of hard wood, such as oak or walnut.

When the paper is wrapped round the mandril or *former*, the rolling board is used to compress the paper, and make it round and smooth.

Sec. VI. Of the Driver for charging large Rockets.

This contrivance is similar to a pile driver in construction; and, by means of a weight falling upon the rammer, the charge is sent home with great force. Its use is confined to the largest kind of rockets.

Sec. VII. Of Mortars and Pestles.

Mortars are employed for the pulverization of substances, and, according to their use, may be either of wood, marble, brass, or cast-iron, which last costs less than the others. Large mortars have covers, in order to confine the finer particles. The pestles should be of very hard wood; because, in that case, no danger would be apprehended of an explosion of the materials, an occurrence which might take place, if iron were used. This, however, depends on the substances submitted to the pestle.

Sec. VIII. Of the Choaker or Strangler.

The choaker is nothing more than a contrivance, usually made of rope, by which the closing of the end of the rocket is effected, [234] so as to form a kind of cup or mouth.

Sec. IX. Of the Table and Sack for mealing Gunpowder.

This table may be either square or an octagon, and made of hard wood. There is a rim, a few inches high, raised round it, and a gutter at one end to allow the powder to pass out, when the operation is finished. See plate, fig. 7 and 8.

This mode of mealing powder is by no means to be preferred. (See *Gunpowder.*)

A sack is also used for crushing powder. It should be made of strong elastic leather, and sewed together in such a manner as to prevent the impalpable powder from passing through its seams. They are of an oblong shape, and contain from 20 to 25 pounds. Fifteen pounds are generally put in at a time. This method of crushing powder is preferred, as it is less liable to accidents. It is hardly necessary to add, that the bag is beaten with a cylindrical stick.

Sec. X. Of Sieves.

There are several kinds of sieve. The common sieve has neither a cover nor a receiver, and may be either formed of horse hair, or of brass or copper wire. It is necessary to have some sieves of a finer kind. For this purpose, silk and gauze are generally used. The cover is merely leather, fixed in a frame, which fits on the top. The receiver is formed nearly in the same manner, having a skin stretched over a frame, which fits on the under part of the sieve.

Sec. XI. Of the Paper Press.

A press, for the purpose of pressing paper, is formed of two pieces of wood, which are brought together by means of one, or several screws. This press is sometimes, though seldom, used. If pasteboard is made, when it cannot be had ready prepared, then the press is actually necessary. The intention is to unite the several sheets, which have been pasted, by using the pressure of the screw, and to remove any extraneous paste, so that the paper may have no inequalities on its surface. In lieu of the screw-press, heavy weights laid on the paper for several hours, will answer the same purpose.

CHAPTER II. [235]

Preliminary operations in the preparation of fire-works, and observations on the preservation of gunpowder, and sundry manipulations.

Sec. I. Of the Workshop.

We have already noticed the principal furniture of a laboratory, and, therefore, can add nothing new on this head. There are, however, some utensils employed for particular works, which we may here describe.

In the disposition of the workshop, the tables, utensils, &c. are arranged, according as the judgment may dictate for convenience and use. Care must be taken to prevent the access of fire, and to prevent, as far as possible, the presence of moisture. Lanterns, if light is required, are always to be preferred; but the best manner of communicating light is through a window, placing the lights outside of the building, or apartment, as is done in powder mills. Other precautions may be necessary, which will readily suggest themselves.

In conducting the work, the workmen are to be so arranged, as that, while some are employed in the preliminary operations, others are making and finishing the preparations. The compositions may be ready prepared, and well preserved in jars or other vessels. This is named by the French, *Cabinet de composition*. It is a place, also, where the substances are weighed, and mixed.

Sec. II. Of the Magazine.

The magazine is a place of deposite for gunpowder, to preserve it from fire, and moisture. We have already mentioned the preservation of gunpowder in the article on that subject; but it may not be improper to offer some remarks, respecting the construction of magazines.

Authors differ in opinion, both in regard to their situation and construction; but they all agree, that they ought to be arched, and bomb-proof. The first powder magazines were made with gothic arches: Vauban constructed them in a semicircular form, to make them stronger. Their dimensions were, sixty feet long, within, and twenty-five broad. The foundations were eight or nine feet thick, and eight feet high, to the spring of the arch. The floors were two feet from the ground, for the purpose of keeping the magazine free from dampness.

It is observed, that the centres of semicircular arches will settle at the crown, and their sinking must break the cement. A [236] remedy was applied for this inconvenience, by the *arch of equilibration*, as described in Hutton's work on bridges. As, in powder magazines, the ill effect of the breaking of the cement is particularly felt, Mr. Hutton proposed to find an arch of equilibration for them in particular, and to construct it, when the span is twenty feet, the pitch or height, ten, (which are the same dimensions as the semicircle), the inclined exterior walls at top, forming an angle of 113 degrees, and the height of their angular point, above the top of the arch, equal to seven feet.

A wall built round a magazine, gives it an additional security. The roof should be slated, or covered with lead or copper, and it ought to be furnished with a lightning rod, placed ten or fifteen yards from the building. The points of the rods may be either gilt, or of solid gold. Silver, however, is generally used; but, above all, platinum is to be preferred. The advantage of these points is, that they do not rust like iron, or become oxidized, an occurrence which would diminish their powers as conductors of the electric fluid.

To prevent the access of moisture, or rather to absorb it, some have recommended the inner walls to be covered with a composition of powdered coal, &c. Lining of magazines with sheet lead, appears to have some advantages.

St. Pierre observes, that a Prussian officer informed him, that, having remarked that vapour was attracted by lead, he had employed it for drying the atmosphere of a powder magazine, constructed under ground, in the throat of a bastion, rendered useless from its humidity. He ordered the concave ceiling of the arch to be lined with lead, where the gunpowder was deposited in barrels: the vapour of the wall collected in drops on the leaden roof, ran off, and left the gunpowder barrels perfectly dry.

Sec. III. Of the Driving or Ramming of Sky-rockets.

We purpose in the present article to give some general directions for the driving of rockets.

Rockets may be driven solid, or over a piercer. In the latter case, they must not have so much composition put in them at a time. The piercer, accompanying a greater part of the bore of the case, would cause the rammer to rise too high; so that the pressure of it would not be so great on the composition, nor would it be driven equally. For rockets rammed over a piercer, let the ladle, or [237] copper scoop, hold as much composition, as, when driven, will raise the drift one-half the interior diameter of the case; and, for those driven solid, let it contain as much as will raise the drift one-half the exterior diameter of the case. Ladles are generally made to go easily into the case, and the length of the scoop is about one and a half of its own diameter.

The charge of rockets must always be driven one diameter above the piercer, and, on it, must be rammed, one-third of a diameter of clay; through the middle of which a small hole must be bored to the composition, so that, when the charge is burnt to the top, it may communicate its fire, through the hole, to the stars in the head. (See plate, fig. 14.) Great care must be taken to strike, with the mallet, with an equal force, giving the same number of strokes to each ladleful of composition; otherwise the rocket will not rise with a uniform motion, or burn equally and regularly, for which reason, they cannot carry a proper tail. It will break, in this case, before the rocket has ascended to its extreme height, where the rocket should break and disperse the stars, rain, or whatever is contained in the head. When in the act of ramming, the drift or driver must be kept constantly turning or moving; and when the hollow rammers are used, the composition is to be knocked out every now and then, or the piercer will split them. To a rocket of four ounces, give to each ladleful of charge, 16 strokes; to a rocket of 1 lb. 28; to a 2 pounder, 36; to a 4 pounder, 42; to a 6 pounder, 56. But rockets of a larger sort cannot be driven by hand, and must be rammed with a machine similar to a pile-driver.

The method of ramming wheel cases, or any other sort, in which the charge is driven solid, is much the same as that used for sky-rockets; for the same proportion may be observed in the ladle, and the same number of strokes given, according to their diameters, all cases being distinguished by their diameters. In this manner, a case, whose bore is equal to that of a rocket of four ounces, is called a four ounce case; and one which is equal, in bore, to an eight ounce rocket, an eight ounce case, &c. The method of ramming cases, without moulds, will answer for strong pasted cases, and save the expense of making so many moulds. In filling any case, it must be placed on a perpendicular block of wood, in order to keep it firm and solid; otherwise the composition would be rammed unequally.

When cases are to be filled without moulds, procure some nipples, made of brass or iron, in proportion to the cases, to screw or [238] fix in the top of the driving block. When the nipple is fixed in, make, at about one and half inches from it, a square hole in the block, six inches deep, and one inch in diameter. Then have a piece of wood, six inches longer than the case intended to be filled, and two inches square. On one side of it, cut a groove, almost the length of the case, whose breadth and depth must be sufficient to cover near one-half the case. Then cut the other end, to fit the hole in the block; but take care to cut it, so that the groove may be at a proper distance from the nipple. This half mould being made, and fixed tight in the block, cut, in another piece of wood, nearly of the same length as the case, a groove of the same dimensions as that in the fixed piece. Then put the case on the nipple, and, with the cord, tie it, and the two half moulds together; and the case will be prepared for filling. The dimensions of the above half moulds are proportionable for cases of eight ounces; but they differ in size in proportion to the cases.

Sec. IV. Of the Boring of Rockets.

The machine, for boring rockets, is similar, in some respects, to a lathe. The rocket is confined in a box, and, by means of a wheel, which is made to turn a second one, an auger rammer is put in motion. The rammer must be of a size, proportionate to the rocket, and of the same diameter, as the top of the bore intended, and continue of that thickness, a little longer than the depth of the bore required. The thick end of each *rammer* must be made square, and all of the same size. The rammer is made to move backward, and forward, so that, after the rammer is marked three and a half diameters of the rocket, from the point, set the guide, allowing for the thickness of the front of the rocket box, and the neck and mouth of the rocket. When the rocket is fixed in the box, it must be pushed forward against the rammer, and, when the scoop of the rammer is full, draw the box back, and knock out the composition. A little oil is sometimes used, to prevent the friction from setting fire to the rocket. Having bored a number of rockets, taps must be used. These taps are similar to the common spicket. When employed, it is necessary to mark them three and a half diameters from the point, allowing for the thickness of the rocket's neck.

There are several contrivances for the boring of rockets. The operation is sometimes done, by confining the rocket in a box, and [239] boring it with a borer, fixed in a brace, using, at the same time, a proper director. This brace is like the common *brace*, used by carpenters, or formed on that principle, and made of iron. The motion, given by the hand, performs the operation.

Sec. V. Of the Preservation of Steel or Iron Filings.

When treating of iron, we mentioned, that it has the property of oxidizing rapidly, when exposed to the air and moisture; and that its effects in fire-works, in that case, would be either destroyed, or considerably diminished. And even fire-works, in which iron enters as a component part, will, if kept long, lose some of their effect, in consequence of the change, which the iron suffers; for, instead of producing brilliant sparks, which is their intention, it would impart a dull red appearance.

Two methods are recommended for the preservation of iron. The one is to melt a portion of sulphur, and throw the filings into it, and afterwards to separate the extraneous sulphur. The other consists in wrapping them up in oiled paper. As to the first method, we may apprehend the effect of the sulphur, combining with some of the iron, instead of coating it, forming thereby a sulphuret, which, besides, is readily decomposed by the contact of air and moisture, producing sulphate of iron. The second method, of wrapping them in oil, or, in fact, covering them with oil, is certainly a greater preventive from rust, for where the oil is in contact, no oxidizement can take place.

There are several methods recommended to preserve iron-work from rusting. The use of paint and varnish for this purpose is familiar. In Sweden, they cover iron-work with a mixture of pitch, tar, and wood soot, which acquires a gloss, similar to that of varnish, and is said to prevent the oxidizement of the metal very effectually. Fat-oil varnish, mixed with four-fifths of rectified spirit of turpentine, has been recommended. It is applied with a brush, or sponge. Articles, varnished with this preparation, are said to retain their metallic brilliancy, and never contract any spots of rust. Another composition, for the same purpose, is highly recommended. It consists in applying a mixture of one pound of hogs' lard, free from salt, one ounce of camphor, two drachms of black lead in powder, and two drachms of dragon's blood. At Sheffield and Birmingham, sundry articles, made of steel and iron, are preserved from rust, when sent to foreign markets, by wrapping them in coarse brown paper, prepared first with oil. [240]

Among the different preparations, recommended at various times to prevent iron from contracting rust, we may mention one, which has been used with success, and which gives a lead colour. It is nothing more than taking some litharge, and heating it in an iron pot, and scattering over it some sulphur. The litharge will change its colour, forming a kind of sulphuret of lead, which is then ground with drying oil, and applied like paint. We are told, that this preparation gets remarkably hard, and resists the weather more effectually than any other lead colour.

Sec. VI. Of the making of Wheels and other Works incombustible.

It is usual to give a coat of paint to the wood-work of wheels, &c. which are designed to carry a number of cases. To prevent their taking fire, paint, in some measure, has the effect. The following composition is recommended: Take brick dust, coal-ashes, and iron filings, of each an equal quantity, and mix them with a double size, made hot. Apply this to the wood, and when dry, give it another coat.

Several methods have been adopted for the same purpose; but wood may be made to resist, in a great degree, the action of fire, and rendered almost incombustible, by soaking it in a solution of the supersulphate of potassa and alumina, (alum), in sulphate of iron, (green vitriol), and in other salts, which are incombustible.

With respect to the use of alum as a preservative against fire, it is certain, that, although its use in this way is very ancient, it was not often recommended; for writers on the art of war, such, for example, as Anas, mentions the use of vinegar, in the following quotation from his *Poliorcet.* cap. 24: "Majus juverit, si prius ligna aceto linantur; nam a materia aceto illita, ignis abstinet."

The use of alum, to prevent substances from taking fire, is not a new invention; notwithstanding we find it recommended in modern works, not only for wood, but also for paper, and linen and cotton dresses, &c. Aulus Gellius relates, that Archelaus, one of the generals of Mithridates, washed over a wooden tower with a solution of alum, and thereby rendered it so much proof against fire, that all Sylla's attempts to set it in flames proved abortive.

A writer in the *Anthologia Hibernica*, vol. iii, for 1794, observes, that the use of alum to prevent the action of fire, on wood, or [241]
other combustible bodies, is not new, and those, who lay claim, are not entitled to originality on that head.

Another mode to prevent wood from taking fire may also be adopted. It consists in mixing together, one ounce of sulphur, one ounce of red ochre, and six ounces of green vitriol. The wood work is covered with joiners' glue, and the mixture is then put over it. This process is to be repeated three or four times, allowing the glue to dry before a new coat is applied.

There are several other preparations for the same purpose, not only for the covering of wood, but also paper. But M. Ruggeri is of opinion, that they cannot be depended upon, when used on paper; for the paper will, in part, be consumed. The formula for one of these compositions, is thus given by that gentleman: To a pound of flour, mix a handful of powdered alum, and add to it strong glue-water, and bring it to a proper consistence with clay. Flour and glue-water, mixed together, with the addition of a small quantity of muriate of soda, (common salt), is also recommended for the same purpose. Wood, steeped in a solution of common salt, so as to be thoroughly impregnated with it, is very difficult of combustion. In Persia, salt is used to prevent timber from the attack of worms. The practice of *salting* ship timber is highly recommended.

Wood, in fact, may be rendered incombustible by several processes, some of which we have given. Earl Stanhope, among others, made some interesting experiments on this subject.[23]

Having thus given some of the modes, usually adopted to render wood incombustible, or to prevent its taking fire so
instantaneously, we purpose to add some remarks respecting the processes for colouring it. An excellent preservation against [242]
moisture, which communicates a colour at the same time, is formed of 12 lbs of rosin, 3 lbs of sulphur, and 12 pints of whale oil, melted and mixed with a sufficient quantity of red or yellow ochre, and applied by means of a brush. Pulverized black lead may be substituted for the ochre. Several coats of this mixture may be put on, allowing each coat to dry before another is applied. This composition is particularly well adapted for wheel work, &c. and for aquatic fire-works. Chaptal advises, for the same purpose, a mixture of equal parts of white turpentine, bees' wax, and maltha, or, in the place of maltha, coal tar. Wood, covered with three coats of this composition, and immersed for two years in water, was found to be quite dry. It would be well, however, to cover it with some of the preparation, to render wood incombustible.

With respect to the staining of wood of various colours, several preparations may be used. To communicate a green colour, a hot solution of acetate of copper may be used; or verdigris, alum, and vinegar, boiled together. A decoction of brazil wood, with alum and cream of tartar, will impart a red; indigo, dissolved in sulphuric acid, (liquid blue dye), a blue; a decoction of logwood, nut-galls, and copperas, a black; a solution of dragon's blood, or of alkanet wood, in turpentine, a mahogany colour, &c. The imitation of bronze on wood may be effected, by covering it first with isinglass size, then suffering it to dry, and putting on a coat of oil gold size, and covering it with bronze powder, a preparation sold for that purpose. A solution of aloes in spirits, which communicates a greenish-black, is a great preservative of wood against worms.

M. Ollivier (*Archives des Découvertes*, v, p. 386) has given a variety of recipes for imitating bronze, stone, &c. He recommends the following for the imitation of ancient bronze, which may be applied to wood-work. Melt together 150 lbs of fine sand, 170 lbs of lead ore, (Galena), and 30 lbs of manganese, and add one-sixth part of brass. This compound is then pulverized. It is applied on the usual ground.

Black earth, as it is called, made of green earth, oxide of manganese, oxide of iron, and oxide of copper, is also recommended for covering wood-work. The composition for *imitation marble*, is 1 part of green earth, $^1/_2$ a part of sand, and $^1/_8$th of a part of bol. armen. By adding $^1/_{14}$th part of *yellow burnt copper*, the colour will approach to green. The same composition, with $^1/_{16}$th part of copper, and $^1/_{32}$d iron, will give a black.

Sec. VII. Of the formation of Rocket, and other Cases. [243]

The cases for rockets, as a general rule, are to be made $6^1/_2$ times their exterior diameter in length; and all other cases, that are to be filled in moulds, must be as long as the moulds, within a half of the interior diameter. Rocket cases, from the smallest, to 4 or 6 pounds, are generally made of the strongest sort of cartridge paper, and rolled dry; but the large sort are made of pasted pasteboard. (See observations on that subject.) As it is very difficult to roll the ends of the cases quite even, the best way is to keep a pattern of the paper for the different kinds of cases. These patterns should be longer than the case they are designed for, and the number of sheets required should be marked, which will prevent any paper being cut to waste. Cut the paper of a proper size, and the last sheet for each case, with a slope at one end; so that when the cases are rolled, it may form a spiral line round the outside; and that this slope may always be the same, let the pattern be so formed for a constant guide. Before you begin to roll, fold down one end of the first sheet so far, as that the fold will go two or three times round the former; then, in the double edge, lay the former with its handle off the table, and after rolling two or three turns, lay the next sheet on that which is loose, and roll it all on.

The smoothing board, which is about twenty inches long, is now to be applied; and after rolling the paper three or four times, lay on, in the same manner, another sheet of paper, and smooth it in the same manner. This operation is to be repeated till the case is sufficiently thick. When the last sheet is rolled, we must observe, that the point of the slope is placed at the small end of the roller.

The case being made, the small end of the former is put in, to about one diameter of the end of the case, and the end piece is inserted within a little distance of the former. Then give the pinching cord one turn round the case, between the former and the end piece. At first, pull easy, and keep moving the case, which will make the neck smooth, and without large wrinkles. This operation is called by the French *strangling*, or *choaking*. When the cases are hard to choak, let each sheet of paper (except the first and last in that part where the neck is formed) be a little moistened with water. Immediately after you have struck the concave stroke, bind the neck of the case round with small twine, which must not be tied in a knot, but fastened with two or three [244] hitches.

Having thus pinched and tied the case, so as not to give way, put it into the mould without its foot, and, with a small mallet, drive the former hard on the end piece, which will force the neck close and smooth. When this is done, cut the case to its proper length, allowing, from the neck to the edge of the mouth, half a diameter, which is equal to the height of the nipple. Then take out the former, and drive the case over the piercer with the long rammer, and the vent will be of a proper size.

Wheel cases are sometimes driven on a nipple, with a point to close the neck, and make the vent of the size required; which, in most cases, is generally 1/4th of their interior diameter. As it is very often difficult, when the cases are rolled, to draw the roller out, a hole must be made in its handle, and a pin, as a purchase, put in.

The machine for pinching cases consists of a treadle, which, when pressed hard with the foot, will act upon a cord, and draw it tight. The cord runs over a small pulley, and is fixed to an upright piece. It is wound once round the case, between the former and end piece; and when the cord is drawn, the case is brought together.

Cases are commonly rolled wet for wheels and fixed pieces; and when they are required to contain a great length of charge, the method of making these cases is thus: The paper must be cut as usual, except the last, which ought not to have a slope. Having it ready, paste each sheet on one side, and then fold down the first sheet as before directed; but be careful that the paste does not touch the upper side of the fold. If the roller be wetted, it will tear the paper in drawing it out. In pasting the last sheet, observe not to wet the last turn or two in that part where it is to be pinched; for if that part be damp, the pinching cord will stick to it, and tear the paper. Therefore, in choaking those cases, roll a bit of dry paper once round the case, before the pinching cord is used. This paper is to be taken off after the operation. The rolling board, and all other methods, according to the former directions for the rolling and pinching of cases, must be used for these, as well as other cases. See *Encyclopedia Britannica*, vol. xv, p. 692.

Morel, in a practical work, (*Traité Practique des Feux d'Artifice*) speaking of rocket cases, observes, that the rule is, to give to their thickness, half the interior diameter, or half the diameter of the roller. If the roller, for instance, were half an inch, the case [245] should be 1/4th of an inch in thickness. A rocket is divided into three equal parts; two for the interior diameter, and one for the thickness of the case.

As to the length of sky-rockets, it is regulated by the length of the piercer, if they are pierced in the charging. One-third more than this length is allowed for the *choak*, and the rest, of course, for the composition. With respect to other cases, Morel remarks, that the cases for turning pieces are usually six inches in length, and, for fixed pieces, seven and eight inches. The cases of *Roman candles*, are of the same thickness as those of rockets. In length they are, as well as the *Mosaic candle*, fifteen inches. They are choaked and cut.

Those of *serpents* are made with one or two cards, which are rolled upon a former of wood, or metal, 1/4th of an inch in diameter, and four inches in length. When made, the case measures three inches. Dry rolling is considered sufficient for these cases.

The *fixed stars* are made of common pasteboard, 3 1/2 inches long, on a mandril, 1/2 an inch in diameter. They are pasted with ordinary paste, but mixed with clay, and choaked, and bound as usual.

Sec. VIII. Of Tourbillon Cases.

This kind of case is generally made 8 diameters long; but, if very large, seven will be sufficient. From four ounces to two pounds, will succeed perfectly, but, when larger, there is no certainty. They are best rolled wet with paste, and the last sheet must have a straight edge, so that the case may be all of a thickness. After rolling them in the same manner as wheel cases, pinch them close at one end; then, with a rammer, drive the ends down flat, and, afterwards, ram in about one-third of a diameter of dried clay. The diameter of the former for these cases, must be the same as for sky-rockets. Tourbillons are to be rammed in moulds, without a nipple, or in a mould without its foot. (*Ency. Brit.*)

Sec. IX. Of Balloon Cases, or Paper Shells.

First, prepare an oval former, turned out of smooth wood; then paste a quantity of brown, or cartridge paper, and let it lie until the paste is quite soaked through. This being done, rub the former with soap or grease, to prevent the paper from sticking to it. [246] Next, lay the paper on in small slips, until you have made it one-third the thickness of the shell intended. Having this done, set it to dry; and when dry, cut it round the middle, and the two halves will easily come off: but, observe, when you cut, to leave about one inch not cut, which will make the halves join much better than if quite separated. When you have some ready to join, place the halves even together, and paste a slip of paper round the opening, to hold them together, and let them dry. Then lay on paper, all over as before, every where equally, excepting that end which goes downward in the mortar, which may be a little thicker than the rest; for that part, which receives the blow from the pounder in the chamber of the mortar, consequently requires the greatest strength.

When the shell is perfectly dry, burn a vent at the top, with an iron, large enough for the fuse. This method will answer for balloons from 4 inches 2/5ths, to 8 inches in diameter; but, if they are larger, or required to be thrown to a great height, let the first shell be turned of elm, instead of being made of paper.

For balloons 4 inches 2/5ths, let the former be 3 inches 1/8th, in diameter, and 5 1/2 inches long. For a balloon of 5 1/2 inches, the diameter of the former must be 4 inches, and 8 inches long. For a balloon of 8 inches, let the diameter of the form be 5 inches and 15/16ths, and 11 inches 7/8ths long. For a 10 inch balloon, let the form be 7 inches 3/16ths, in diameter, and 14 1/2 inches long. The thickness of a shell for a balloon of 4 inches 2/5ths, must be 1/2 an inch. For a balloon of 5 1/2 inches, let the thickness of the paper be 5/8ths, of an inch; for an 8 inch balloon, 7/8ths, of an inch; and for a ten inch balloon, 1 inch and 1/8th of an inch.

Shells, that are designed for stars only, may be made quite round, and the thinner they are at the opening, the better; for if they are too strong, the stars are apt to break at the busting of the shell. When making the shell, employ a pair of callipers, or a round gage; so that you may not lay the paper thicker in one place than other, and also that you may be able to know, when the shell is of a proper thickness. Balloons must always be made to go easy into the mortars. (See *Encycl. Brit. Art. Balloon cases.*)

Sect. X. Of Cases for Illumination Port-fires.

These must be made very thin, of paper, and rolled on formers; from 2 to 3/8ths of an inch in diameter, and from 2 to 6 inches [247] long: they are pinched close at one end, and left open at the other. When they are to be filled, put in but a little composition at a time, and ram it lightly, so as not to break the case. Three or four rounds of paper, with the last round pasted, will be sufficiently strong for these cases. (*Ibid.*)

Sect. XI. Of Cases and Moulds for Common Port-fires.

Common port-fires, are intended purposely to fire the works, their fire being very slow, and the heat of the flame so intense, that, if applied to rockets, leaders, &c. it will fire them immediately. When used, they are held in copper sockets, fixed in the end of a long stick. These sockets are made like port-crayons, only with a screw instead of a ring.

Port-fires, or *lances of service of the French*, may be made of any length, but are seldom more than 21 inches long.

The interior diameter of port-fire moulds should be 10/16ths, of an inch, and the diameter of the former half an inch. The cases must be rolled wet with paste, and one end pinched or folded down. The moulds should be made of brass, and to take in 2 pieces lengthwise: when the case is in the two sides, they are held together by brass rings or hoops, which are made to fit over the outside. The bore of the mould must not be quite through, so that there will be no occasion for a foot. The French make the cases of five thicknesses of paper, and form the moulds upon rollers of 3/8ths of an inch in diameter.

Port fire, according to the full acceptation of the term *Porte-feu* of the French, means a *porter*, or carrier of fire, and implies all sorts of fusées or matches, by which fire is communicated.

In a treatise on *Military Fire-works*, as taught at Strasburg in 1764, an extract of which was translated and published by order of the War Department in 1800, there are some observations on port-fires, which, as the mode of making them according to these directions appears to have been adopted, may be useful to notice in this place.

"*Port-fires* may be made in two ways. The first is made and beaten in a mould; the other simply rolled on a ramrod, and filled lying on the table.

"To make port-fires of the first kind, the mould must be made of dry wood, such as pear-tree, nut or box wood. The height of the mould is 13.85 inches; its diameter at the bottom, 3.2 inches; its diameter above, 2.13 inches; diameter of the hole or caliber, .62 [248] inches; height of the base, 2.13 inches; its diameter, 3.2 inches.

"The base of the mould has in the middle a nob, which the turner leaves there, the diameter of which is equal to the whole of the mould, and one inch high, including the circle, which should be rounded like a hemisphere. There must be three rods, one of which, of hard wood to roll the cartridge upon; the two others of iron to ram down with. The one to roll upon, or the form, is to be of the length of the mould, exclusive of the handle, which is 3.2 inches longer. The diameter of this rod is .45 parts of an inch. The first, or greater one to charge with, is the same length with that to roll upon; the second is but half the length, and both are .44 parts of an inch in diameter.

"To make good cartridges, you must have good paper, well sized, cut according to the length of the rolling rod or form, which must be rolled very tightly round the form, so that the vacancy left may be exactly equal to the size of the mould, and that the paper should exactly fill the space between the form and the mould. Then the form is drawn out, after having tied it at the end with packthread. To fill it, it must be replaced in the mould. A cupful of composition is then put in, and five or six strokes given with the large ramrod. The ramrod is then withdrawn, and a new charge is put in, which is beaten like the first, until the cartridge is filled to the height of the mould. It is then drawn out, and primed with priming powder.

"The port-fire is filled with ease, in using a tunnel placed at the end of the cartouch, through which you pass the rod.

"*Composition of Port-fires of the first kind.*

Saltpetre	4	lbs.	2	oz.
Sulphur	1		12	
Priming powder	0		12	

"After having mixed these materials well together with the hand, and then with a rolling pin, you pass them through a hair sieve, and fill your wooden bowls.

"*The second kind of Port-fires*, are made in rolling strips of paper 3 inches wide, and 1.278 inches long, on a form of hard wood, about 14 inches long, and .35 parts of an inch in diameter. When about two-thirds of the paper is rolled, the remainder of it is to be pasted over with paste made of flour and glue. You then finish it, by passing your hand along the extremity of the pasted paper. [249] Having finished the number required, you place them in the sun, or near a stove, and turn them from time to time, to prevent them from sticking together, or bending.

"Cartridges being well dried, you must fill them with the following composition. Fold the paper at one of the ends, and at the other, pour in the composition, placing your cartridge against the composition; and having placed it perpendicularly on the table, you give it several strokes, to drive down the composition. Then you take your iron rod, which is .53 parts of an inch longer than the one which you use to roll with, and a little less in thickness at the top. There should be a ring, that it may hang to the finger, and move the more easily. Having laid your cartridges on the table, you introduce the rod, and with it compress the composition. Having withdrawn it, more is put in, it is pressed again, and so on until entirely full. You will take care to press the last layer of the composition more than the other, to prevent its falling out by moving.

"The port-fire cartridges being finished, they are laid by for use, putting ten in a packet as before.

"*Composition of Port-fires of the second kind.*

Saltpetre	6	ounces.
Sulphur	2	do.
Priming powder	3	do.

"These three articles being mixed, you will put them in a wooden bowl, and moisten them with linseed oil, until you find the composition (being pressed well) is sufficiently hard."

It may be sufficient to observe, that the present improved process of making port-fires is preferable. (See *Port-fires.*)

Sec. XII. Of Pasteboard, and its Uses.

The pasteboard, used in pyrotechny, is made of fine white paper, by joining together five, and sometimes six, seven, and eight sheets of paper. That which is generally employed, is made of five sheets, and the other descriptions are employed for large cases. Sized paper is preferable, having more firmness than the other.

Pasteboard is made in the following way: A paste of flour is first prepared with hot water, and passed through a hair sieve, to [250] separate the lumps. A sheet of paper is stretched upon a table, and covered, by means of a brush, with paste, and a sheet is then laid over it. This is compressed, and another coat of paste applied; then another sheet, then paste, and the number is added according to the thickness required. After five or more sheets are thus pasted together, a dry sheet is laid over, and the operation is repeated, till five more are joined. Then a dry sheet is put on, and the pasting is renewed. By this means, every five sheets are joined together, and the sheet, thus formed, is kept apart from the rest, by the dry sheet. A pile of pasteboard, consisting of some hundred sheets, may be made in this manner at one time. They are then put into a press for the space of five or six hours, by which they become firmly united, and all the extraneous paste is pressed out. When a press cannot be had, they may be put between boards, and heavy weights laid on. The pasteboard is then hung up in the air to dry, and again submitted to the press, to remove any inequalities, and to make it smooth.

When glazed paper is used for making pasteboard, we may employ, alternately, a sheet of brown paper. It is better, however, to use more of the glazed paper, than of the brown paper. Pasteboard of three thicknesses will be sufficient for most purposes. It is this kind, which is used for the heads of rockets.

Several kinds of paper, however, are used in fire-works. For small preparations, common white paper is sufficient. For port-fire cases, the common brown paper; for the joints, guarding places from fire, and covering tubes of communication, any kind of gray paper; and for covering marrons, the most indifferent kind may be used. Cartridge paper, as known by that name, may be used for a variety of purposes.

Paper may be rendered incombustible, or nearly so, by soaking it repeatedly in a strong solution of alum. In the *Literary Journal* of 1785, of Petersburg, there is a discovery mentioned of a kind of pasteboard, which neither fire can consume, nor water soften. It appears that alumina, and its salt (alum) were used in this preparation.

In the *Journal des Arts et Manufactures*, tom. ii, p. 205, is an account of the manufacture of pasteboard at Malmedy; and in the Transactions of the Society of Stockholm for 1785, is a description of the process for making the Swedish stone paper, which resists equally fire and water. Stone paper is manufactured in France, (*Dictionnaire de l'Industrie*, article *Carton*), by taking two [251] parts of martial earth, (ochre, for instance), and mixing them with one part of animal oil, and two parts of vegetable matter, previously made into a pulp. The *British Repository of Arts* contains several specifications of patents for the preparation of the same paper.

Although paper may be rendered very difficult of combustion by the process already mentioned, that of soaking it in a strong solution of alum, yet to make a paper completely indestructible by fire, it must be made of amianthus. The process for manufacturing paper with this mineral, was announced in the *Gazette de France* in 1778. Professor Carbury received a medal for the invention.

Incombustible paper, for cartridges, ought to have the property, not of inflaming, but of simply carbonizing, when exposed to heat. M. Brugnatelli (*Bulletin des Neustin*) recommends the paper to be prepared with silicated alkali, commonly called the liquor of flints. Muriate of potassa, and supersulphate of alumina-and-potassa are both used for a similar purpose.

Paper made according to Brugnatelli's process, is merely carbonized by fire, and reduced to powder.

M. Hermbstaedt (*Bulletin des Découvertes*,) observes, that paper, made with silicated liquor, attracts humidity, and proposes simply a solution of green vitriol, which has not that property.

Paper may be stained, or coloured, in a variety of ways, as is the case with the portable Chinese fire-works, that are brought to this country. Thus, a red paper may be formed by dipping it in a decoction of brazil wood and alum; yellow, by using fustic; a green, by a mixed bath of blue and yellow dye, or a solution of copper, &c. Coloured paper may be glazed with weak size, rubbing it afterwards with a polished stone.

The Chinese are in possession of several processes, as well for making, as for ornamenting paper. Their silver paper, which is sometimes put on their fire-works, is variously figured. The art is very simple. Two scruples of glue, and one scruple of alum, are dissolved in a pint of water. This is evaporated, and put on the paper, where they want it, and finally pulverized *silvery talc* (a magnesian stone) is sifted over it. It is then exposed to the sun, and the extraneous talc is brushed off. The glue, it is obvious, causes the talc to adhere.

The Abbé Raynal (*Histoire Philosophique des deux Indes* t. iii, p. 225) has some interesting facts respecting Chinese paper. Some [252] useful remarks on paper hangings, paper for decorations, tapestry paper, &c. may be found in the *Journal de Paris*, 1785, the *Lycée des Arts* 1795, and the *Encyclopedie Method. Arts et Metiers*, t. iv, p. 393. On the formation of paper vases, in imitation of Japan vases, consult the *Dictionnaire de l'Industrie*, article *vases*. The different patents, respecting paper, may be seen in the British *Repertory of Arts*, and the manufacture of paper generally, in Rees's *Cyclopedia*, and the *Artist's Manual*. The American improvements are noticed in the latter. Beckman (*History of Inventions*) has a variety of remarks on the same subject; and, in his article on paper hangings, &c. vol. ii, p. 161, says, that artists employed the silver-coloured glimmer (isinglass) for the covering of paper, and that the nuns of Reichtinstein ornamented with it, the images, which they made; as the nuns in France, and other catholic countries, ornamented their *agni Dei*, by strewing over them a shining kind of talc.

The quality of the paste, which is employed in making pasteboard, ought to be attended to. The flour should be of rye, and well boiled, after mixing it uniformly with cold water. Strong bookbinder's paste has the addition of a fourth, fifth, or sixth of the weight of the flour, of powdered alum. The *patent paste* is prepared by extracting starch from potatoes, in the usual manner, by means of cold water, and mixing it with mashed potatoes, after they have been boiled, and boiling the whole in water.

The Japanese cement, or rice-glue, may be advantageously used in many cases. It is formed by mixing rice flour intimately with cold water, and then boiling it very gently. It is beautifully white, and dries almost transparent. We are told, that it is preferable, in every respect, to the paste made with flour; and its strength is such, that paper, pasted together with it, will sooner separate in their own substance than at the joining.

The Chinese, to prevent accidents, and in order that they may fire their works without injury, and particularly their cases which are charged with brilliant fire, have a process, for preparing a paste of a different kind. With the exception of the clay, the same substances have been employed elsewhere for the like purpose. It consists of one pound of rye flour, boiled in water; to which is added, a small handful of common salt, the whole being *thickened* with finely pulverized white clay. The pasteboard, we are informed, which is made with this paste, is not only very solid, but not so susceptible of inflammation, as that prepared in the usual way.

A Chinese paste is announced in the *Bulletin de la Société d'Encouragement*, 1815, which is very economical, and used with [253] success. It is made by mixing ten pounds of bullock's blood, with one pound of quicklime, and occasionally flour.

Sec. XIII. Of the Pulverization of Substances.

Various substances are employed either in grain, laminæ, filings, or impalpable powder. When treating of nitre, sulphur, and charcoal, and other bodies, we mentioned the processes for reducing them to powder. It will be sufficient here to remark, that cannon powder, when it is converted into fine powder, takes the name of meal-powder; the conversion being effected, by beating it in a leather sack, already described, by rolling it upon the mealing-table, or by the action of a wooden pestle in a mortar. It is then passed through a fine sieve. The sack is said to be a preferable mode, as nearly the whole of it becomes pulverized. Saltpetre, sulphur, charcoal, antimony, &c. may be reduced to powder in a mortar of cast-iron, marble, or wood. The best method of pulverizing saltpetre is given under that article, which consists in boiling it in a copper, and stirring it continually at the end of the process. The best mode of pulverizing, or bringing cast-iron to a state of fineness, is mentioned in the article on *Iron*. Some of the metals, as iron, zinc, the alloy of copper and zinc, (brass,) &c. are brought to a sufficient fineness by the file. The filings, if so required, may be afterwards sifted. Zinc, when in small pieces, may be pulverized, by means of a steel mortar and pestle. It may be granulated, by suffering it to run, when melted, through an iron cullender into water. For the pulverization of camphor, see that article.

Sec. XIV. Of Mixtures.

All compositions for fire-works, are generally made at first in mortars, and the mixture is then finished by passing it through a sieve; it being returned to the sieve, and again sifted. This operation is sometimes repeated several times. Of all compositions, that for sky-rockets requires to be most intimately blended.

To receive the sifted matter, leather or parchment is used; but, in lieu of either, pasteboard, or several sheets of paper, cemented or glued together will answer. It is obvious, that, in preparing mixtures, of two, three, or four articles, they should not [254] only be very fine, but uniformly and intimately mixed.

Several receivers, made by stitching leather over a rim, in the manner of a sieve, would be found very convenient; but wooden bowls, and copper basins, are generally used.

Some ingredients must be passed through a lawn sieve, after having been previously incorporated. A receiver, with a top, is the kind of sieve to be preferred. The composition for wheels, and common works, need not be so fine as for rockets. But in all fixed works, from which the fire is to play regularly, the ingredients must be very fine, and great care taken in mixing them together; and in those works, into the composition of which, iron and steel enter, the hands must neither touch them, nor moisture be suffered to come in contact. In either case, they would be apt to rust.

PART III. [255]

FIRE-WORKS IN GENERAL.

CHAPTER I.

OBSERVATIONS ON FIRE-WORKS.

In Europe, the invention of fire-works is of a recent date, and ascribed to the Italians. In China, however, fire-works have been known for centuries. Some recent exhibitions at Pekin prove, that the Chinese have attained to a degree of perfection, not surpassed by the artists of France, Italy, or England. The observations of Mr. Barrow, (*Travels in China*), on this subject are worthy of notice. "The fire-works, in some particulars," says he, "exceeded any thing of the kind I had ever seen. In grandeur, magnificence, and variety, they were, I own, inferior to the Chinese fire-works, we had seen at Batavia, but infinitely superior in point of novelty, neatness, and ingenuity of contrivance. One piece of machinery I greatly admired; a chest five feet square, was hoisted up by a pulley, to the height of fifty or sixty feet from the ground: the bottom was so constructed as then, suddenly, to fall out, and make way for twenty or thirty strings of lanterns, enclosed in a box, to descend from it, unfolding themselves from one another by degrees, so as, at last, to form a collection of full 500, each having a light of a beautifully coloured flame, burning brightly within it. This devolution and development of lanterns was several times repeated, and, at every time, exhibited a difference of colour and figure. On each side, was a correspondence of smaller boxes, which opened in like manner as the others, and let down an immense net-work of fire, with divisions and compartments of various forms and dimensions, round and square, hexagons, octagons, &c. which shone like the brightest burnished copper, and flashed like prismatic colours, with every impulse of the wind. The diversity of colours, with which the Chinese have the secret of clothing fire, seems one of the chief merits of their [256] pyrotechny. The whole concluded with a volcano, or general explosion and discharge of suns, stars, squibs, crackers, rockets, and granadoes, which involved the gardens for above an hour in a cloud of intolerable smoke."

Thevenot (*Travels in the Levant*) says, that during the bairam, or carnival, which takes place with a great deal of ceremony, the sultan causes fire-works to be played off all night; the sultan and sultanas diverting themselves with these and other amusements. Dr. Pococke (*Travels through Egypt*), says, that at Cairo, when the Nile is high, besides aquatic excursions, concerts of music, and other diversions, fire-works form a part of those pleasures and recreations. In a *Description of the East Indies*, fire-works are stated to be often exhibited at the marriage of the Banians or Gentoos.

With respect to the arrangement and display of sundry pieces of fire-works, either alone or combined, the effect depends, as well upon the ingredients, which compose the several sorts of fire, as on the taste displayed in their exhibition. It would be altogether unnecessary to notice, at this time, the order of exhibition usually adopted, reserving this subject until we have gone into the various preparations, which constitute, as it is called, a *system of fire-works*. In order, however, to become familiar with the manner of arranging them, as well as with their composition and preparation, whether designed for a general or a partial display, for the open air or for rooms, we purpose to appropriate distinct chapters for their consideration.

The variety of preparations, which become necessary where a full exhibition is intended, the accuracy of the different mixtures, and the adjustment of cases to wheels, whether vertical or horizontal, and the arrangement of the leaders, or communicators of fire, from one part to another of the work, with many other circumstances, in relation to stars, rain, &c. all require, from the artist, particular care and attention.

For the mere exhibition of one or two pieces, as a plain rocket, rocket with serpents, or the like, and likewise for some exhibitions, on water, called aquatic fire-works, in rooms or apartments, with scented fire, or on the stage; the preparations are by no means extensive.

It is, therefore, our design to present a view of the whole subject in detail, and to speak of the different combinations of [257]
arrangement, which are made according to fancy and taste, and calculated, as we have remarked, either for small or extensive exhibitions.

We have, in a preceding part of this work, made some observations on certain preliminary operations; on the various sizes and charges for cases; on the paper, necessary to be used, for different kinds of cases; and, generally, on sundry manipulations, connected with the making, filling, and preparation of sundry descriptions of fire-works. It remains, therefore, in the course of this subject, to give the several formulæ, with such observations as immediately concern the subject; and for this purpose we will pursue the following order:

Frazier is of opinion, that the arrangement of fire-works, which have been exhibited with effect, may, on particular occasions, be established as a guide. For this reason, Morel introduces an account of the celebrated fire-works at Versailles and Paris, in 1739, which we shall here notice.

Exhibition of fire-works at the city house of Paris, on occasion of the peace in 1739.

The theatre was a building, forty feet square, with a pyramid of eighty feet in height, on which was placed a globe, containing artificial fire, and accompanied with sixteen large vases of different forms.

All the edifice was ornamented with a variety of decorations, combined with figures and emblems of peace, and painted on marble.

After several guns were fired, as a signal, the exhibition commenced, with the discharge of a large number of *honorary rockets*, fired three and three at a time. Nearly five hundred *lances*, and *saucissons* garnished, lighted the four sides of the body of the works. Thirty cases of artificial fire, furnished with *fusées*, and double *marquises*, were placed upon the large terrace, with 1200 *pots à feu* (fire-pots); and upon the ballustrade of the same terrace, forty *jets*, twenty of which were *aigrettes*, and eight, revolving suns, four in the middle, and four on the angles. Four large fixed suns were placed above the four which revolved, and four *pattes d'oies*, (*geese feet*,) were situated before the grand pedestal of the pyramid, with *jets*, and *pots* with *aigrette*.

At the foot of the pyramid, on the steps, were placed 1200 *fire-pots*, and upon the pedestal of the pyramid, twelve large pots of
aigrette, on the extremity of which, were arranged *aigrettes* in groups, and three large luminous stars, formed of two hundred fire [258]
lances. The four faces of the pyramid were lined with about fifty other *jets*; after which there were cascades, or fountains of fire. The first horizontal wheel was composed of, or furnished with, six cases, and contained also two hundred and forty double *marquises*. The second wheel contained two hundred and forty *fire-pots*, and six cases, with upwards of three hundred *fusées*, all in stars, twelve air balloons in the middle, but placed at the bottom of the fire-work. To this was added, twelve artificial bombs, fixed in mortars, and placed near the cannon, which pointed to the works.

This outline of the brilliant exhibition of fire-works in 1739, will give the reader some idea of the taste and magnificence of the work at that period. We may here add, however, that the improvements, which have since taken place, both in the composition of artificial fire, and its arrangement, are such as to place the modern exhibitions of this kind far above that we have just spoken of. But the following account of the execution of fire-works, performed on the *Pont Neuf*, in August of the same year, is more extensive, as the exhibition appears to have been more grand.

The theatre, which represented the temple of Hymen, was an edifice of the doric order. It was square. A gallery of five hundred feet in length was supported by thirty-two columns, four feet in diameter, and thirty-three feet in height. In the interior, were two solid bodies, and also one or more stair cases. At the two sides of this temple, along the parapets of the *Pont Neuf*, were thirty-six pyramids, eighteen of which were forty feet high, and the others, twenty-six feet. They were joined by what is called, in architecture, a *corbil*, and carried vases on their summits.

The signal for the exhibition was given by the firing of cannon. Immediately, were seen, rising into the air from each side of the temple, three hundred rockets, fired twelve at a time. They were discharged from the eight towers of the *Pont Neuf*, which face the Tuileries, and were succeeded (upon the same towers,) by one hundred and eighty *pots of aigrette*. The *Chinese trees* were disposed in such a manner, as to form a pyramid. A succession of *Chinese trees* now appeared, immediately on the tablet of the cornice of the bridge; then followed a great *fixed sun*, sixty feet in diameter, which appeared in all its splendour, in the midst of surrounding objects. Under this, was placed a large *illuminated cypher*, thirty feet in height, which consisted of different colours,
in imitation of jewels. At the sides, between the pillars of the temple, were also two other artificial *cyphers*, six feet high, and [259]
composed of *blue fire*, which had a surprising effect. There were placed upon the two walks of the bridge, on the right and left of the temple, beyond the illuminated pyramids, two hundred cases of *fusées de partement*, of five or six dozen each. These cases were fired, five at a time, and succeeded the rockets. They began, on each side, from the first near the temple, and in succession, as far as the extremities to the right and left. There appeared then cascades of *red fire*, issuing from the five arches of the bridge, which seemed to pierce the illumination, and so vivid was the light, that the eye could scarcely sustain it. The combat of the *dragons* next ensued; and the *water-fire*, or aquatic fire-works, covered almost the whole surface of the river. Eight *boats*, containing works for the display on water, were arranged in symmetrical order, with the *boats of illumination*. There were also thirty-six *cascades* or fountains of fire, about thirty feet high, which appeared to rise out of the water. This exhibition of the cascades, was preceded by a revolving *water-sun*, and a discharge of *stars* from one hundred and sixty pots of *aigrettes*, which were placed at the lower part of the terrace.

Four large boats, containing aquatic fire-works, were moored near the arches of the bridge, and four others were disposed on the side next to the Tuileries. The fire-works, which they contained, consisted of a great number of large and small casks, charged with *gerbes* and *pots*, which, when discharged, filled the air with *serpents*, *stars*, &c. There was, also, a large number of *hand gerbes*, and revolving *water-suns*.

When the exhibition of the cascades was finished, the grand chandelier, composed of six thousand *fusées*, and resting on the top of the temple, was lighted. Both extremities were set on fire at the same time. This was followed by two smaller chandeliers, previously placed on each side of the foot-way of the bridge, and containing five hundred *fusées* each.

The fire-works, exhibited at Versailles, in the same year, and on the same occasion, were also magnificent. The account we have of them is the following: There was a large building erected, representing the temple of Hymen, nine hundred feet in length, and one hundred and twenty in height, in the gardens of Versailles, in front of the grand gallery. It was in the form of a portico, with re-enterings and salients at the two extremities, which faced the two great basins; and, in the centre, were illuminated works.

The forges of Vulcan, in the grottos, commenced with the sound of the hammers of the Cyclops. The sparks, then produced, [260]
covered, in a few instants, the two basins, provided for the purpose, with an apparent sheet or volume of fire.

From the summit of a rock, came out a *jet* of brilliant fire, more than thirty feet in height, accompanied with four others of less elevation, representing torrents of fire as from volcanoes. To this succeeded a great *jet* of water, forty-five feet in height, leading with it, as it were, seventeen other *jets*, which surrounded the rocks, and rushing forth with avidity, produced, in appearance, a mixture of flame and water, which, in the end, consumed entirely the two grottos.

After this, the fire-works, behind the decoration, were exhibited. Two hundred and fifty *boxes*, and as many caissons, arranged on both sides of the turf, which descended to the grass, were first exhibited. This, however, was less brilliant than the fire from the Cyclops. To this succeeded a brilliant fire, placed before the illumination. This composition, elevating itself to a mean height, pleased equally by its form, as by its brilliant whiteness. This fire composed three distinct decorations, which succeeded as the one replaced the other, following the same order. The spouting waters, which decorated the gardens, together with the artificial fire, appeared in the form of cascades and fountains. The first decoration, at the head of the two great basins, exhibited two handsome cascades, in the form of a white sheet, and surmounted with an *aigrette* twenty-five feet in height. This was accompanied with two *pattes d'oies* (*geese feet*) of seven *jets* each, and accompanied also with fifty *jets* playing from each of the sides, twenty feet in height, and occupying the fore ground.

The second appeared under the form of the *pattes d'oies*, of eleven jets each, of which four, at the head of the basins, were large, and all projected a body of fire, fifty feet in height. They were intermixed, however, with the pots of *aigrettes*, twenty feet in height, which threw a crown, composed of stars, &c. to the height of fifty feet, which produced in the atmosphere a lively and brilliant light.

The third represented thirteen fountains of fire, twenty-five feet in height, and thirty feet in diameter, with an *aigrette* in each. In these, there were six circular, and six spiral fountains. The largest was placed between the two basins, with four others on the right and left.

The fountains, which represented the combat of animals, had in each of them two. The animals threw, at the same time, jets of [261]
water and fire, and, between each of the fountains, large brilliant jets or spouts. This part of the exhibition was finished, by throwing into the air the *garnishing* or furniture of the pots, which produced crowns, &c. of great splendour.

To these three decorations, succeeded the exhibition of twelve *Italian pots*, placed six in a row, and in the middle of two great basins, which produced repeated discharges.

The whole was then closed by setting fire to two great chandeliers, which were placed behind the grand decoration, and contained more than three thousand *fusées*.

It appears from history, that when Henry II, entered Rheims, there was a representation of several figures in fire; and in 1606, the duke of Sully made an exhibition of fire-works at Fontainbleau; and in 1612, Morel, commissary of artillery, prepared a splendid exhibition of the same kind. It appears, also, that the art of communicating fire from one piece of fire-work to another, as in the combined piece of nine mutations, and the pyric-piece (which will be noticed hereafter) was discovered by Ruggeri, artificer to the king, at Boulogne, in France, in 1743.

It may not be improper, in concluding this article, to notice, in a general manner, the exhibition of the works of fire by the ancients.

The fire-works of the ancients consisted, for the principal part, of illuminations, and the use of some particular descriptions of fire. They were, however, very imperfect. Since the invention of gunpowder, its effects as well as its modifications, in this particular, became known; and, so far as respects the various preparations of artificial fire, gunpowder itself has produced a new era in pyrotechny, and the various modifications, to which it is subject, have occasioned a great variety of fire-works.

According to the authority we have on the subject, it appears, that the ancients, in exhibiting their preparations of fire, set them off by the hand, and directed them among the people, which produced great eclat.

Another description of fire-work was designed expressly for the theatre, part of which was exhibited in the form of man or beast. Of their theatrical works, our accounts are imperfect. Their works, generally, were formed of *lardons*, *stars*, and *fire-balls*, in imitation of *grenades*, and *flying fusées* or *rockets*. That they neither had a system in arranging, nor regularity in exhibiting their works, is evident from a variety of circumstances; for, although the number of their pieces, such as they were, was great; yet, they [262]
so crowded them upon each other, as that, when they were fired, they frequently destroyed the persons in their vicinity. An author of antiquity observes, that "he has seen a great many artificial machines, but, to speak the truth, few which have succeeded; and it is commonly after acclamations of joy, that the spectacle is finished by the destruction of some, and the wounding of a great number."

This fact is not at all surprising; because their works were prepared in wooden tubes, at least among the more modern, as paper cases were not then known. These tubes, moreover, were not secured by any covering, and were the more likely to burst, and hence accidents were common. The moderns, however, have rejected altogether the use of wood, in the formation of cases, and have availed themselves of the use of paper, which can be made of any size or thickness. (See *Pasteboard*.)

Notwithstanding wood is not employed by experienced fire-workers, partly in consequence of the reasons just given, and partly because paper furnishes a material in every way adapted to the purpose; yet, within a few years past, reed has been used in Spain, which, however, is secured by cloth and pack thread. Such substitutes, nevertheless, besides being more or less dangerous, have nothing to recommend them. It is a fact, that the Chinese, who undoubtedly excel in the manufacture of fire-works, if we believe the authority of the English embassy, use altogether paper cases; but in the *war-rocket*, employed by the natives against the British at *Seringapatam*, which did, according to the English account, great execution, their cases were formed entirely of sheet-iron. In their smaller works, which are prepared expressly for sale, paper cases are altogether made use of.

CHAPTER II.

FIRE-WORKS FOR THEATRICAL PURPOSES.

Sec. I. Of Puffs, or Bouffées.

The *bouffée*, according to the term used in French, signifies a species of fire, which exhibits itself in *puffs*, or in alternate appearances, more or less brilliant. It is also called the flambeaux of the furies. This description of artificial fire is used in *theatres*, [263] and frequently in ordinary fire-works. It is fired from, and exhibited with, a funnel of tin, or sheet iron, having a hole at the apex of the cone. The hole is to be sufficiently large to admit the fire from a quick match. It is particularly calculated, when a gulf, crater, or the caves of the Cyclops, intended to eject flame, are to be exhibited.

Although many compositions may be used for this purpose, yet the following, which is employed in France, is considered preferable:

Composition for Bouffées.

Saltpetre	16	oz.
Meal-powder	4	oz.
Charcoal	8	oz.

When the materials are well mixed, a piece of silk paper is prepared in a round shape, by pressing it on the end of a roller, in the same manner as the ordinary cases. About one ounce of the composition is put into it, on which is placed very lightly two drachms of meal-powder. A double quick-match is now put on the meal-powder, and the paper is closed by pressing it between the fingers. It is then tied with twine. The quick-match is left sufficiently long to pass through the hole at the apex of the cone, in which is introduced the *puff*, being pressed a little at the bottom. The excess of the quick-match, should there be any, is cut off within an inch of the extremity of the funnel. When used, it is inflamed by a lance or port fire. The effect of the puff, in the first place, is to throw out of the funnel, by the meal-powder, a volume of fire, which will cause the appearances before mentioned.

Sec. II. Of Eruptions.

If the appearance of a volcano, or the effect of a mine is required in a piece, the following method is commonly followed: a tin, sheet-iron, or brass box is provided, either round or square, of nine inches in height, and three inches and a half in diameter, and placed on a wooden stand, sufficiently large to prevent it from overturning.

Three, four, or five ounces of the composition, mentioned in *Sec. i.* of this chapter, is put into it, according to the effect intended to be produced. The composition is pressed a little with the hand, and a piece of quick-match is used. This match projects out of [264] the case, and is secured with a piece of paper, pasted over its circumference.

When the fire is presented to the quick-match, it communicates with rapidity to the inside of the box, or case, which produces an eruption, from twelve to fifteen feet in height. The effect may be made more or less great, by making the boxes of a proportional size, or by using several of them at the same time.

If a mine is the subject of representation, it is necessary to employ some large *marrons*, which should communicate with the boxes, and in such a manner, as that they may operate at the same time.

This exhibition, it is obvious, may be varied according to circumstances, either by employing a larger quantity of the composition in several cases, or by using one or more marrons, or some other descriptions of fire-works, the effect of which is calculated to increase the flame, and to produce the necessary variations.

Sec. III. Of the Flames.

If a flame is to be represented, as for example, the effect of an incendiary, and its appearance is to be prolonged, the fire from tow being too transient, small iron kettles, of four inches in diameter, and depth, may be used. In these are put three or four ounces of the composition of the *lances of service*, which is moistened with the oil or spirit of turpentine. When set on fire, they will produce a blaze three or four feet in height, and one and a half in diameter. Several may be used, according to the effect required. See the composition for the *lances of service.*

Sec. IV. Of the Fire-rain.

A variety of compositions for fire-rain are used, which will be noticed, when we speak of the *garnishing* of rockets, and other fire-works.

Cases are prepared of seven-twelfths of an inch in diameter, and ten inches long, which are choaked in such a manner, as that the hole of communication should be one-third of the diameter of the interior case. They are then charged with the following composition:

Composition of the fire-rain.

Saltpetre	8	ounces.
Sulphur	4	do.
Meal powder	16	ounces. [265]
Charcoal of oak	2½	do.
Pitcoal	2½	do.

When the cases are charged and primed, they are tied upon a rod, having a groove cut in its length. In the inside of the groove, is a port-fire, or leader, which is tied to the cases with twine, and the groove is then covered with several pieces of paper, in the shape of a band.

This precaution is thus taken for the theatre, in order to prevent the inflamed port-fire from falling on the stage.

Sec. V. Of other Compositions for Fire-rain, in Chinese fire.

The composition of Chinese fire, which we will have occasion to mention more fully hereafter, is calculated to exhibit a more brilliant fire, with a steady and uniform effect. It is used principally on the French stage, in large operas. It is charged and used, in all respects, like the preceding.

Composition of Chinese Fire.

Saltpetre,	8	ounces
Meal powder,	16	
Sulphur,	4	
Charcoal,	2	
Powdered cast iron,	10	

The elegance of the flame, produced by this mixture, depends entirely upon the effect, which cast iron possesses; and, by its combination with charcoal, sulphur, meal powder, and nitre, while an oxide of iron results from the combustion, we have, likewise, other products, arising from the decomposition of the nitre, and the union of carbon and sulphur respectively with a part of the oxygen of the nitric acid of the nitre. The gunpowder decomposes itself by reason of the nature of its own composition; but the sulphur, charcoal, and iron, decompose the nitric acid of the nitre, in the act of combustion. So that, to produce the effect, an additional quantity of nitre to that which is in the gunpowder, is required in this preparation.

Sec. VI. Of Thunderbolts. (Foudres F.)

The thunderbolts are charged in cases of two-thirds of an inch in diameter, in the same manner as cases for wheels and rockets. They are primed, whitened, well pasted, and left to dry. Some preliminary operations are required in their exhibition, as the use of [266] the piercer, the tying of one end of the case, which is to descend first from the top of the theatre, &c. A port-fire is used for setting them off.

Composition of Thunderbolts.

Meal powder,	6	ounces.
Saltpetre,	6	——
Sulphur,	3	——
Antimony,	4	drachms.[24]

Sec. VII. Of Dragons and other Monsters.

In certain pieces, exhibitions of this kind are made. They are formed in such a way, as to make them throw fire from the mouth, nose, and ears, which is blown out into the air. Cases, charged with brilliant fire, are so arranged that their fire may act all at the same time. Puffs may also be produced to go out at the mouth, by means of a tube or funnel, placed behind the monster. These preparations and exhibitions are so susceptible of variations, that, having a previous knowledge of the composition and effect of the fire-work, it may be so arranged as to produce a variety of appearances.

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Sec. VIII. Of Lightning.

The effect of lightning may be shown by several preparations. Lycopodium, or puff-ball, is the substance most commonly employed. When it cannot be procured, rosin may be substituted; and, generally, as the latter is cheaper, it is used. Rosin, reduced to an impalpable powder, and thrown upon a flame, will produce the effect in a remarkable degree, and when blown through a tube, the effect is more striking.

Several fluid substances, when ejected from a syringe on a lighted candle, have the same appearance. Alcohol has this effect. The difficulty of preparing and employing them, has given the lycopodium a preference.

A tin or brass tube, larger at one end than the other, and covered at the former end, with a cover, perforated with holes, similar to the branch of a watering pot, is used for holding the composition, or substance made use of. Through this cover, or lid, a cotton wick is put, which, before lighting, is well soaked in alcohol or spirits of wine. When lighted, the torch or tube, containing the lycopodium, or rosin, is shaken at the smaller extremity; when these substances will pass through the holes in small quantities, and be successively inflamed.

Sec. IX. Of the Artifice of Destruction.

When, in any exhibition, palaces, castles, or forts are to be demolished, or thrown down, there are about twenty petards fixed on rods. Petards, for this use, are made with cases, and sometimes with wheels. The cases are generally three-quarters of an inch in diameter, charged with grain powder, and choaked at both ends. They are arranged in a zigzag direction.

This series of *crackers* has a fine effect. It is obvious, that, in all these exhibitions, intelligent artizans may employ various descriptions of artificial fire, where, in particular, it often seems, that there is something yet to be wished for.

Sec. X. Of the Spur-fire.

The spur-fire is so called, because its fire or sparks resemble the rowel of a spur. It is used in theatres and in rooms. It is the most beautiful of any yet known, and was invented by the Chinese, but greatly improved in Europe.

It requires great care to make it properly. Care ought to be taken that all the ingredients are of the best quality, that the [268] lampblack is neither damp nor clodded, that the saltpetre is the best refined, and the sulphur perfectly pure. This composition is generally rammed into one or two ounce cases, about five or six inches long, but not driven very hard; and the cases must have their concave stroke struck very smooth, and the choak or vent not quite so large as the usual proportion: this charge, when driven, and kept a few months, will be much better than when rammed. If kept dry, it will last many years.

As the beauty of this composition cannot be seen at so great a distance as brilliant fire, it has a better effect in a theatre or room, than in the open air; and may be fired in a chamber, without danger. Its effect is of so innocent a nature, that it has been called *cold fire*; and so extraordinary is the fire produced from this composition, that if well made, the sparks will not burn a handkerchief when held in the midst of them. The hand, brought in contact with the spark, will feel only a sensation similar to that occasioned by the falling of rain. When any of these spurs are fired singly, they are called *artificial fire-pots*; but some of them, placed round a transparent pyramid of paper, and fired in a large room, make a very elegant appearance.

Composition of Spur-Fire.

1.	Saltpetre,	4½	lbs.
	Sulphur,	2	lbs.
	Lampblack,	1½	lbs. or,
2.	Saltpetre,	1	lb.
	Sulphur,	½	lb.
	Lampblack,	4	quarts.

The saltpetre and sulphur must be first mixed together, and sifted, and then put into a marble mortar, and the lampblack with them, which are to be worked by degrees, with a wooden pestle, till all the ingredients appear of one colour, which will be a gray, approaching to black. It is then to be tried by driving a little of it into a case, and fired in a dark place; and if the sparks, which are called *stars*, or *pinks*, come out in clusters, and afterwards spread well, without any other sparks, it is a criterion of its goodness. If any drossy sparks appear, and the stars are not full, it is then not mixed sufficiently: but, if the pinks are very small, and soon break, it is a proof that it has been rubbed too much; for, in this case, few stars will appear. When, on the contrary, the mixture is [269] not rubbed sufficiently, the combustion will be too weak, and lumps, resembling dross, with an obscure smoke, but without stars, will be emitted.

The peculiar effect of this composition is owing to the carbon of the lampblack, one part of which is inflamed, its combustion being supported by the oxygen gas of the atmosphere.

Sec. XI. Of the coloured Flame of Alcohol.

We have already remarked, in treating of alcohol, that its flame may be changed of various colours, by using certain native substances. See *Alcohol.*

Alcohol, thus mixed, or combined with substances, may be exhibited on certain occasions; for even cotton, when immersed in it, and set on fire, will show the same appearances. Morel remarks, that, if vinegar, a small portion of crude tartar, and common salt, and a still smaller quantity of saltpetre, be mixed together, and distilled, a liquid will be obtained, which burns with great brilliancy. It is doubtful, however, if we judge from analogy, whether either tartar, the salt, or saltpetre, will communicate any peculiar property to the distilled vinegar; for these saline substances will remain unaltered in the distilling vessel. The vinegar, nevertheless, may be obtained in a more concentrated state, being deprived of its colouring and other matter, and the greater part of its water, and, therefore, approach to the state of acetic acid.

With respect to alcohol, it is known to dissolve a variety of saline substances, most of which have the property of changing the colour of its flame. Although we have not made any experiments with the spirits of turpentine, yet we are of opinion, that it may be used with resins, &c. in the same manner. In all cases, it is evident, that the fluid made use of must be inflammable.

Macquer (*Memoirs of the Turin Academy*) made a number of experiments on the solubility of salts in alcohol, and on the different coloured flames, which they produced. The principal results of his experiments, are the following:

Quantity in grains.	Salts soluble in 200 grains of spirit.	Peculiar phenomena of the flame.
4	Nitrate of potassa,	{ Flame, larger, higher, { more ardent, yellow, { and luminous.
5	Muriate of potassa,	{ Large, ardent, yellow, { and luminous.
0	Sulphate of soda,	Considerably red. [270]
15	Nitrate of soda,	{ Yellow, luminous, { detonating.
0	Muriate of soda,	{ Larger, more ardent, { and reddish.

0	Sulphate of ammonia,	None.
108	Nitrate of ammonia,	Whiter, more luminous.
24	Muriate of ammonia,	None.
288	Nitrate of lime,	{ Larger, more luminous, { red, and decrepitating.
288	Muriate of lime,	{ Like that of nitrate of { lime.
84	Nitrate of silver,	None.
204	Muriate of mercury,	{ Large, yellow, luminous, { and decrepitating.
4	Nitrate of iron,	Red and decrepitating.
36	Muriate of iron,	{ More white, luminous, { and sparkling.
48	Nitrate of copper,	{ More white, luminous, { and green, much smoke. { The saline residuum { became black and burnt.
48	Muriate of copper,	{ Fine green, white { and red fulgurations.

The alcohol, he employed, had a specific gravity of 0.840.

Sec. XII. Of Red fire.

Dr. Ure (*Chemical Dictionary*) informs us, that the beautiful red, which is now frequently used at the theatres, is composed of the following ingredients: 40 parts of dry nitrate of strontia; 13 parts of finely powdered sulphur; 5 parts of chlorate (hyperoxymuriate) of potassa, and 4 parts of sulphuret of antimony. The chlorate of potassa and sulphuret of antimony, should be powdered, separately, in a mortar, and then mixed together on paper; after which they may be added to the other ingredients, previously powdered and mixed. No other kind of mixture than rubbing together on paper is required. Sometimes a little realgar is added to [271] the sulphuret of antimony, and frequently, when the fire burns dim and badly, a very small quantity of very finely powdered charcoal or lampblack will make it perfect.

CHAPTER III.

OF PORTABLE FIRE-WORKS.

Sec. I. Of exhibitions on Tables.

Fire-works, it is obvious, may be employed in a variety of ways, either large or small, in the open air, or in apartments, according to circumstances. *Fire-tables* are composed of a great many works, the same as is exhibited upon a large scale; but of a size corresponding with small exhibitions. As *fire-tables* are used only in apartments, and the works are shown from tables, on which they are arranged, it is necessary that the cases which contain them should be of a small caliber, and their fire less extensive.

The cases or cartridges are made of one-eighth of an inch in diameter, and charged with the best pistol powder, which produces less *smoke* than cannon powder. These small works are usually exhibited on pasteboard, differently arranged.

Among the works are frequently figures, resembling fruit contained in *gerbes* and even small *caprices*. *Pinks*, which are also used, are generally modified, or accompanied with other decorations, and furnished with illuminated suns. *Fire-pots* of one inch in diameter, filled with small *bombs* and various devices, are employed, when a *surprise* is intended. The fire-table is arranged, although upon a small scale, in the same manner as other works. Their arrangement, therefore, is the same as for other kinds of fire-works, only proportioning them accordingly.

Brilliant fire.

Meal powder,	16	oz.
Fine filings of steel.	2½	do

Jessamine.

Meal powder,	16	oz.
Saltpetre,	½	—
Sulphur,	½	—
Fine steel filings,	2½	—

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Aurora.

Meal powder,	16	oz.
Gold powder,	2	—

White.

Meal powder,	16	oz.
Saltpetre,	6	—
Sulphur,	10	—

Rays.

Meal powder,	16	oz.
Needle filings, (or filings of the best steel,)	1½	—

Silver rain.

Meal powder,	16	oz.
Saltpetre,	½	—
Sulphur,	½	—
Needle filings, (or filings of the best steel,)		—

Chinese silver rain.

Meal powder,	18	oz.
Sulphur,	2	—
Saltpetre,	1	—
Powder of cast iron, of the best,	5	—

As to *aquatic fire-works*, some of which are frequently shown in rooms, the reader will find in the article on that subject, a full account of the manner of forming them. He may also consult a treatise on *Artificial fire-works* by Perrint D'Orval, published in 1745. This work gives ample instructions for performing all kinds of fire-work on water.

In the article alluded to will be found several formulæ for preparing odoriferous fire, which may be used for exhibitions on the table. The succeeding chapter, however, is sufficiently comprehensive on that subject.

Sec. II. Of Table Rockets.

Table rockets are not calculated for exhibition. They are designed merely to show the truth of driving, and the judgment of a fire-worker. They have no other effect, when fired, than spinning round in the same place where they began, till they are burnt out, and showing a horizontal circle of fire. The method of making these rockets, is the following: Have a cone, turned out of solid wood, 2½ inches in diameter, and of the same height, and, round its base, draw a line. On this line, fix four spokes, two inches long each, so as to stand one opposite the other; then fill four nine-inch one pound cases with any strong composition, within two inches of the top. These cases are made like tourbillons, and must be rammed with the greatest exactness. The rockets being filled, fix [273] their open ends on the short spokes; then, in the side of each case, bore a hole near the clay. All these holes or vents must be so made, that the fire of each case may act the same way; and from these vents carry leaders to the top of the cone, and tie them together. When the rockets are to be fixed, set them on a smooth table, and light the leaders in the middle, and all the cases will fire together, and spin on the point of the cone. These rockets may be made to rise, like tourbillons, by making the cases shorter, and boring four holes in the under side of each, at equal distances. This being done, they are called double tourbillons.

All the vents in the under sides of the cases, must be lighted at once; and the sharp point of the cone cut off, at which place, it is to be made spherical.

Sect. III. Of the Transparent Illuminated Table Star.

The table star is usually twelve feet in diameter, and, from the nearest extremity to the frame, four feet. This proportion, observed on each side, will make the centre frame four feet square. In this square, a transparent star is fixed. This star may be painted blue, and its rays made like the flaming stars. The wheels for this star may be composed of different coloured fires, with a charge or two of slow fire. The wheels, on the extremities, may be clothed with any number of cases; so that the star-wheel consists of the same. The illuminated fires, which must be placed very near each other on the frames, in order to have a proper effect, ought to burn as long as the wheels, and be lighted at the same time.

Sect. IV. Of Detonating Works.

We have noticed various fulminating preparations in different parts of our work, such as the ordinary fulminating powder, Higgins's fulminating powder, fulminating oil, and several metallic powders. We have also given some preparations made with fulminating silver, the making of which we have noticed.

Besides the torpedo, &c. prepared with fulminating silver, there are some other preparations made with the same substance, which we purpose to give in this place.

Waterloo crackers. Take a slip of cartridge paper, about three-quarters of an inch in width, paste and double it. Let it remain till [274] dry, and cut it into two equal parts in length, (No. 1 and 2), according to the following pattern.

No. 1.	Glass.	S.	Glass.	No. 2.

Take some of the glass composition, and lay it across the paper as in the pattern, and put about a quarter of a grain of fulminating silver in the place marked S.; and, while the glass composition is moist, put the paper, marked No. 2, over the farthest row of glass. Over all, paste, twice over the part that covers the silver, a piece of paper; let it dry. By pulling both ends apart, the friction by the glass, will cause the fulminating silver to explode.

Detonating Girdle. Procure a piece of girth, from 12 to 18 inches in length. Double it, and fold it down about $1\frac{1}{2}$ inches, similar to the fold of a letter, and then turn back one end of the girth, and it will form two compartments. Then dissolve some gum arabic in water, and thicken it by adding coarsely powdered glass. Place two upright rows of the glass composition, in the inside of one of the folds, about a quarter of an inch in width, and, when they are dry, sow the first fold together on the edge, and then the second at the opposite end; so that one end may be open. Then in the centre of the two rows, put about a grain of fulminating silver, and paste a piece of cotton or silk over it. Make a hole at each end of the girdle, and hang it to a hook in the door post, and the other hook on the door; observing to place the silk part, so that it may come against the edge of the door upon being opened, which will occasion a report.

Detonating Tape. This is made of binding, about $\frac{3}{8}$ths of an inch in width. The same directions are to be attended to, as those we have just given for making the girdle. It may be exploded by taking hold of each end, and rolling the ends from each other sharply, or by two persons pulling at opposite ends.

Detonating Balls. These are made in several ways, either by enclosing a shot in paper with fulminating silver, which is exploded by throwing it on the ground, or made of small glass globes. For the latter, procure some small glass globes, between the size of a pea and a small marble, in which there must be a small hole; put into it half a grain of fulminating silver, and paste a piece of paper over the hole. When this ball is put on the ground, and trod upon, it will go off with a loud noise. If put under the leg of a chair, and pressed by the weight of the body, the same effect will take place.

Detonating Cards. Take a piece of card, about three fourths of an inch in breadth and 12 in length; slit it at one end, and place in [275]
the opening a quarter of a grain of fulminating silver, close the end down with a little paste, and when dry light the end in a candle.

Fulminating silver may be used in several other ways, affording a variety in the effect, as the following: Fold a letter in the usual manner, and along with the wafer introduce the fulminating silver mixed with some glass: when the wafer is broken, in the act of opening the letter, a violent explosion will take place.

By placing a quarter of a grain of the powder in the midst of some tobacco in a pipe, or between the leaves of a segar, and closing the end again to prevent the powder from falling out; it need hardly be stated, that on lighting it, an explosion ensues. Such experiments should be made with caution.

One-third of a grain of fulminating silver, folded in a small piece of paper, and wrapped in another piece, then pasted round a pin, which is to be stuck in the wick of a candle, will make a loud report.

As fulminating silver explodes by heat, or friction, it is obvious, that various contrivances may be used for this purpose. If, for instance, half a grain be put on a piece of *glass paper*, (paper covered with a mixture of powdered glass and gum), then inclosed in a piece of tin foil, and put in the bottom or side of a drawer; on opening or shutting it, the powder will immediately explode. The same effect takes place by putting a quarter of a grain into a piece of paper, and placing it in the snuffers. When the candle is snuffed, it will go off.

Two figures, one of which blows out and the other relights a candle, are sometimes exhibited in rooms. This is performed by making two figures of any shape or material, and inserting in the mouth of one, a small tube, at the end of which is a piece of phosphorus, and in the mouth of the other, a tube containing at the end a few grains of gunpowder; observing that each be retained in the tube by a piece of paper. If the second figure be applied to the flame of a taper, it will extinguish it, by reason of the gunpowder, and the first will light it again.

Candle bombs. These are usually called candle crackers, and are made of glass. They are blown in small bubbles, having a neck about half an inch long, with very slender bores, by means of which a small quantity of water or spirit of wine is introduced. The orifice is then closed. When they are stuck into a candle, the heat converts the water or alcohol into vapour, which breaks the [276]
glass with a loud report, extinguishing the flame at the same time.

Detonations by Electricity. The electric fluid, it is known, will inflame combustible bodies, and, for the purpose of experiment, several contrivances have been used. That of placing the substance, gunpowder for instance, on a small insulated stand, and passing the spark through it by means of conductors, will cause its inflammation. The *electrical house* is also an exemplification of the effect of the electric fluid.

Detonations by Galvanism. Substances, placed on a glass plate, and brought in contact with the positive and negative poles of a galvanic battery, are readily inflamed. Hence phosphorus, gunpowder, the metals, &c. may be inflamed in this manner. The deflagrator of professor Hare of the University of Pennsylvania, is a powerful apparatus for the purpose; for the construction of which, and the details of its effects, see the American Journal of Science by professor Silliman, of Yale College.

Among the means of producing heat that of compression is well known. The common condensing syringe, for inflaming spunk or touch paper, is on this principle.

This syringe is now made very portable, not more than six inches in length and about three-eighths of an inch in diameter. The end of the piston, which fits tight in the cylinder, has a small cavity, in which the spunk is put, so that, when the piston is suddenly compressed, the air is condensed, and a temperature produced, sufficient to inflame it. The air, in the cylinder, is condensed in the ratio of about one to forty. The calculations on the degree of compression, which atmospheric air must undergo to produce fire by this kind of percussion, with observations on the subject, may be seen in M. Biot, (*Traité de Physique Experimentale, &c.* tome ii, p. 17), with other remarks concerning the sources of caloric.

To account for certain phenomena in the atmosphere, some of which are accompanied with detonations, Mr. Nicholson (*Chemical Dictionary*, article Air, atmospherical), conceives that the lower atmosphere consists chiefly of oxygen and nitrogen, together with moisture, and the occasional vapours or exhalations of bodies. The upper atmosphere seems to be composed of a large proportion of hydrogen, a fluid of so much less specific gravity than any other, that it must naturally ascend to the highest place; where, being occasionally set on fire by electricity, it appears to be the cause of the aurora borealis and fire-balls. It may easily be understood, that this will only happen on the confines of the respective masses of common atmospherical air, and of the [277]
inflammable air; that the combustion will extend progressively, though rapidly, in flashings from the place where it commences; and that, when, by any means, a stream of inflammable air, in its progress towards the upper atmosphere, is set on fire at one end, its ignition may be much more rapid than what happens higher up, where oxygen is wanting; and at the same time more definite in its figure and progression, so as to form the appearance of a fire-ball.

Detonations frequently accompany combustion. There are many interesting experiments on this subject, some of which we will notice in this place, *viz.*

Experiment 1. If a small portion of fulminating powder be placed on a fire-shovel over a hot fire, it will become brown, then melt, and swell up, and finally explode. See *Fulminating powder.*

Experiment 2. Iron filings and sulphur, made into a paste with water, and buried in the ground for a few hours, will unite, decompose the water, and inflame; throwing up the earth with violence and noise. See *Artificial Volcano.*

Experiment 3. If nitrate of copper be spread on tin foil and wetted, and the foil immediately wrapped up, scintillations of fire will follow, accompanied with slight detonations.

Experiment 4. Five or six grains of sulphuret of antimony, with half its weight of chlorate of potassa, when struck with a hammer will cause a loud detonation.

Experiment 5. Two grains of chlorate of potassa, and one grain of flowers of sulphur, when rubbed together, will produce a detonating noise; and the same mixture, struck with a hammer, will give a loud report. See *Chlorate of Potassa.*

Experiment 6. One grain of phosphorus and two grains of chlorate of potassa, struck in the same manner, will produce a violent explosion. See *Phosphorus.*

Experiment 7. Mix ten grains of chlorate of potassa with one grain of phosphorus, and drop the mixture into sulphuric acid; detonation and flame will be the consequence.

Experiment 8. Make a mixture of arsenic and chlorate of potassa. On presenting a lighted match, combustion, accompanied with a detonation, will ensue; and, if a train of gunpowder be laid, and both inflamed at the same time, the arsenical mixture will burn with the rapidity of lightning, while the other burns with comparative slowness.

Experiment 9. If one grain of dry nitrate of bismuth be mixed with one grain of phosphorus, and rubbed together in a metallic [278]
mortar, a loud detonation will be produced.

Experiment 10. If a globule of potassium be thrown upon water, an instantaneous explosion will be produced.

Experiment 11. A grain of fulminating gold, struck gently with a hammer, will produce a loud explosion.

Experiment 12. A few grains of fulminating mercury, struck in the same manner, will produce a loud detonation.

Experiment 13. When a grain or two of potassium are mixed with the same quantity of sodium, no effect will take place; but if the mixture be brought in contact with a globule of mercury, and agitated, combustion, with a slight detonation, will follow, showing the vivid combustion of three metals, when brought in contact with each other.

Experiment 14. If to six grains of chlorate of potassa, we add three grains of pulverized charcoal, and rub the two in a mortar, no effect will ensue; but if we add to this mixture two grains of sulphur, and continue the rubbing, inflammation, accompanied with a report, will take place. See *Gunpowder of chlorate of potassa.*

Experiment 15. Chlorate of potassa and sulphur, rubbed in a mortar, will produce a crackling noise, similar to that of a whip. These reports will follow in succession as the pestle is pressed on the mixture.

Experiment 16. Combustion, with a slight detonation, takes place during the melting of coin in a nut-shell. For this purpose, make a mixture of three parts of nitre, one part of sulphur, and one of very fine dry saw dust; press a small portion of this powder into a walnut shell, and put on it a small silver or copper coin, rolled up, and fill the shell with the mixture. If the mixture be now inflamed, it will melt the coin in a mass, while the shell will be only blackened.

Experiment 17. Introduce, into an inflammable air pistol, a mixture of hydrogen gas with oxygen gas, or, in the place of the latter, atmospheric air, and apply a lighted taper: a violent detonation will be produced. See *Inflammable air works.*

Experiment 18. Mix some fine musket powder with pulverized glass, and strike the mixture with a hammer on an anvil; the gunpowder will explode. See *Gunpowder.*

Experiment 19. Take a small portion of fulminating platinum, and place it on the end of a spatula, or on the blade of a knife, and hold it over the flame of a candle; a sharp explosion will take place. See *Fulminating platinum.*

Experiment 20. If soap bubbles be formed of a mixture of hydrogen gas and atmospheric air, and touched with a lighted taper, [279]
they will detonate in the air.

Experiment 21. If a portion of detonating oil, (*Chloride of azote*) be heated to 212°, a violent explosion will ensue; or,

Experiment 22. If a portion of the same oil, of the size of a pin-head, be brought in contact with olive oil, the effect will be still more violent. See *Detonating oil.*

Experiment 23. Take ten or fifteen grains of *Higgins's* fulminating powder, and expose it to heat on a shovel: detonation will follow. See *Higgins's Fulminating powder.*

Experiment 24. If oxalate of mercury, to the amount of three or four grains, be struck with a hammer, a detonation will ensue, in the same manner as with the nitrous etherized oxalate of mercury, or Howard's fulminating mercury. See *Mercury.*

Experiment 25. Take some of the detonating powder, prepared from indigo, and wrap it up in paper, and strike the paper with a hammer: an explosion will ensue. See *Detonating powder from indigo.*

Experiment 26. If some gunpowder be placed on the stand of an electrical discharger, and the electric spark passed through it, combustion, with a detonation, will be produced.

Experiment 27. If some gunpowder be wrapped in tin foil, and placed on a glass plate, and the two wires of a galvanic battery brought in contact with the foil; the foil will inflame and explode the powder.

Experiment 28. Mix in a mortar one part of sulphuret of potassa with two parts of nitrate of potassa, and expose the mixture to the action of heat in the same manner as fulminating powder: a violent detonation will take place. The sulphuret of potassa is recommended, in lieu of potassa and sulphur in a separate state; and although called Bergman's fulminating powder, this compound is in fact, according to the theory of its explosion, the same as the ordinary fulminating powder.

Experiment 29. If, says Morey, (*Silliman's Journal* ii, 21), a given quantity of strongly compressed boiling water, be suddenly discharged into about an equal quantity of oil or rosin, at or near the boiling point, it will explode, to every appearance, as quickly and violently as gunpowder.

Experiment 30. If zinc or iron filings, or pulverized antimony, be mixed with chlorate of potassa, and struck with a hammer,
violent detonations will ensue. If sulphuret of iron be used, the same effect will ensue. See MM. Fourcroy and Vauquelin's [280]
communication to the *Société Philomatique*, in their *Transactions*.

Experiment 31. If oxide of mercury, obtained from its solution in nitric acid by means of caustic potassa, be dried, and mixed with flowers of sulphur, and struck with a hammer, a detonation will be produced. (See *Journal de Physique*, 1779.)

Experiment 32. If alcohol or ether be mixed with chlorate of potassa, into a thick paste, and the mixture struck with a hammer, an explosion will be the consequence: or,

Experiment 33. If, instead of alcohol or ether, we make use of fixed or volatile oils, and proceed in the same manner, the same effect will ensue.

Experiment 34. If a small portion of chloride of azote (*Detonating oil*) be dropped into a solution of phosphorus in ether or alcohol, a violent explosion will take place: or,

Experiment 35. If in the place of phosphorized ether, other oils, as camphorated oil, palm oil, whale oil, linseed oil, sulphuretted oil, oil of turpentine, naphtha, &c. be brought in contact, the same effect will ensue.

Experiment 36. Chloride of azote will also detonate with sundry gaseous and solid substances, as supersulphuretted hydrogen, sulphuretted hydrogen, phosphuretted hydrogen, nitrous gas, aqueous ammonia, phosphuret of lime, ambergris, fused potassa, and sundry metallic soaps. Messrs. Porret, Wilson, and Kirk, brought one hundred and twenty-five substances in contact with it, and twenty-eight of the number produced detonations. (*Nicholson's Journal*, vol. 34.)

Experiment 37. If a small quantity of ammoniacal nitrate of copper be wrapped in paper, or in a piece of tin foil, and struck with a hammer, a detonation will ensue.

Experiment 38. If a small portion of arsenic and chlorate of potassa be mixed, and smartly struck, a flame will be produced, accompanied with an explosion; or,

Experiment 39. If the same mixture be touched with a lighted match, it will burn with considerable rapidity; or,

Experiment 40. If it be thrown into concentrated sulphuric acid, at the instant of contact, a flame will rise into the air like a flash of lightning.

Experiment 41. Heat a portion of deutoxide of chlorine: when the temperature arrives at 212°, an explosion will take place, and chlorine and oxygen be evolved.

Experiment 42. If prussine gas, otherwise called cyanogen, or carburet of azote, be mixed with atmospheric air, in the
proportion of about one to four in volume, and the electric spark made to pass through the mixture; a violent detonation will result, [281]
leaving a mixture of carbonic acid gas and azotic gas.

Experiment 43. If a mixture of equal parts of nitrate of potassa, and titanium, be thrown into a red-hot crucible, detonation will follow.

Experiment 44. Melt some nitrate of potassa in a crucible, and bring it to the state of ignition: now throw in a small quantity of pulverized zinc, and a very violent detonation will take place.

Experiment 45. If one part of zinc filings and two parts of dry arsenic acid be distilled in a retort, or exposed to heat in a crucible, the moment it becomes red, a detonation will be produced.

Experiment 46. If a few drops of deutoxide of hydrogen, or the oxygenized water of Thenard, be let fall on dry oxide of silver, a violent action will follow, accompanied with an explosion. Several other oxides have the same effect.

Experiment 47. If a portion of black wadd, an ore of manganese found in Derbyshire, England, be brought in contact with linseed oil; the oil will take fire, producing sometimes slight detonations.

Experiment 48. Take a portion of the brown oxide of tungsten, formed by transmitting hydrogen gas over tungstic acid, in an ignited glass tube; mix it with chlorate of potassa, and strike the mixture with a hammer: a loud detonation will ensue; or,

Experiment 49. Heat some of the brown oxide in the air. It will take fire, and burn like tinder, passing to the state of the yellow oxide, or tungstic acid.

Experiment 50. If one measure of oxygen gas, and two measures of hydrogen gas be mixed in the explosive eudiometer, and the electric spark passed through them, a detonation will ensue, and a complete condensation take place.

Experiment 51. When equal volumes of protoxide of azote, or gaseous oxide of azote, (called also nitrous oxide), and hydrogen gas, are treated in the same manner, the mixture will explode, leaving a residuum, consisting of azotic gas.

Experiment 52. If two measures of carbonic oxide or gaseous oxide of carbon, and one measure of oxygen, be submitted to the action of the electric spark, a detonation will ensue, and the carbonic oxide will be changed into carbonic acid.

Experiment 53. If one measure of carburetted hydrogen gas, either the heavy or light carburetted hydrogen, called also the hydroguret and bi-hydroguret of carbon, (the former being sometimes called olefiant gas), be mixed with two or three measures of oxygen gas, and the electric spark transmitted through them; a detonation will ensue, forming water and carbonic acid. [282]

Experiment 54. If one measure of cyanogen, (carburet of azote), be mixed with two and a half measures of oxygen gas, and treated with the electric spark, the mixed gases will explode very loudly. The cyanogen burns, in this case, with a blue flame; although it is usually of a purple colour. The products of combustion are carbonic acid and azote. (See Experiment 42.)

Experiment 55. If one measure of arsenuretted hydrogen gas, (obtained from an alloy of three parts of tin and one of arsenic, by treating it with muriatic acid), and two measures of oxygen gas are mixed together, and the electric spark is passed through the mixture; a detonation will ensue, and water and arsenious acid be formed.

Experiment 56. If potassium be made to act upon a compound of chlorine and sulphur, called chloride of sulphur, an explosion will immediately ensue; but,

Experiment 57. If potassium be dropped into chlorine gas, inflammation only will take place, accompanied with a vivid light, forming chloride of potassium, (dry muriate of potassa.)

Experiment 58. If sulphuret of potassium be heated in the air, it will burn with great brilliancy, forming sulphate of potassa; but, if mixed with chlorate of potassa, and struck with a hammer, a violent detonation will be produced.

Experiment 59. If potassium be heated in sulphuretted hydrogen gas, it takes fire, and burns with a vivid flame, and pure hydrogen is set free; thus proving that sulphuretted hydrogen gas, although inflammable itself in oxygen gas, is a supporter of combustion for potassium.

Experiment 60. If phosphuret of potassium be exposed to the air, it will inflame spontaneously, forming phosphate of potassa; but if it be dropped into water, it will produce a violent explosion, in consequence of the immediate disengagement of phosphuretted hydrogen gas.

Experiment 61. If potassium be moderately heated in the air, it inflames, burns with a red light, and emits alkaline fumes.

Experiment 62. If potassium be thrown upon water, it acts with great violence, burning with a beautiful light, of a red colour, mixed with purple, the water becoming a solution of potassa. [283]

Experiment 63. When sodium is heated strongly in oxygen or chlorine, it burns with great brilliancy; but it does not inflame, when thrown into water. It is converted, however, into soda. If it be heated in oxygen gas in excess, it burns, and is converted into the peroxide of sodium, which, when mixed with combustible bodies, and exposed to the action of heat, deflagrates with violence, giving off its excess of oxygen, and becoming changed into soda, or protoxide of sodium.

Experiment 64. When sulphuret of sodium is mixed with chlorate of potassa, and struck with a hammer, a detonation will ensue; and when sodium is heated nearly to fusion, in contact with sulphuretted hydrogen gas, it will unite with the sulphur; flame will be produced, and hydrogen gas set at liberty. A sulphuret of sodium is thus formed, which is usually combined with some sulphuretted hydrogen.

Experiment 65. When a mixture of ammoniacal gas, in a dry state, and oxygen gas, is submitted to the influence of the electric spark, in the explosive eudiometer, explosion will take place, and water and azotic gas result.

Experiment 66. If potassium or sodium be heated in fluoric gas, a rapid combustion takes place, in all respects as brilliant as in oxygen gas.

Experiment 67. If gallic acid be placed on a red-hot iron, it burns with flame, and emits an aromatic smell, similar to that of benzoic acid; but, if mixed with chlorate of potassa and struck with a *hot* hammer, a detonation will ensue. Various vegetable acids, as the benzoic, which is highly inflammable, produce similar effects.

CHAPTER IV.

OF SCENTED FIRE-WORKS.

There is a variety of scented fires, all partaking, in a greater or lesser degree, of a peculiar flavour, according to the substances, which enter into their composition. It is a fact, that, in the ordinary odoriferous fire, into which, either the so called scented gums, or essential oils, enter as a component part, these substances are not only decomposed in the act of combustion, but evolve, during that process, a part of their respective *odours*, to which we attribute the *scent* imparted to the atmosphere. In those instances, in [284] which gunpowder forms a part of the composition, it is to be remarked, that the peculiar smell of fired gunpowder is scarcely recognized, owing to the preponderance of the scent in the composition. Hence it is, that scented fire-works are more calculated for confined places than for the open air.

Scented fires are various both in their nature and composition, and may always be so modified, as, in their effect, to produce, not only the particular flame, or appearance of the fire, but the extrication, along with the gaseous products, of the odour of the essential oil, or other substance made use of.

Linnæus, in a dissertation on the odours of different substances, endeavoured to classify them. M. Lorrey (*Mémoires de la Société Royale de Medicine* 1784) divided them into five classes; viz. camphors, narcotics, ethers, volatile acids, and alkalies; but it is obvious, that it is an impossibility to class all the odours which exist, and may be formed by the mixture, or combination of various substances. We may consider them either pleasant, or unpleasant to the sense of smelling. But as we recognize bodies very frequently by their odour, with which we become familiar, as camphor and assafœtida, for instance; so the olfactories may be affected by other odours. Aromatic and fetid odours are opposite to each other. Some of the gases, as the olefiant, have a fragrant smell, and others, as hydrogen, and sulphuretted hydrogen, either alone or mixed, are extremely unpleasant. The intestinal gas (*gas intestinaux* of the French) is a particular instance of the odour of a compound gas, or mixture of gaseous fluids. The experiments of M. Jurine of Geneva, of MM. Chevreul and Magendie, (*Ann. de Chim. et de Phys.* t. ii, 294), of M. Vauquelin, (*Journal de Pharmacie*, t. iii, p. 205), and of MM. Lameyran and Fremy, (*Bulletin de Pharmacie*, t. 1, p. 358), are interesting on this subject. Intestinal gas differs in its composition. It always contains carbonic acid gas, and azotic gas, and hydrogen gas, either pure, or combined with carbon and sulphur. Thenard (*Traité de Chimie*, iii, p. 576) contains some observations on this subject.

In the camphor odour, Lorrey includes not only camphor itself, but various species of laurel, myrrh, and turpentine. In the narcotic odour, he embraces opium, various gum-resins, roses, lillies, jessamine, &c. and musk, amber, and castor. In the ethereal [285] odour, different kinds of ether. Under the odour of volatile acids, he considers that of fruits, aromatic barks, citron; and under the alkaline odour, the acrid, and, in general, the antiscorbutic plants. Fourcroy, in treating of the aroma of plants, or the *spiritus rector* of Boerhaave, (*Bulletin de la Société Philomatique*, an. 6, p. 52,) has some interesting facts on this subject.

It is evident, that perfumes, so called, owe their peculiar fragrance to an essential oil, which characterizes each kind; for the essential oil obtained by distillation, partakes of the odour of the plant. Hence the oils of mint, roses, thyme, cinnamon, cloves, &c. &c. all of which are peculiar in this respect. Odoriferous fire-works owe their particular properties to the presence of some gum, resin, or oil. As to the expansibility, or rather the divisibility of odour, several interesting facts are known. In a work, entitled *l'Existence de Dieu, par les merveilles de la Nature*, we are informed, that, if we take the one-fourth of a drachm of benzoin, and place it in the four corners of a room, the odour will be recognised in an instant. The chamber in which the experiment was made, the author states, was 24 feet by 16, and contained 9212 cubic feet of air, which, multiplied by 1000, would give 9216000 inches, and 1000000 parts of an inch were rendered appreciable. Therefore, he infers, that 9216000000000 are equally perceptible in the chamber. Prevot (*Bulletin de la Société Philomatique*, an. 6) has some observations of the same nature, respecting camphor. If such are the effects with benzoin, what, we may ask, would be those of the more powerful perfumes, such as musk? One grain, or perhaps the tenth part of a grain of musk, would scent the atmosphere of a room very perfectly.

De Laval (*Description of the Maldiva Islands*) mentions the use of scented fire by the inhabitants, in the celebration of their festivals. On the day of every new moon, they place at the entrance of the churches, and the gates of their houses, cocoa shells cut in the middle, and filled with white sand and burning coals, upon which they burn, almost all night, sweet scented gums and woods; and at the nocturnal festival, called *maulude*, the night on which Mahomet died, their halls are illuminated with a multitude of lamps, and the air is filled with the smoke of perfumes. The use of scented fire appears to form a principal part of their devotional exercises. Perfumes are even burnt on the graves of deceased persons.

Having mentioned the use of odoriferous plants in scented fire, we may add, that all plants possess some peculiar character, if [286] aromatic, which, as one of their characters, serves to distinguish them.

The qualities of plants are said to be similar, when they have the same taste and odour. The odours of plants, Richard divides into 1. Fragrant, 2. Aromatic, 3. Ambrosiac, or resembling amber, 4. Alliaceous, or resembling garlic, 5. Fetid, 6. Nauseous. The three first are innoxious.

In the composition of scented fire-works, it is also to be observed, that gunpowder does not always form a part; and hence their character is various, according to the purposes they are applied to, or their uses.

In the odoriferous water balloons, (for which, see *aquatic fire-works*), we have, for instance, along with saltpetre and other substances, in the different compositions, either amber and flowers of benzoin; or frankincense, myrrh, and camphor; or amber, cedar raspings, and the essential oils of roses and bergamot; or the saw-dust of juniper, cypress, camphor, myrrh, dried rosemary, cortex elaterii, and oil of roses. These are the substances, therefore, which enter into the different compositions, in the order here given, and which impart to the fire an odoriferous character. The relative proportions may be learnt, by referring to the chapter on *Aquatic fire-works*.

Scented fires are, however, little used. Their effect is nevertheless agreeable in close rooms; but in the open air they lose this property, or rather it is not perceptible, owing to its extreme division.

The *vases of scent* were greatly employed in the public feasts and ceremonies at Rome, Athens, and, above all, in Egypt. In temples, palaces, &c. they were mostly used. The vessels, which contained the composition, were placed by the Athenians in sculptured or painted vases, as well to hide their appearance, as to serve for ornament.

Sec. I. Of Pastilles.

Pastilles, or fire crayons, are small conical troches, in the form of a loaf, of one and a quarter inches in height, and about an inch thick. They are made of the following composition, which is moistened with rose-water, having some gum arabic previously dissolved in it. The paste is made neither too thick nor too thin, but of a sufficient consistence to work with the hand.

Composition of Pastilles. [287]

Storax calamite,	2	oz.
Benzoin,	2	—
Gum Juniper,	2	—
Olibanum,	1	—
Mastich,	1	—
Frankincense,	1	—
White or yellow Amber,	1	—
Camphor,	1	—
Saltpetre,	3	—
Charcoal of the linden, or willow,	4	—

The pastilles are burnt upon a plate, and communicate to the air an agreeable odour.

Odoriferous paste.

Gum Benzoin,	½	oz.
Storax calamite,	4	scruples.
Peruvian balsam, (dried)	¼	oz.
Cascarilla,	4	scruples.
Cloves,	½	drachm.
Charcoal,	1½	oz.

Nitre,	1	drachm.
Oil of Lemon,	½	do.
Tincture of Amber,	½	do.

The dry substances are pulverized very fine, and mixed intimately together, and the oil of lemon and tincture of amber then added. The whole is then made into a thick paste with common mucilage, and formed into pieces as before mentioned. These pieces ought to be conical. When used, they are placed on a stone, or a piece of metal, and inflamed. This composition is said to burn with scintillations, and to exhale a very fragrant and agreeable odour. See *Dictionnaire de l'Industrie*.

Perfume for Apartments.

Orrisroot,	1	oz.
Benzoin,	½	—
Charcoal,	¼	—
Ess. Bergamot,	1	drachm.

These ingredients are mixed into a paste in the usual manner, with orange flower water, and a small quantity of gum. A small portion, when dry, thrown on ignited coals, will exhale an agreeable odour.—*Ibid.*

M. Brillat-Savarin (*Archives des Découvertes* iii, p. 328) has invented a machine, which he calls the *irrorateur*, for perfuming [288] apartments. He objects to the ordinary mode of perfuming by fire, and sprinkling odoriferous fluids in a room. His *irrorateur* consists of a small fountain, which, by compression, forces out the odour required, and may be conveyed to any place.

Sec. II. Of Vases of Scent.

We observed, that these vases were much in use at the public feasts and ceremonies of the Athenians, Romans, and Egyptians.

Composition for the Vases.

Storax,	4	oz.
Benzoin,	4	—
Frankincense,	4	—
Camphor,	2	—
Gum Juniper,	1	—
Charcoal of the willow,	1	—

These substances are pulverized, and intimately mixed, and oil of juniper is added. The mixture is put in an earthen vessel, having a cotton, similar to a wick, supported by means of a wire. Among the ancients, the earthen vessels were afterwards placed in sculptured, or otherwise ornamented vases. By using stone-ware vessels, and mixing the composition with the spirit or oil of turpentine, the combustion will be more rapid, and the flame more enlarged.

Sec. III. Remarks on Spontaneous Accension.

The spontaneous accension of spirit of turpentine by the addition of nitric acid, might furnish also a means of preparing a scented fire extemporaneously; by putting into the vessel, previously to the spirit of turpentine, the composition above mentioned. See *Nitric Acid*, in the article *Nitre.*

An extemporaneous fire may also be prepared, by placing, on the scented mixture, the following composition, namely, chlorate, or hyperoxymuriate, of potassa and sugar, and touching the mixture with a glass rod dipped in sulphuric acid, or oil of vitriol. The fire will then communicate to the other materials. See *Chlorate of Potassa* and the article on *Pyrophori.*

Camphor, which imparts an agreeable odour, may be readily inflamed in this manner, and the experiment even be made on snow or ice. See *Camphor.*

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Sec. IV. Of Torches, and Odoriferous Flambeaux.

Flambeaux are usually wax torches. Odoriferous flambeaux may be formed by melting with the wax, camphor and frankincense, and mixing with the whole, when fluid, some of the essence of bergamot. Although there are no directions given on that subject; yet, judging from analogy, a mixture of that kind would be an improvement on the flambeau, when it is to be used in rooms or for particular occasions. They may be made either large or small, with a wick of a proportionate size.

Torches are principally used for military purposes, to give light, when an army is marching at night, during sieges, &c. They ought not to be extinguished by wind or rain. The *Torches inextinguibles*, of the French, are of this character.

Torches are made in the following manner: Take four large cotton matches, three or four feet long; boil them in a solution of saltpetre, and arrange them round a pine stick. Afterwards, cover them with priming powder and sulphur, made into a thin paste with brandy. When dry, they are to be covered with the following composition:

Composition for torches.

Yellow wax,	2	lbs.
White turpentine,	2	—
Sulphur	12	oz.
Camphor,	6	—
Pitch,	4	—

Ibid.

White pitch,	32	parts.
Hard turpentine,	4	do.
Yellow wax,	32	do.
Sulphur,	12	do.
Camphor,	6	do.

Ibid.

Black pitch,	24	parts.
White pitch,	24	do.
Turpentine,	4	do.

The second composition is that which is used in France, and, therefore, in all likelihood, is the best formula. The flame may be more or less scented, by using, at the same time, some of the aromatic substances before noticed. This, however, is unnecessary for common purposes. See *Fire-works used in war.* The flambeau, invented by Petitpierre, (*Bulletin de la Société* [290] *d'Encouragement*, No. 102), is intended to give light to apartments.

Sec. V. Remarks concerning Odoriferous and Fetid Fire.

Fire-works may be made extremely unpleasant to the olfactory nerves, by mixing with their compositions, sundry substances of an opposite quality to odoriferous oils and aromatic gums. It will be sufficient, however, to remark, that this effect is communicated more particularly, as in the *stink-balls* of service, by using sulphur, rasped horses' and asses' hoofs, burnt in the fire, assafœtida, seraphim gum, and sundry fetid herbs or plants. The addition of the acid of amber, called succinnic acid, and, in the shops, the *salt of amber*, will give to the atmosphere in the vicinity of the fire, the peculiar property of causing a continual sneezing and coughing. Such are some of the opposite effects, which different substances produce in conjunction with fire-works. Some of these substances, it is obvious, would, if used in too large a proportion, retard, if not entirely prevent the combustion; and for that reason, they bear only a given proportion to the powder, nitre and charcoal, which forms the basis of some, as, for instance, the *stink-ball* composition. But in such cases, the combustion being in itself rapid, and the degree of heat consequently proportionate, these fixed, and otherwise incombustible bodies, in a general sense, are acted upon by the fire, already created; and, therefore, the smoke that results must necessarily possess, and partake of the fetid qualities of the substances employed. On the same principle, we may account for the effect of the scented paste, and the scented vases; but with this difference, that many of those substances are themselves inflammable, and, during their decomposition, emit the odour peculiar to each of them. We know, that the elementary principles of these bodies are carbon, hydrogen, and oxygen, variously combined, some of which are, and some are not inflammable; and that, in combustion, when it takes place, they are decomposed and new products necessarily ensue from a new arrangement of the elementary principles.

It is difficult, however, to give the precise order in which decompositions by fire result; since the substances made use of are numerous and employed in given proportions; and since their action upon each other, depends frequently on external agents, anomalous circumstances, and causes which do not follow at all times the same order of succession. Generally speaking, however, [291] we may obtain such a datum, all things being considered, a datum derived from the known laws of chemical decomposition, as will furnish a *rationale* to explain both the cause and effect. See *General Theory of Fire-works.*

There is no doubt, that, by the action of fire on fetid, and particularly animal, substances, as *hoofs*, &c. products may be formed in the very act of combustion, which would increase the fetid properties of the smoke. Zimome, obtained from the gluten of wheat by alcohol, which takes up the gliadine, when thrown upon red-hot coals, exhales an odour, similar to that of burning hair or hoofs, and burns with flame. The *pyro-products* are the immediate consequences of the decomposition of the substance; the elements of which either separate entirely, or recombine under some other form, as we find in the process of destructive distillation.

Bones, and other hard parts of animals, when subjected to distillation, furnish several products, as impure ammonia, animal oil, and the like. Wood also, we remarked, when treating of its carbonization for the formation of coal, produces, besides gaseous and other volatile products, the result of its decomposition, a quantity of acid liquor, formerly called the pyroligneous, but now the pyroacetic acid. By separating the empyreumatic flavour, which at first constitutes a part of the acid, the acetic acid is obtained in a state of purity. The pyro-tartaric acid is also the result of the action of heat; and we know, when animal substances are calcined with potash, they produce cyanogen, the basis of the hydrocyanic and ferrocyanic acids, the latter of which when united with the peroxide of iron, forms the perferrocyanate of iron, commonly called Prussian blue. Caromel also, that peculiar substance which is disengaged from sugar and various saccharine substances, when submitted to the action of heat, is a product, resulting from the decomposition of the sugar. The empyreumatic, or *burnt* flavour of certain distilled liquors, which is corrected by redistillation with charcoal, or passing the liquor through a filter of charcoal, is owing to the same cause. The changes, that bodies undergo by partial roasting, are familiar to every one; as, for instance, the torrefaction of barley, after germination, in the preparation of malt, the degree of which determines the colour and taste of the beer; the roasting of rye and coffee, before they can be employed to form a beverage; and the torrefaction of the cocoa, before it can be made into chocolate, the sweet taste and brown colour of [292] which are acquired in the process, are all examples of the effect of heat on bodies. The action of heat, according to its temperature, produces, therefore, effects of a particular kind; and, as we regulate the heat in such cases, we form products of different kinds. Destructive distillation, however, would again change the character of these products. Of this kind, we may consider the effect of the heat, produced in the combustion of inflammable substances. In a word, the action of heat may be so graduated, in the same manner as the tempering of steel, as to produce only partial changes, which must ensue at certain temperatures; or, by an increment of heat, in which a total decomposition takes place, the effect is regulated, by the force of affinities, exerting their influence under modified circumstances. Hence we perceive, by reasoning *a priori*, that as substances are altered by the action of heat, so they produce new compounds, according to the circumstances of the action, and with or without the agency of foreign bodies. These facts are so far applicable to the subject under consideration, as to enable us to explain, or account for the effects that result on the mixture, or combustion, of bodies, a knowledge of which is undoubtedly necessary to form a theory of fire-works in general.

CHAPTER V.

OF MATCHES, LEADERS, AND TOUCH PAPER.

We purpose, in the fourth part of our work, to go into the detail of the manufacture of various kinds of matches, which belong more particularly to military pyrotechny, adding, at this time, that fire matches are differently formed, and are called the quick and slow match. The former is commonly made of three cotton strands, drawn into lengths, and put into a kettle, and just covered with vinegar, (usually white wine vinegar), a quantity of saltpetre and meal powder being added, and the whole boiled together. Some put only saltpetre into water, and, after soaking the cotton, place it, while hot, in a trough with some meal powder, moistened with some spirits of wine, or brandy, which are thoroughly worked into the cotton, by rolling it backwards, and forwards with the hands. When this is done, they are taken out separately, and, after being drawn through meal powder, dried upon a line. Another mode is to steep the cotton first in vinegar, and then rub into it the following composition:

Composition for quick-match. [293]

Vinegar in which matches are soaked,	2	quarts.
Brandy,	1	do.
Saltpetre,	½	lb.
Priming powder,	1	do.
As much cotton as will take up all the above, which will be about,	1	do.

To the proportions of one pound and three-quarters of cotton, one pound of saltpetre, two quarts of spirits of wine, one pound of meal powder, and three quarts of water, some recommend the addition of four ounces of isinglass, dissolved in three pints of water.

Another method is to steep the matches in brandy, and then rub them well with priming powder.

Slow match is made of hemp, or tow, spun on a wheel like cord, but very slack, and is composed of three twists, which are afterwards again covered with tow, so that the twists do not appear. It is finished by boiling in the lees of old wine. This, when lighted at the end, burns gradually, without going out.

There are several modes of preparing slow match. There is also, a kind of slow match, which is *slower* in carrying fire than the preceding quick match. The quick match, for this purpose, is drawn through the following composition, which is melted, and the operation is continued until it attains the size of a small candle; it is then hung up to dry.

Composition for a slow match.

Gum mastich,	1	lb.
Saltpetre,	1	lb.
Rosin,	½	lb.
Yellow wax,	½	lb.
Charcoal,	2	oz.

When these matches are used, they are to be *lighted*, and then blown out. If well made, they will burn a long time. They may be used for communicating fire from one work to another. Another slow match, used for common purposes, is made by soaking hempen cord in the following ley:

Lixivium for slow match.

Oak ashes,	3	lbs.
Quicklime,	1	lb.
Liquor of horse dung,	2	lbs.
Saltpetre,	1	lb. [294]
Water,	a sufficient quantity.	

The cords are put into a pot, and boiled for two or three days, renewing the lixivium from time to time, as it evaporates. They are then taken out and dried. Good match makes a hard coal. Its duration depends upon the quality of the materials; but, generally, four inches will last an hour.

Further remarks on this subject, will be found in the fourth part of this work, in which the various modern improvements are given.

The preparation of *touch paper*, for capping of serpents, crackers, &c. may be here noticed. The directions of artists are: To dissolve in spirits of wine, or vinegar, a little saltpetre, and immerse into the solution, some purple or blue paper, and dry it for use. There is no advantage gained by using either spirits of wine, or vinegar: for the simple solution of the saltpetre in water, will be sufficient. In the former case, it may dry sooner, but neither of these fluids can add to the effect of the saltpetre.

In using this paper, care must be taken to prevent the paste which is made use of, from touching any part, that is to burn. The method of using it, is by cutting it into slips, sufficiently long to go once round the mouth of a serpent, cracker, &c. When they are pasted on, be careful to leave a little above the mouth of the case not pasted; then prime with meal powder, and twist the paper to a point.

The mode of threading and joining leaders, and placing them on different works, we shall here describe. The observations of a writer in the *Encyclopedia Britannica*, vol. xv, p. 713, are pointed on this subject, which we will briefly notice. Joining and placing leaders, is a very essential part of fire-works; as it is on the leaders that the performance of all complex works depends. The works being prepared, and ready to be clothed, the pipes must be cut of a sufficient length to reach from one case to the other; and then put in the quick match, which must always be made to go in very easy. When the match is in, cut it off within about an inch of the end of the pipe, and let it project as much at the other end; then fasten the pipe to the mouth of each case, with a pin, and put the loose ends of the match into the mouths of the cases, with a little meal powder. This being done, paste over the mouth of each case, two or three bits of paper. This method is used for large cases.

The practice adopted for small cases, and for illuminations, is the following: First, thread a long pipe; then lay it on the tops of [295]
the cases, and cut a bit of the under side over the mouth of each case, so that the match may appear, and then pin the pipe to every other case, observing, before the pipes are put on, to put a little meal powder in the mouth of each case. If the cases, thus clothed, are port-fires on illuminated works, cover the mouth of each case, with a single paper; but if they are choaked cases, situated so, that a number of sparks from other works, may fall on them before they are fired, secure them with three or four papers, which must be pasted on very smooth, that there may be no creases for the sparks to lodge in, which often set fire to the works before their time. Avoid, as much as possible, placing the leaders too near, or one across the other, so as to touch; as it may happen, that the flash of one will fire the other. If the works should be so formed that the leaders must cross, or touch, they must be made very strong, and well secured at the joints, and at every opening.

When a great length of pipe is required, it must be made by joining several pipes, in the following manner: Having put on one length of match, as many pipes as it will hold, paste paper over every joint; but, if a still greater length is required, more pipe must be joined, by cutting about an inch off one side of each pipe near the end, laying the quick-match together, and tying them fast with a small twine; after which, cover the joining with pasted paper.

Leaders, or pipes of communication, are formed of paper, which is cut into slips three or four inches broad, so that, when it is rolled on the mandril or form, it may go three or four times round. When they are very thick, they are too strong for the paper which fastens them to the works, and will sometimes fly off without leading the fire. The forms for these leaders are made from two to six-sixteenths of an inch in diameter; but four-sixteenths is the size generally made use of. The forms are made of smooth brass wire; and, when used, they are to be rubbed over with grease, or wet with paste, to prevent their sticking to the paper, which must be pasted all over. In rolling of pipes, make use of a rolling board, but press it lightly. Having rolled a pipe, draw out the form with one hand, holding the pipe as light as possible with the other, and avoiding any unnecessary pressure. Leaders are made of different lengths; and, in cutting them, as is often the case, care must be taken to do it with as little waste as possible. Leaders for marron batteries must be made of strong cartridge paper.

The *Etoupille* of the French is the same as the former match; it being nothing more than a kind of quick-match, prepared by [296]

soaking three threads of cotton in a paste, composed of the best priming gunpowder and brandy. It is designed to communicate fire with promptness, from one part of a fire-work to another, and, therefore, has the same effect as the common cotton quick-match. The cotton is usually soaked, or steeped in a paste of gunpowder and brandy, neither too thick nor too thin, for the space of two hours, adding more of the brandy as it evaporates. In the French preparation, gum arabic is used, in the proportion of one ounce to a pound of powder. In the English preparation, isinglass, or fish glue is employed, in the proportion of four ounces dissolved in three pints of water. Gummy and gelatinous substances are calculated for no other purpose, than to make the powder adhere to the cotton, the quantity not being sufficient to retard the combustion of the match. Pipes or leaders of communication, are an essential part of fire-works, and hence great care and attention are required in preparing them. Cotton, prepared in the manner already described, is the substance generally made use of. It has the property of imbibing fluids with facility; and when spirit of wine, or brandy, or even water, is used, it absorbs, and mechanically combines with the gunpowder, the impregnation with which determines the quality of the match. Alcohol, deprived of as much water as possible, or, in other words, the most concentrated, appears to have an advantage over brandy or water. If it be used merely as a vehicle, in order to suspend the gunpowder, and likewise to carry it, as it were, into the fibres of the cotton, which appears to be its *modus operandi*, then it is undoubtedly preferable to either brandy or water. The former, as it never exceeds fourth proof, contains always a considerable quantity of water; and, therefore, as water decomposes gunpowder, by dissolving the nitre, and separating the sulphur and charcoal, on which it has no effect, it is obvious, that the gunpowder itself, when mixed with brandy, is more or less injured. It is true, however, that the cotton in that case would be more effectually saturated with the nitre; but it does not follow, that it would be saturated with the gunpowder; as two of its component parts, *viz.* the charcoal and sulphur, would be separated. We have seen, that *touch paper* is nothing more than paper, soaked in a solution of, and consequently impregnated with, nitre; but, in order to render a match more combustible, and convey fire with more rapidity, which is required in many cases, gunpowder is the only [297]
substance, that possesses this property in any degree.

The cotton, which is used for this purpose, is the same as that for candle wick, and, with respect to thickness, may be from one to six threads, according to the pipe, it is intended for. The pipe must always be large enough for the match, so that the match may be pushed in easily without breaking it. After it is doubled into as many strands as required, it is usually put into a flat bottomed copper, or earthen pan, and there boiled in a solution of saltpetre. It is then taken out, and coiled into another pan, and the remaining solution is poured on. Meal-powder is then put in, and pressed down, till it is quite wet. It is then wound upon a reel, keeping the hands moistened with the powder and fluid of the last kettle, and suffered to remain a short time; when it is taken down, and meal-powder sifted on both sides of it, till it appears quite dry. When dry, it is cut, and secured in skins.

There is one advantage in this process, that the cotton in the first place is saturated with nitre; and, in the second place, while still wet, is combined mechanically with the meal-powder. The match I apprehend, is in all respects equal to the *etoupille* of the French.

The priming paste, as it is called, consisting of meal-powder and brandy, may be preserved in close vessels for a length of time; and, when used, may be brought to a proper degree of consistency, to be worked, by the addition of more brandy.

The preparation of the *etoupille*, or match for communicating fire, will be given at large, when we treat of military fire-matches. It will be sufficient to remark, that its preparation, according to Bigot, (*Traité d'Artifice de Guerre*, p. 74), consists in macerating the cotton in vinegar, then pressing it, and steeping it in brandy, and afterwards working it in a paste, composed of meal-powder, gum arabic, camphor, and brandy, and then rolling it on a table with meal-powder.

In preparing all kinds of matches, we may increase or lessen their effect by increasing or diminishing the quantity of gunpowder. By combining powder and sulphur with one or more parts of melted wax and rosin, in the manner before mentioned, and immersing the cotton into it, a match will be formed, which, for some purposes, is considered preferable to the ordinary kind.

The following proportions are given for preparing 100,000 *priming fusées*, or matches:

Cotton,	50	lbs.	[298]
Meal-powder,	30	lbs.	
Vinegar,	12	galls.	
Brandy,	7	galls.	
Gum arabic,	2	lbs.	
Camphor,	1	lb.	

CHAPTER VI.

OF THE FURNITURE, OR DECORATIONS FOR FIRE-WORKS.

By the term *garniture*, used by the French, we understand the furniture, equipage, embellishments, or decorations for sundry fire-works, as rockets, bombs, batteries, fire-pots, &c.

Sec. I. Of Serpents.

The directions, given for the formation of serpents, are the same in Morel and Bigot. Paper is rolled lengthwise on a mandril, or form, which is a quarter of an inch in diameter, of three thicknesses, according as it is stout, and the last turn of the paper is pasted. They are made tight and strong, and strangled first at one end. They are then put upright in a square or round box, called a *bushel*, for the purpose of charging them. For this end we must have a small mallet, and a rammer of brass, of a smaller diameter than the form. The composition is put in and rammed, proportioning the number and force of the blows to the size of the case. The *petard* is formed, with extremely fine powder, then rammed, and the case choaked. To prime them, we open the ends with a piercer, and by means of a spatula introduce a portion of priming paste, or priming powder, in order that the fire may communicate.

We may here remark, that large cases for serpents, as well as wheel cases, are driven solid. There is usually a mould, in which is a nipple, with a point at top, that serves, when the case is filling, to stop the neck, and prevent the composition from falling out. The air, in that event, would get into the case, and cause it to burst. These sorts of moulds are made of any length or diameter, as the cases are required; but the diameter of the form must be equal to half the caliber, and the rammers solid.

Lardons are of much the same nature as serpents, but are made stronger. They are charged in the same manner. To prime them, [299] they are first pierced about five or six lines (or half an inch,) in depth, which presents a greater surface to the fire, and produces, when inflamed, more scintillations than serpents.

Composition of ordinary serpents.

	1st proportion,		2nd proportion.	
Meal powder,	16	parts.		
Saltpetre,	3	do.	15	parts.
Sulphur,	2	do.	4	do.
Charcoal,	½	do.	2½	do.

Mine pots, or Serpents.

Meal powder,	1	lb.
Charcoal,	1	oz.

Ibid.

Meal powder,	9	oz.
Charcoal,	1	—

Serpents for Pots de Brins.

Meal powder,	1½	lbs.
Saltpetre,	12	oz.
Charcoal,	2	—

The serpents or snakes for pots of aigrettes, small mortars, skyrockets, &c. are made from two and a half inches, to seven inches long. Their formers are from three-sixteenths to five-eighths of an inch in diameter; but the diameter of the cases must always be equal to two diameters of the former. They are rolled and choaked like other cases, and filled with composition, five-eighths of an inch to one and a half inches high, according to the size of the mortars or rockets, they are designed for. The remainder of the cases are charged or *bounced* with grained powder, and their ends pinched and tied close. Before they are used, their mouths must be primed with wet meal powder or priming paste as before-mentioned.

Serpents, or snakes, in fire-works, are so called from the particular appearance, and the effect which ensues, namely, a *hissing* and *spitting*. This peculiar character is given by the charcoal; for, while one part is actually consumed, in immediate contact with the substances that enter into the composition; another part is thrown out with violence in the state of ignition, in the form of sparks, and receives, for the support of its combustion, the oxygen of the air, in consequence of which carbonic acid is produced.

Sec. II. Of Crackers. [300]

Crackers are made in the following manner; cut some cartridge paper into pieces, three and a half inches broad, and one foot long. One edge of each paper fold down lengthwise, about three-quarters of an inch broad. Then fold the double edge down one quarter of an inch, and turn the single edge back half over the double fold. Open it, and lay all along the channel, which is formed by the folding of the paper, some meal powder. It must now be folded over and over till all the paper is doubled up, rubbing it at every turn. It is now to be bent backwards and forwards, two and a half inches or more, as often as the paper will allow. These folds are to be held flat and close; and, with a small pinching cord, give one turn round the middle of the cracker, and pinch it close. Bind, as usual, with pack thread, in the place where it was pinched. Prime one end of it, and cap it with touch paper. When these crackers are fired, they will give a report at every turn of the paper. If there are to be a great number of *bounces*, the paper must be cut longer, or be joined after they are made. If, however, they are made very long before they are pinched, there must be a piece of wood, having a groove sufficiently deep to let in half the cracker, which will hold it straight, while it is pinching.

The report, produced by crackers, is on the same principle as the report of a gun. The reports, which succeed each other, in crackers, formed in this manner, depends, as we remarked, on the turn of the paper, each turn producing that effect. Every part of the cracker, by this division, represents in fact a gun; and hence, as the combustion of one part necessarily succeeds that of another, we have, according to the number of turns, successive explosions.

Crackers, formed in this way, may furnish a variety in exhibitions. They may be either hung on a board, or set off on the ground. As to the report itself, it may be increased or diminished by enlarging or diminishing the size of each cracker, or division.

Crackers, as they are usually called, are nothing more than small cases charged with gunpowder. The Chinese squibs are crackers of this description. Some are four ounce cases; but the squibs, so named, hold about half a thimble full of powder. A piece of twisted match paper is inserted in the mouth of each of them. They are made of five or six turns of paper, and the last one is pasted and formed of red paper. The interior diameter is about a quarter of an inch.

Sec. III. Of Single Reports. [301]

Cases for reports are generally rolled on one or two ounce formers, and seldom made larger, except on particular occasions. They are from two to four inches in length, and are formed of thick paper. Having rolled a case, pinch one end, quite close, and drive it down. Then fill the case with grain powder, leaving sufficient room to pinch at the top. Before it is pinched, a piece of paper is to be put on the powder at the top. Reports are fired by a vent bored in the middle, or at one end. Among the portable Chinese fire-works, reports form usually a large number. They are closed with clay, which is perforated to admit the match and priming.

Sec. IV. Of Serpent Stars.

There are a variety of compositions, used to produce the appearance of stars. Thus, there are stars of different colours, which also produce tails of sparks, scintillations, more or less vivid, &c. and are calculated for particular exhibitions. The serpent stars, however, have a different object, namely, to imitate a star at first, and afterwards a serpent.

The cases for serpent stars are choaked half an inch lower than the common kind; and, after filling the hole with meal powder, the following composition is put in. It is finished, but without the operation of choaking, by adapting a piece of quickmatch, and adding more priming powder.

Composition for serpent stars.

Saltpetre,	16	oz.
Sulphur,	8	—

Meal powder,	4	—
Antimony,	1	—

This is the formula, given by Morel; but the formulæ of Bigot are in some respects different, namely:

1.	Saltpetre,	16	oz.
	Sulphur,	8	—
	Meal powder,	5	—
	Antimony,	2	—
2.	Saltpetre,	$19\frac{3}{4}$	—
	Sulphur,	$8\frac{5}{8}$	—
	Antimony,	2	—
	Charcoal,	$0\frac{5}{8}$	—

Serpent stars are of two kinds. The one is intended as the furniture for rockets, &c. and the other, when moulded, to be employed in the Roman candles.

When required to be moulded, or made into cakes, the composition is mixed with gum and brandy, into a paste, which is spread [302] upon a table, having previously covered the table with meal powder. Small cubical or other shaped pieces are cut out, sprinkled with meal powder, and dried in the shade. The meal powder serves as a priming, so that they may all take fire at the same time. The composition may be formed into balls.

Serpent stars, being designed to produce a combined effect, it appears, that, while charcoal, (and, in some instances, the sulphur, according to the formula, but more especially the charcoal), imparts the serpentlike appearance, the antimony, in its turn, diversifies the flame by giving to it an asteroid character. The antimony, used in these compositions, is not the regulus, but the crude, or common sulphuret. Metallic antimony, however, would produce the effect in a greater degree: but as sulphur enters into their composition, and also into the crude antimony, there would be but little, if any, advantage, gained in the use of the regulus.

Besides the ordinary products of the combustion of gunpowder, or similar products, by employing nitre, charcoal, and sulphur, the antimony, by its combustion, would be changed into an oxide, or, if the combustion is sufficiently rapid, and the quantity of oxygen absorbed proportionate thereto, it would form the antimonic acid. That it is oxidized, however, and that during its oxidizement, the appearance we have mentioned takes place, there can be no doubt.

Sec. V. Of Whirling Serpents.

Serpents, prepared in the following manner, have a peculiar effect, by which they are characterized. They form in the air a kind of whirling sun; and, as they revolve by reason of their fire issuing out at the opposite sides of their extremities, they resemble the sun turning on its axis.

Barker's hydraulic machine, described in Gregory's Mechanics, which is put in motion by two opposite currents of water, acting from the two extremities of an oblong box, supported by a perpendicular hollow shaft, through which the water first passes, acts upon the same principle as this revolving sun. The ascension of rockets is also to be accounted for in the same way. See *General Theory of Fire-works.*

The whirling serpents are charged entirely with composition. No grain powder is used. A small paper stopper is rammed on the top of the composition. Near the two chokes, but in opposite sides, the cases are pierced with small holes, which are made to [303] communicate with each other, and with the composition, by means of a short leader or match.

Sec. VI. Of Chinese Flyers.

Somewhat similar to whirling serpents are the Chinese flyers. Cases for flyers may be made of different sizes, from one to eight ounces. They are formed of thick paper, and are eight interior diameters long. They are rolled in the same manner as tourbillons, with a straight pasted edge, and pinched close at one end.

The case, being put in a mould, whose cylinder, or foot, must be flat at top, without a nipple, is to be filled within half a diameter of the middle. Then ram in half a diameter of clay, and, on that, as much composition as before; and again put in half a diameter of clay. Pinch the case then close, and drive it down flat, and afterwards bore a hole exactly through the centre of the clay in the middle. In opposite sides, at both ends, make a vent, and, in that side, intended to be fired first, a small hole to the composition, near the clay in the middle, from which carry a quickmatch, covered with a single paper, to the vent at the other end. Then, when the charge is burnt on one side, it will, by means of the quickmatch, communicate to the charge on the other, which may be of a different sort.

The flyers being thus prepared, put an iron pin, that must be fixed in the work, in which they are to be fired, and on which they are to run, through the hole in the middle. On the end of this pin, must be a nut to secure it. If they are required to turn back again, after they are burnt, make both the vents at the ends in the same side, which will alter its course the contrary way.

These flyers are intended to revolve on an axis, and to discharge at different periods. For this purpose, a communication is made from one vent to the other. It is evident, that the clay, which occupies the middle of the case, is intended to prevent any communication of fire, in the tube, from one end to the other, as this is effected on the outside.

Sec. VII. Of Simple Stars.

The stars, which are not made upon the former, or roller, serve to furnish bombs and rockets. They are made in the following manner: The composition being well mixed, and passed through a fine sieve, is made into a paste, with gum arabic and brandy. [304] The proportion of the gum to the composition, is as one to sixteen. The composition is spread equally on a table, about the thickness of a finger, and cut into small square pieces. They are then covered with meal-powder, which will serve for priming, and are dried in the shade.

Composition for Simple Stars.

Saltpetre,	2	lbs.
Sulphur,	1	—
Meal-powder,	$\frac{1}{2}$	—
Antimony,	$\frac{3}{16}$	—

This is the general composition, however, for stars.

Sec. VIII. Of Rolled Stars.

It will be sufficient to remark, that rolled stars are formed of the same composition as the simple stars. The composition is mixed with gum and brandy, formed into a paste, spread upon a table, and cut, by a circular instrument, into pieces of the size of the Roman candle, of which we shall speak hereafter. They are primed with the best pistol powder, and dried in the shade. See *Roman Candle.*

Sec. IX. Of Cracking Stars.

Cracking stars are nothing more than small marrons. They are primed, and covered afterwards with *star-paste*, in the same manner as meteors. They are employed as furniture for serpents and stars. They are rolled in meal-powder, before they are used. They are the *étoiles à pet* of the French.

Sec. X. Of Sundry Compositions for Stars designed for Various Purposes.

We purpose, in this section, to present a connected view of the different star-compositions, by merely introducing the formulæ for their preparation. Their application will claim our attention hereafter, when we treat of rockets and other works.

Rocket Stars.

White.	Meal-powder,	4	oz.
	Saltpetre,	12	—
	Sulphur vivum,	6	—
	Oil of spike,	2	—

	Camphor,	5	—	
Blue stars.	Meal-powder,	8	oz.	[305]
	Saltpetre,	4	—	
	Sulphur,	2	—	
	Spirit of wine,	2	—	
	Oil of spike,	2	—	
Variegated.	Meal-powder,	8	drachms.	
	Saltpetre,	4	oz.	
	Sulphur vivum,	2	—	
	Camphor,	2	—	
Brilliant.	Saltpetre,	3½	—	
	Sulphur,	1½	—	
	Meal powder,	¾	—	

Worked up with spirit of wine only.

Common.	Saltpetre,	1	lb.
	Sulphur,	¼	—
	Antimony,	4¾	oz.
	Isinglass,	½	—
	Camphor,	½	—
	Spirit of wine,	¾	—
Tailed.	Meal-powder,	3	oz
	Sulphur,	2	—
	Saltpetre,	1	—
	Charcoal, coarsely ground,	¾	—
Drove. 1.	Saltpetre,	3	lbs.
	Sulphur,	1	—
	Brass filings, fine,	¾	—
	Antimony,	3	oz.
Or 2.	Saltpetre,	1	lb.
	Antimony,	¼	—
	Sulphur,	½	—
Fixed pointed.	Saltpetre,	8½	oz.
	Sulphur,	2	—
	Antimony,	1	oz. 10 dr.
Fine colour.	Sulphur,	1	oz.
	Meal-powder,	1	—
	Saltpetre,	1	—
	Camphor,	½	—
	Spirits of Turpentine,	½	—

Composition of stars of different colours.

1.	Meal-powder,	4	oz.	
	Saltpetre,	2	—	
	Sulphur,	2	—	
	Steel-filings,	1½	—	
	Camphor,	½	oz.	[306]
	White amber,	½	—	
	Corrosive sublimate,	½	—	
	Antimony,	½	—	
2.	Roche-petre,	10	oz.	
	Sulphur,	¾	—	
	Charcoal,	¾	—	
	Antimony,	¾	—	
	Meal-powder,	¾	—	
	Camphor,	¾	—	
	Oil of Turpentine, sufficient to moisten them.			

These compositions are made into stars, by being first worked into a paste with brandy, in which has been dissolved some gum, usually gum arabic, or gum tragacanth. After being rolled in powder, a hole is made through the middle of each, and they are then strung on quick-match, leaving about two inches between each.

3.	Saltpetre,	8	oz.
	Sulphur,	2	—
	Amber,	1	—
	Antimony,	1	—
	Meal-powder,	3	—
4.	Sulphur,	2½	oz.
	Saltpetre,	6	—
	Frankincense,	4	—
	Mastich,	4	—
	Corrosive sublimate,	4	—
	Meal-powder,	5	—
	White and yellow amber, of each,	1	—
	Camphor,	1	—
	Antimony and orpiment, each,	½	—
5.	Saltpetre,	1	lb.
	Sulphur,	½	—
	Meal-powder,	½	—
	Oil of petroleum, sufficient to moisten them.		
6.	Meal-powder,	½	lb.
	Sulphur,	4	oz.
	Saltpetre,	4	—
7.	Saltpetre,	4	oz.
	Sulphur,	2	—
	Meal-powder,	1	—

The composition of stars, which carry tails of sparks, is the following:

1.	Sulphur,	6	—
	Antimony,	2	oz.
	Saltpetre,	4	oz [307]
	Rosin,	4	—
2.	Saltpetre, rosin, and charcoal, of each,	2	oz
	Sulphur,	1	—
	Pitch,	1	—

These compositions are sometimes melted in a pan, and, before they are made into stars, mixed with chopped cotton match. They may be worked in the usual manner.

The composition for stars, which yield some sparks, is the following. To be made into stars, it must be wetted in gum-water, and spirits of wine, that the whole may have the consistence of a thick fluid. One ounce of lint is put into the composition; where it remains, until it has taken up enough to be rolled into stars.

1.	Camphor,	2	oz.
	Saltpetre,	1	—
	Meal-powder,	1	—
2.	Saltpetre,	1	oz.
	Sal prunelle,	½	—
	Camphor,	2	—

The composition for stars of a yellowish colour is to be incorporated, and made into stars after the common method.

Composition for Yellow Stars.

Gum arabic, finely pulverized,	4	oz.
Camphor, dissolved in brandy,	2	—
Saltpetre,	1	lb.
Sulphur,	½	—
Glass, in coarse powder,	4	oz.
White amber,	1½	—
Orpiment,	2	—

The composition for another kind of star, is the following: The ingredients to be well mixed, and then rolled into stars, proportionable to the rockets they are intended for.

Camphor, dissolved in spirit of wine by heat,	1	lb.
Gum arabic, dissolved in water,	1	—
Saltpetre,	1	—
Sulphur,	6	oz.
Meal-powder,	5	—

We will have occasion hereafter, to notice the different modes of fixing, and arranging stars; the formation of strung stars, rolled and drove stars, &c. Great care must be taken in making stars, that the several ingredients are reduced to a fine powder, and the composition is well worked and mixed. The instructions for rolling of stars, are the following: Before we begin to roll, take a pound [308] of the composition, and wet it with the following liquid, sufficient to make it stick together, and roll easy, *viz*: Spirit of wine one quart, in which dissolve 1/4 of an ounce of isinglass. If a great quantity of composition be wetted at once, the spirit will evaporate, and leave it dry, before all the stars are rolled. Having rolled one portion, shake the stars in meal-powder, and set them to dry, which will require three or four days; but, if wanted for immediate use, they may be dried in an earthen pan, over a slow heat, or in an oven. It is very difficult to make the stars all of an equal size, when the composition is taken up promiscuously with the fingers; but, by the following method, they may be made very exact: When the mixture is moistened properly, roll it on a flat smooth stone, and cut it into square pieces, making each square large enough for the stars required. There is another method used by some, which consists in rolling the composition in long pieces, and then cutting off the stars; so that each star will be of a cylindrical form. This method, however, is not so good as the former; for, in order to make the composition roll in this manner, it must be made very wet, which makes the stars heavy, as well as weakens their effect. All stars must be kept as much from the air as possible; otherwise they will lose their properties.

What are called, in pyrotechny, the flaming stars, with brilliant wheels, the moon and seven stars, the transparent stars with illuminated rays, the transparent table star, the projected star, and the illuminated star wheel, are all particular exhibitions, which are produced by disposing the works in a certain form and order. They have, therefore, no relation to those preparations, or compositions, which produce stars. They will be considered, however, in their respective places, when we treat of the disposition and arrangement of fire-works.

As a general theory of stars, we may remark, that while combustion ensues, as in other fire-works, in the manner explained in our chapter on that subject, some substances are always employed, which have, for their object, two effects in particular; *viz.* that of modifying the appearance of the flame, by producing certain colours, and increasing or diminishing the degree of combustion, and that of throwing out, at the same time, scintillations or sparks. The latter effect, however, is not so great in stars, as in some other preparations, which are designed especially for the purpose. That certain substances have a particular effect, which uniformly ensues, under the same circumstances, is a fact obvious to all. Hence, we see in all the numerous formulæ for stars, for [309] those that produce a red, a blue, a yellow, or any other flame, and those which form tails, sparks, &c. being modified according to circumstances, that the *effect* is owing to the presence of one, and sometimes to the action of two, three, and more substances, co-operating together. That combustion may be greater or less; that it may be accelerated, retarded, and otherwise modified; that the flame of inflammable bodies may be varied, as to colour, by the presence of foreign substances; that the action of one substance upon another, in certain elevated temperatures, may produce results which would not take place at a reduced temperature; that, for the support of combustion, the oxygen of the nitre, or the oxygen gas of the atmosphere, may, singly, or jointly, produce that effect, as in instances of rapid combustion, and in the combustion of bodies actually thrown out in the state of ignition;—these are so many considerations, all necessary to be attended to, in establishing a theory of stars, as well as of fire-works in general.

Sec. XI. Of the Fire-rain, (filamentous.)

Fire-rains are generally two inches long, and formed on a small copper, iron, or wooden roller, two and a half lines in diameter. Two turns of the paper are considered sufficient for them. They are twisted at their extremities, and struck afterwards on a table, to flatten and close them in the same manner as common cases. Using a small funnel, they are charged with the following composition, in the same manner as serpents. Grained powder, however, is not employed. When charged, they are primed with paste, having also, a piece of cotton-match attached to them.

Composition.

Meal-powder,	16	oz.
Fine oak charcoal,	3	—

Six ounces of charcoal to a pound of powder, is the formula of Bigot. The one given is that of Morel.

Sec. XII. Of Sparks.

The second kind of rain-fire, called sparks, is made in the following manner: The composition is formed into a thick liquid paste with brandy; and eight ounces of flax are immersed in it, and kept there for some time. The flax is then rolled into small balls, about the size of peas. They are then rolled in dry meal-powder, and hung up in the open air, in the shade to dry.

Composition. [310]

Saltpetre,	8	oz.
Meal-powder,	8	—

Camphor,	16	—
Flax,	8	—

Sec. XIII. Of Gold Rain.

We purpose to enumerate, in the following section, all the compositions which have been used for forming gold, as well as silver rain. The recipe here given, it may be proper to remark, appears to have been preferred to all others; as some French authors, and particularly Morel, have given it a distinct place.

Composition for Gold Rain.

Meal-powder,	8	oz.
Sulphur,	1½	—
Gum arabic,	½	—
Pulverized soot,	½	—
Lampblack,	½	—
Saltpetre,	½	—

These substances are mixed, treated, cut, and primed in the same way as simple stars. They must be cut all of the same size. In the furnishing of rockets and bombs, the effect they produce, is very striking. With respect to the scintillated rain-fire, or that which appears in sparks, the effect is owing to the flax, which, being soaked in a mixture of meal-powder, saltpetre, camphor, and brandy, in the same manner as before stated, produces, when inflamed, a succession of fire, under the form we have mentioned. The camphor seems to add to the brilliancy of the flame. There is no doubt but a part, at least, if not the whole, is burnt, in consequence of the oxygen of the air, the inflammation of the gunpowder bringing it to the state of ignition. The powder itself produces at first the combustion. The flax is, therefore, consumed, which seems to be the last of the process, filaments, at the same time, being produced, and the combustion accelerated by the nitre.

The fire-rain owes its effect to the charcoal, which is thrown out in the state of ignition. In the gold fire, the effect is owing to the presence of lampblack, soot, and nitre. There are several methods of producing both gold and silver rains, which we will notice in the following section.

Sec. XIV. Of Rains in General, for Sky-Rockets, &c. [311]

The following compositions are also used in the formation of fire-rain;

Gold rain,	1.	Saltpetre,	1	lb.
		Meal powder,	4	oz.
		Sulphur,	4	—
		Brass filings,	1	—
		Sawdust,	2¼	—
		Pulverized glass,	¾	—
	2.	Meal powder,	12	oz.
		Saltpetre,	2	—
		Charcoal,	4	—
	3.	Saltpetre,	8	oz.
		Sulphur,	2	—
		Glass dust,	1	—
		Antimony,	¾	—
		Brass filings,	¼	—
		Sawdust,	1½	—
Silver-rain.	1.	Saltpetre,	4	oz.
		Sulphur,	2	—
		Meal-powder,	2	—
		Antimony,	2	—
		Sal prunelle,	½	—
	2.	Saltpetre,	½	lb.
		Sulphur,	2	oz.
		Charcoal,	4	—
	3.	Saltpetre,	1	lb.
		Sulphur,	¼	—
		Antimony,	6	oz.
	4.	Saltpetre,	4	oz.
		Sulphur,	1	—
		Powder,	2	—
		Steel dust,	¾	—
		For Calibers above two-thirds of an inch.		
	5.	Meal-powder,	16	parts.
		Saltpetre,	1	——
		Sulphur,	1	——
		Steel filings,	4½	——

Sec. XV. Of Rain-Falls, and Stars, double and single.

The cases which contain the gold and silver rain composition, are pinched close at one end. If they are rolled dry, four or five [312] rounds of paper will be sufficient; but, if they are pasted, three rounds will be strong enough. The thin sort of cartridge paper is best for those small cases, which, in rolling, must not have the inside edge turned down, as in other cases, for a double edge would be too thick for so small a caliber. The moulds for rain falls should be made of brass, and turned very smooth in the inside; or the cases, being very thin, would tear in coming out. The charge must be driven in light, and the better the case fits the mould, the more driving it will bear. These moulds have no nipple, but are made flat. It is necessary to have a funnel made of thin tin, to fit on the top of the case, by the help of which, they may be filled very fast. For single rain-falls for four ounce rockets, let the diameter of the former or roller be two-sixteenths of an inch, and the length of the case two inches; for eight-ounce rockets, four-sixteenths, and two diameters of the rocket long; for two-pound rockets, five-sixteenths, and three and a half inches long; for four-pound rockets, six-sixteenths, and four and a half inches long; and for six pounders, seven-sixteenths, in diameter, and five inches long.

There are two kinds of double rain-falls described: some appear first like a star, and then as rain; and some appear first as rain, and then like a star. These different appearances may be produced in the following manner: When stars are to be formed first, the cases must be filled within half an inch of the top, with rain composition, and the remainder with star composition; but when it is intended that the rain should be first, we must drive the case half an inch with star composition, and the rest with rain. By this method, they may make many changes of fire; for in large rockets, they may be made to burn first as stars, then as rain, and again as stars; or, they may first show rain, then stars, and finish with a report. When they are thus managed, cut open the first rammed end, after they are filled and *bounced*, at which place they are to be primed. The star composition for this purpose, must be a little stronger than that for rolled stars.

Sec. XVI. Of Substances which show in Sparks.

There are many substances, which show in sparks, when rammed in choaked cases. The set colours are produced by regular charges. Other charges are called compound and brilliant. Set colours, produced by sparks, are divided into four sorts, which are [313] denominated, the white, black, gray, and red. The charges, to produce these several effects, are composed of various ingredients. Thus, meal-powder and charcoal compose the black charges; saltpetre, sulphur, and charcoal, the white; meal powder, saltpetre, sulphur, and charcoal, the gray; and saltpetre, charcoal, and sawdust, the red.

With respect to compound and brilliant charges, the former is composed of many ingredients; such as meal-powder, saltpetre, sulphur, charcoal, sawdust, sea-coal, antimony, glass-dust, brass-dust, steel dust, cast-iron, tanner's dust, &c. or any thing that will yield sparks; all which must be managed with discretion, or judgment. Brilliant charges, on the contrary, are composed of meal-powder, saltpetre, sulphur, and steel-filings, or of meal-powder and steel-filings only, and sometimes of Chinese fire.

Sec. XVII. Of Italian Roses, or Fixed Stars.

We prepare cases for these works, in the same manner as described in the article respecting fixed stars. Half a spoonful of clay is put into them, which is rammed tightly, with twelve blows of a mallet of a moderate size. The height of the clay is then marked upon the case, which is then charged with four spoonfuls of the composition, ramming each spoonful with twelve blows of the mallet. These four charges should occupy about two fingers in height. After this we add another spoonful of earth; and divide, on the outside of the case, from the point we marked, five equal parts. We then apply the quick-match and paste. One end of the match is of a sufficient length, in order that it may turn round, and come out above the other choke. We afterwards roll the case in white paper, which must go twice round, and extend beyond each extremity about one and a half inches. This is called the covering. The lower end is twisted. The other end, the side of which is twisted, resembles a goblet, and serves to inflame the rose.

The composition of the rose is given in the table for those of revolving and fixed pieces. Their effect is, that they will produce as many *streams* of flames as there are holes, and consequently form the roses or stars. The composition is six parts of powder, eight saltpetre, five sulphur, and half a part of antimony; or two powder, four saltpetre, and one sulphur.

Sec. XVIII. Of Lances of Illumination, white, blue, and yellow. [314]

We have already given the caliber, and the manner of forming the lances. They are charged by using the funnel and rammer, in the same manner as serpents, but without any grain-powder. They are filled within two-twelfths of their end, and primed with the paste without the match. The blue and yellow lances are loaded in the same manner. The yellow are made one-third of an inch in diameter, and one inch and a third in length; so as not to be of a longer duration in burning than the others.

Composition of lances.

White lances.			Blue lances.			Yellow lances.		
Saltpetre	16	oz.	Saltpetre	16	oz.	Saltpetre	16	oz.
Sulphur	8	oz.	Antimony	8	oz.	Sulphur	16	oz.
Powder	4	oz.				Powder	8	oz.
Antimony	1	oz.				Amber	8	oz.

Lances, or port-fires of illumination, may be made also without antimony, as follows:

Port-fire composition for Illuminations.

Saltpetre,	1	lb.
Sulphur,	6	oz.
Meal-powder,	6	oz.

The composition of the *lance à feu* of the French, which is used chiefly to throw occasional light across the platform, whilst artificial fire-works are preparing, and like port-fires and matches, to communicate fire, is given as follows: (*Œuvres Militaires*, tom xi, p. 208.)

Composition of the lance à feu.

Saltpetre,	3	parts.
Sulphur,	2	——
Antimony,	2	——

The *lance à feu puant* is of a different kind. It is the stink-fire lance, used for military purposes, and prepared in the same [315] manner as stink-pots. They are used principally in the mine, and produce so powerful an exhalation, as to render it impossible to approach the quarter for three or four days, and occasion also, even to the miners, an apparent suffocation. The *lance de feu*, however, is a different preparation from either. It is a species of squib, which is used by the garrison of a besieged town against a scaling party. For the preparation of *fire lances*, see the subsequent part.

Sec. XIX. Of Slow White-flame Lances.

The composition of this lance, or port-fire, is such, that it will burn longer than the ordinary lance. There are two formulæ given for it. Both compositions, when driven one and a quarter inches in an ounce case, will burn one minute, which is considered by some a much longer time than an equal quantity of any composition, yet known, will last.

Composition of slow Fire.

1.	Saltpetre,	2	lbs.	2.	Saltpetre,	3½	lbs.
	Sulphur,	3	lbs.		Sulphur,	2½	lbs.
	Antimony,	1	lb.		Meal-powder,	1	lb.
					Antimony,	½	lb.
					Glass-dust,	¼	lb.
					Brass-dust,	1	oz.

Sec. XX. Of Lights.

We purpose hereafter to treat particularly of the Chinese lights, Bengal lights, amber lights, blue lights, &c. We will merely mention in this place, the composition of some of them.

Composition for Lights.

1.	Saltpetre,	3	lbs.
	Sulphur,	1	lb.
	Meal-powder,	1	lb.
	Antimony,	10½	oz.
	Oil of Spike,	sufficient to mix them.	

Composition for common fire.

Saltpetre,	3	lbs.
Charcoal,	10	oz. [316]
Sulphur,	2	oz.

Composition for red Fire.

Meal-powder,	3	lbs.
Charcoal,	12	oz.
Sawdust,	8	oz.

Common fire for a caliber of one-third of an inch.

Meal-powder,	16	parts.
Charcoal, pulverized,	3	——

Idem, for a caliber half an inch.

Meal-powder,	32	parts.
Charcoal,	7	——

Idem, for a caliber above half an inch.

Meal-powder,	4	parts.
Charcoal,	1	——

Brilliant fire for ordinary calibers.

Meal-powder,	4	parts.
Iron-filings,	1	——

Idem, more brilliant.

Meal-powder,	4	parts.
Steel-filings,	1	——

Brilliant fire for all calibers.

Meal-powder,	9	parts.
Sulphur,	1	——
Steel,	2½	——

Grand brilliant fire, for calibers of three-quarters of an inch, and upwards.

Meal powder,	16	parts.
Sulphur,	1	——
Saltpetre,	1	——
Steel filings,	7	——

Idem, clear and brilliant for any caliber.

Meal powder,	16	parts.	
Saltpetre,	1	part.	[317]
Filings of the best steel,	3	——	

Idem, large jessamine for any caliber.

Meal powder,	16	parts.
Saltpetre,	1	——
Sulphur,	1	——
Best steel,	6	——

Idem, small jessamine for any caliber.

Meal powder,	16	parts.
Saltpetre,	1	——
Sulphur,	1	——
Best steel,	5	——

White fire for any caliber.

Meal powder,	8	parts.
Saltpetre,	4	——
Sulphur,	1	——

COMPOSITIONS.	PARTS OF					
	Meal powder	Salt-petre	Sul-phur	Char-coal	Filings &c.	
White fire for any caliber,	16	0	3	0	0	
Blue, for parasols and cascades,	4	2	3	0	3	Zinc.
Do. for calibers, half an inch and above,	4	8	4	0	17	Zinc.
Do. for any caliber,	6	2	8	0	0	
Sparkling, or shining fire for any caliber,	16	0	0	0	3	Brass.
Green fire, for any caliber,	16	0	0	0	3¼	Brass.
Aurora colour,	16	0	0	0	3	Gold powder.
Chinese fire, for calibers under an inch,	8	8	2	2	7	Ct.iron
Do. for calibers above an inch,	16	0	3	3	7	Do.
Do. for palmtrees and cascades,	8	6	4	2	5	Do.
Do. in white for two-thirds and five-sixths of an inch cal.,	8	8	4	0	6	Do.
Do. for gerbes, of ten, eleven, and twelve lines in diam.,	8	1	1	1	8	Do.
Bengal lights,	0	32	9	0	5	Ant'y.
Amber lights,	9	0	0	0	3	Amber.
Water squibs,	1	0	0	1	0	
Do.	1	0	0	0½	0	

Sec. XXI. Of Lances for Petards. [318]

Lances for petards are a kind of port-fire, used in war, but not very often. As they will be noticed hereafter, it may be sufficient to remark, that they are formed of cartridge paper, and the case is strangled in the usual manner; that a small portion of bran is put in, and then about as much good priming pistol powder in grains; that the case is then strangled, or choaked, about two-thirds of its length, the remaining one-third serving for a handle; and, in using it, that the twisted end is cut off, so that the fire may communicate to the petard.

Sec. XXII. Of Lances of Service.

These lances serve for setting fire to works, &c. They are commonly made fifteen inches long, upon a former or roller, one-fourth of an inch in diameter. Four turns of the paper are sufficient for the case. They are charged in the same way as the petard lances, and also in the manner described for port-fires. They are primed with the match and paste.

Composition for the lances of service.

Saltpetre,	2	lbs.
Sulphur,	1	—
Meal powder,	5	oz.

Sec. XXIII. Of Marrons.

Marrons are made in several ways. We shall first describe those in cases. Formers for marrons are from three-fourths of an inch, to one and a half in diameter. The paper for the cases must be cut twice the diameter of the former; broad, and sufficiently long to make three revolutions. When a case is rolled, paste down the edge, and tie one end close; and to remove the wrinkles, and make it flat at bottom, put in the former and drive it down. The case is then to be charged with granulated powder, one diameter and a quarter high, and the rest of the case, folded down tight on the powder.

The marrons being thus made, wax some strong pack-thread with shoemaker's wax, and wind it up in a ball. Then unwind two or three yards of it, and that part, which is near the ball, make fast to a hook. Now take a marron, and stand as far from the hook as the pack-thread will reach, and wind it lengthwise round it, as close as possible, till it will hold no more in that direction; then turn [319] it, and wind the pack-thread on the short way; then lengthwise again, and continue this winding until the paper is all covered. Make fast the end of the pack-thread, and beat down both ends of the marron to bring it in shape.

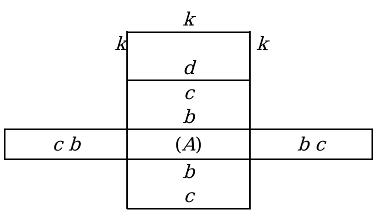
The method of firing marrons is by making a hole at one end with an awl, and putting in a piece of quickmatch. Then take a piece of strong paper, in which wrap the marron with two leaders, put down to the vent, and tie the paper tight round with small twine. These leaders are bent on each side, and their loose ends tied to other marrons, and nailed, in the middle, to the rail of the stand.

Marron batteries are made of several stands, with a number of cross rails for the marrons, which are regulated by leaders, by cutting them of different lengths, and nailing them tight or loose. This arrangement, however, is only intended for a certain purpose. For as marrons, if well managed, will keep time to a march or a piece of music; so, by regulating them in that way, that is to say, by cutting the leaders of different lengths and nailing them tight or loose, we may adjust the time of their explosion by the time of the music. In forming batteries with marrons, the large and small kinds must be used, and the nails for the leaders, or pipes of communication must have flat heads. The *marrons for service* are a different kind; they resemble the incendiary bombs. See Fourth Part of the work.

The other kind of marron for fire-works, as described by Morel, (*Traité Practique des Feux D'Artifice* p. 37,) and Bigot, (*Traité d'Artifice de Guerre* p. 141,) are of a cubical form and of a suitable size for the *pot*, in which it is to enter, or of any dimensions, if it be fired alone, or without being employed as a decoration. These cubes are filled with grain powder, and are covered with two layers of pack-thread, which is bound very tightly, and over this, a coat of pitch or tar. They are pierced to the powder, and a match is adapted in the usual manner. Port-fire has been used, but is considered to possess no advantages.

The cubical marrons are formed in the following manner: Divide a piece of strong pasteboard in such a manner, as that each division will form one of the sides of the cube, as represented in the following figure.

[320]



Pasteboard, formed in the above manner, it is evident, when put together, will make a cube. (A) will be the base, and b c respectively, will form the sides, and d the top, k k k will come in contact with the edge of three sides. In d, (the cover), is a hole, in order to charge it, and, if necessary, to hold the match and priming. This, however, may be attached to either side. All the angles are well secured with paper pasted over them. The pack-thread must be well waxed with shoemakers' wax, before it is wound on it.

Sec. XXIV. Of Shining Marrons.

Shining marrons are cubes of an inch at least on each surface, and prepared in the same manner as the preceding. The excess of the match, which is cut off in the former marron, is sufficient for these smaller marrons. Cotton is macerated, or soaked in a paste of the star composition, in the usual manner, viz: by mixing the composition with brandy, and a small portion of gum, or a solution of isinglass. The marron is then covered, about a finger in thickness, with this cotton; or more may be used, according to circumstances. It is afterwards rolled in meal powder, which serves for priming, and then dried in the shade.

Shining marrons are used in furnishing bombs, fire-pots, and rockets. They produce a brilliant effect; a vivid white light, which finishes with a report.

Sec. XXV. Of Saucissons. [321]

Saucissons differ from marrons only in form. They are intended, like them, for simple detonations. They are generally fired out of large mortars without chambers, the same as those for aigrettes, only somewhat stronger.

Saucissons are made of one or two-ounce cases, five or six inches long, and choaked in the same manner as serpents. Half the number which the mortar contains must be driven one and a half diameters with composition, and the other half, two diameters; so that, when fired, they may give two vollies of reports. But, if the mortars are very strong, and will bear a sufficient charge to throw the saucissons very high, there may be three vollies of reports, by dividing the number of cases into three parts, and making a difference in the height of the charge. After they are filled, pinch and tie them at the top of the charge, almost close; only leaving a small vent to communicate the fire to the upper part of the case, which must be filled with grain powder very near the top. The end then is to be pinched close and tied, and the case, bound very tightly with waxed pack-thread, from the choak, at the top of the composition, to the end of the case. This will strengthen the case, and cause the report to be very loud. Saucissons should be rolled a little thicker of paper than the common proportion. When they are to be put in the mortar, they must be primed in their *mouths*, and fired by a case of brilliant fire, fixed in their centre. The charge for these mortars should be $^1/_6$th or $^1/_8$th more than for *pots d'aigrettes* of the same diameter.

For flying saucissons, the French make use of cases of three-quarters of an inch in exterior diameter. They are charged, to the height of half an inch, with the composition for mosaic tourbillons, which see. They are then choaked and bound at this place, and four fingers of grain powder are put into each, which is then covered with a stopper of paper. They are then again choaked and bound, and the excess of the case is cut off. They are primed with a piece of match, using the priming paste at the same time. When the saucissons are required to make a louder report, the part of the case, in which the powder is, should be wrapped round with pack-thread, much in the same manner as already described, and then covered with glue or pitch. These saucissons are usually put in the pots of the *mosaics*, some times in the place of them, and are arranged for exhibition on the same frame. We may, if we wish to vary the effect, put a saucisson in one pot, and a mosaic in another. When thrown in the air, their effect is to [322] occasion a report. They first, however, form a tail of fire, and finish with an explosion. Bigot gives the difference between their internal and external diameters at four lines, or one-third of an inch.

Saucissons may either be used in the manner we have mentioned or thrown by hand. According to their size, and the strength of the case, so will be the report. They resemble a thick and short sausage, hence their name.

Sec. XXVI. Of Fire-Pumps.

Fire-pumps are intended for a particular use, which we will describe hereafter. The composition is the following:

1.	Saltpetre,			5	lbs.
	Sulphur,			1	—
	Meal powder,			1½	—
	Glass-dust,			1	—
2.	Saltpetre,	5	lbs.	8	oz.
	Sulphur,	2	—		
	Meal powder,	1	—	8	—
	Glass-dust,	1	—	8	—

Cases for fire-pumps are made like those for tourbillons, except that they are pasted, instead of being rolled dry. In charging them, first put in a little meal powder, and then a star; then a ladleful or two of the above composition, which ram tightly; then a little meal powder, on that a star, and then composition again, and so on until the case is filled. Stars for fire-pumps should not be round; but must be made either square, or flat and circular, with a hole through the middle. The quantity of powder for throwing the stars must increase as we come near the top of the case; for, if much powder be put at the bottom, it will burst the case. The stars must differ in size in this manner: Let the star, which is first put in, be about one-fourth less than the caliber of the case; but let the next star be a little larger, and the third star a little larger than the second, and so on for the rest. Let them increase in diameter till within two of the top of the case, which two must fit in tight. As the loading of fire-pumps requires some skill, it will be necessary to make two or three trials before depending on their performance.

When a number of pumps are filled, care must be taken not to put in each an equal quantity of charge between the stars; so that, when they are fired, they may not throw up too many stars together. Cases for fire-pumps should be made very strong, and rolled [323] on four or eight-ounce formers, each ten or twelve inches long. For the composition and preparation of stars, see *stars.*

Sec. XXVII. Of the Volcano of Lemery.

The artificial earthquake, or volcano of Lemery, is formed by mixing into a paste with water, about equal parts of sulphur and steel or iron filings, and burying the mixture in the earth. The composition in a short time, will grow hot, and burst out; the earth will break, and open in several places.

Baumé mixed 100 pounds of iron filings and the same quantity of sulphur together, with water, and rammed the mixture into an iron pot. After ten hours, the mass swelled up and grew warm, aqueous vapours arose, and the mass burst. Ten hours afterwards, the heat, vapours, &c. greatly increased, and a flame issued forth, lasting only from 2 to 3 minutes. Finally, the mass became red-hot, and the burning and heat continued 40 hours longer; but without flame.

We may merely remark, that this effect is produced by the chemical union, which takes place between the sulphur and iron, forming a sulphuret of iron, analogous in composition to the native martial pyrites. The water is at the same time, decomposed, during which the mixture swells, becomes hot, and throws up the earth, producing at the same time a large quantity of sulphuretted hydrogen gas. This gas is formed by the combination of a part of the sulphur with the hydrogen of the water; whilst the oxygen, the other element of the water, goes to oxidize the metal and to acidify the remaining sulphur. Hence sulphate of iron, or green vitriol is produced. The experiment may be made in a common basin.

It is a remarkable fact, that spontaneous combustion, which takes place without the application of an ignited body, ensues in a variety of instances; and new facts daily occur, which show, that cases of this kind are more numerous than we had reason to suspect. Besides the old and well known effect of quicklime, pyrites, pyritous schist, &c. in producing spontaneous combustion, it is found, that ashes and oil, oil and cotton, and a number of substances have set fire to cotton mills, and other works.

It is known, that, in the slaking of quicklime, a considerable degree of heat is produced. This is owing to the solidification of the [324] water, or its union with the lime in the form of a hydrate, and the consequent change, which the caloric undergoes from a latent to an uncombined state. Hence inflammable substances, in contact with lime, under these circumstances, are necessarily set on fire.

Spontaneous combustion arises simply from a play of chemical affinities. The following general observations on this subject are given by Nicholson, (*Chemical Dictionary*); and an enumeration of the effects may lead to cautions of importance for preventing serious accidents: "If quicklime, in any quantity, be laid in contact with any combustible, as wood, and be wetted by accident, or to make it into mortar, a sufficient quantity of heat may be extricated to set fire to the wood. Animal or vegetable substances, laid together damp in large heaps, undergo a fermentation, which often excites combustion, as in the case of hay-ricks. Woollen cloth, not freed from the oil used in dressing it, and laid up damp in large heaps, has been known to take fire; and so has painted canvass. Flowers and herbs boiled in oil, as is done by druggists, and then laid in heaps, sometimes do the same. The mixture of linseed oil and lampblack, or of linseed oil and black wad, is very liable to inflame. Torrefied vegetables, as malt, coffee, or bran, put while hot, into coarse bags, are apt to take fire. The spontaneous combustion of phosphorus, and various pyrophori, is well known. It is suspected to be owing to the presence of one or other of these, that charcoal sometimes takes fire without any apparent cause; and the charcoal of peat is said to be particularly liable to this. Hyperoxygenated muriate of potassa, mixed with sulphur, or with sulphur and charcoal, is apt to detonate spontaneously.

"Many cases of spontaneous combustion taking place in the human body too are on record: and it has been observed, that all the persons, who thus suffered, were much addicted to the use of spirituous liquors."

Sec. XXVIII. Of the blue and green Match, for Cyphers Devices, and Decorations.

We had occasion to mention, that blue and green flame may be produced by employing sundry substances, which have the property of changing the colour of flame. This is effected in the present instance.

For the preparation of the match, we melt one pound of roll brimstone in a glazed earthen vessel, over a slow fire, and add one [325] ounce of finely pulverized verdigris, and half an ounce of antimony. The cotton for the match, may be of any length and thickness, as we judge proper; and is to be immersed, and well soaked, in the wetted sulphur, having previously put in the verdigris, and antimony. Sulphur alone will form a blue light.

The matches are afterwards tied to a rod of iron, which is bent according to the design we purpose to form, and to which they are fastened with a very fine iron wire, called the *carcase*. They are covered with priming paste, and a quick match is tied along the whole length. They are then covered with bands of gray paper, and a piece of port-fire is fixed on the end, to communicate fire.

Sec. XXIX. Of the Purple or Violet Match.

The design is made, and the match is attached, in the same manner as described in the last section; but without bending it. The preparation is as follows: Make a decoction of *jujubes*, which have been peeled, and stoned, and thicken it by adding as much of the flour of sulphur, as will bring it to a proper consistence. The cotton is then covered with this mixture, in the manner before stated; its thickness to be determined, according to the time required for it to burn. While hot, the match is primed by rolling it in meal powder. It is then suffered to dry. The design, it is to be observed, ought to be supported at the distance of four or five inches from the rods which hold it, by small cross pieces of iron, to prevent it taking fire; a circumstance necessary to be guarded against.

Sec. XXX. Of Meteors.

Artificial fire-works, to resemble meteors in the atmosphere, have, if properly prepared and exhibited, a brilliant appearance. The composition must be projected to a great height, which is either done by rockets, or from mortars. Meteors are made in the same manner as shining marrons, which we have already described, except, however, that they are of a very large size and usually weigh ten pounds. The larger they are made the better, and the more grand is their effect. See *Shining Marrons.*

CHAPTER VII. [326]

OF ROCKETS AND THEIR APPENDAGES.

A rocket is a flying fusée, (*Fusées Volantes* of the French), formed with paper, of a cylindrical shape, and filled with a composition of certain inflammable substances, being pierced in the diameter of its length. It is furnished with a stick, serving as a counter-weight, or balance, to guide it vertically in its ascension. It carries generally different garnishes, or furniture; as stars, serpents, fire-rains, marrons, meteors &c. which are thrown off, and produce an elegant appearance, when it terminates its flight.

Rockets have been applied to several uses. Thus, the war-rocket, as an incendiary, improved by Congreve, and the signal rocket, are some of its applications. These, however, are modified for the purpose, and will be spoken of hereafter. The Indian rockets, called Fougette (*Baguette à feu* of the French) will also be noticed.

Although as a fire-work for exhibition, the rocket may be considered the most grand, and, especially when furnished with various decorations, the most brilliant, yet its utility for Military and Naval purposes is acknowledged by all.

When treating of sundry preliminary operations in the second part of this work, we had occasion to introduce the subject of rockets, as respects the formation of their cases, the manner of charging and driving them, with the tools required, and the boring of rockets, when they have been driven solid. These subjects may be found in sections iv, v, and viii. We purpose, however, to make such observations as may, with the remarks heretofore offered, furnish the reader with a general knowledge of the making, decorating, and discharging of rockets. On the theory of the ascension of rockets, motion of fire-wheels, &c. and observations on the rocket principle, consult the chapter in the first part of the work, concerning the theory of particular fire-works. For the manner of uniting sheets of paper of several thicknesses, for cases, see *Pasteboard.*

Sec. I. Of the Caliber and Proportion of Rockets.

Sky-rockets are generally made of seven calibers, from half an inch to three inches. Different opinions have been entertained [327] respecting the proper proportions. Some contend that the height should be always regulated by their exterior diameter. On this subject, several experiments, it seems, have been made by an experienced artist, M. Morel, not only to determine the length, which is best calculated to produce the maximum of ascension, but also with respect to the length compared with the caliber of the case.

The following tables are necessary in the formation of rockets. The first shows the size of the caliber of the mould, for rockets of a pound weight, and below; and the second points out the size required for the caliber of moulds, from one pound to fifty pounds. A lb. rocket, it must be observed, is that which is just capable of admitting a leaden bullet of a pound weight, and so of the rest.

TABLE I. *Size of the caliber of moulds of a pound weight, and below to an ounce.*

Weight of Rockets in ounces.	Diameters in lines.
16	19½
12	17
8	15
7	14¾
6	14¼
5	13
4	12⅓
3	11½
2	9⅙
1	6½

Here, it is evident, that the mould of a rocket of twelve ounces in weight, ought to be seventeen lines (12 lines to the inch) in diameter; and one of five ounces, will require a mould of thirteen lines in diameter. Hence, we derive an easy method of finding the size, when the weights are given: and, if the diameter of the rocket be given, it will be equally easy to find the weight of the ball, corresponding to the weight of that caliber.

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TABLE II. *Size of the caliber of moulds, of from one to fifty pound ball.*

Pounds	Caliber	Pounds	Caliber	Pounds	Caliber	Pounds	Caliber
1	100	14	241	27	300	40	341
2	126	15	247	28	304	41	344
3	144	16	252	29	307	42	347
4	158	17	257	30	310	43	350
5	171	18	262	31	314	44	353
6	181	19	267	32	317	45	355
7	191	20	271	33	320	46	358
8	200	21	275	34	323	47	361
9	208	22	280	35	326	48	363
10	215	23	284	36	330	49	366
11	222	24	288	37	333	50	368
12	228	25	292	38	336		
13	235	26	296	39	339		

By this second table, if the weight of the ball be given, the size of the mould may be found: suppose it be eighteen pounds; opposite to it is the number 262. Then we say, by the rule of proportion, (as 19½, see Table 1, is supposed to be divided into a hundred parts) 100 : 19½ : : 262 to the fourth term sought, viz. 51.09; which gives for the required caliber 52 lines nearly, or four inches and four lines. But if the caliber be given in lines, the weight of the ball may be found: suppose the given caliber be 36 lines, then as 19½ : 100 : : 36 : 184. The nearest number in the table to this is 181, which shows that the weight of the ball will be rather more than 6 lbs; or, in other words, that a rocket, the diameter or caliber of which is thirty-six lines, is a rocket of a 6 lb. ball. See *Congreve Rocket.*

As to moulds to prevent the rockets from splitting in the act of charging them, Morel observes, that he has never used them. He remarks, that a case which will not resist the force of the charge, cannot resist the violence of the fire.

On the subject of compositions, he observes, that he has only employed one formula, and, of course, but one standard proportion for all sized calibers; and is of opinion, that it is useless to employ an inferior composition, or one with which we are unacquainted, when we have a formula, on which we may rely. This opinion, however, does not agree with that of others.

Certain rockets, it is to be remarked, show tails of fire in their flight, and others again do not. This depends entirely upon the [329] charcoal; for, if we use charcoal, made from tender and light wood, it burns rapidly, without producing a tail of fire; but if we use the charcoal of oak or of beech, or of other hard wood, the rocket will form a brilliant tail of fire, during the whole period of its ascension. It is said, however, that the charcoal of light wood, is lighter and more inflammable, and for that reason, better calculated for rockets; but, so far from producing the effect, we have mentioned, a quick combustion ensues, leaving no ignited coal to be acted upon by atmospheric air.

It is found by experiment, that even a little more or a little less powder, gives to or takes from, the composition its effective power; and, therefore, that the rockets, in their flight, ascend to a greater or less height.

Some writers have asserted, that powder ought not to enter into the composition of rockets; but in lieu thereof, only its component parts. Where, we may inquire, is the difference? The reason, however, assigned, is, that rockets made with gunpowder and the other substances, will not keep any time, owing to the powder becoming damp, and the composition spoiled. But rockets which have been made in France and carried to the East Indies, and brought back, were found, on trial, not to have lost any of their effect.

Different opinions have also been entertained, respecting the composition for the charging of rockets. Some, it appears, would employ a composition for each rocket, according to its caliber, pre-supposing, that the inflamed matter acquired force by the increase of its volume; without considering, that a large rocket has more weight than a small one, and requires more power to raise it. Experience has demonstrated, that a composition which will completely raise a rocket of three-quarters of an inch, will raise, under the same circumstances, a rocket of three inches; and, on the contrary, that the last will ascend more slowly, in consequence of having to encounter a greater resistance in the air, owing to its size.

Sec. II. Of the Composition of Sky-rockets, and Observations on its Preparation, and on other Subjects respecting Rockets.

The formulæ we here give, which we notice separately from the others, are on the authority of Morel, who, by experience, has found them to excel all others. Nevertheless, we purpose to enumerate other formulæ for the information of the reader.

Composition of Sky-Rockets, according to Morel. [330]

	For Summer.				*Another.*		
1.	Saltpetre,	17	oz.	2.	Saltpetre,	16	oz.
	Sulphur,	3½	—		Sulphur,	4	—
	Meal-powder,	1½	—		Charcoal,	7½	—
	Charcoal of oak,	8	—				
	For Winter.				*Another.*		
3.	Saltpetre,	17	oz.	4.	Saltpetre,	44	oz.
	Sulphur,	3	—		Sulphur,	4	—
	Meal-powder,	4	—		Charcoal,	16	—
	Charcoal of oak,	8	—				
	Another.				*Another.*		
5.	Saltpetre,	16	oz.	6.	Sulphur,	3	oz.
	Sulphur,	2 oz.	3 drachms.		Saltpetre,	20	—
	Charcoal,	6	oz.		Charcoal,	8½	—

Chinese Composition for rockets of honour.

Saltpetre,	5	ounces.
Sulphur,	1¼	——
Charcoal,	2½	——
Meal powder,	1	——
Pulverized cast iron,	2½	——

Two compositions for rockets of any caliber are given by Bigot; (p. 122); viz.

Rockets of Honour.

Meal powder,	2	parts.
Saltpetre,	10	——
Sulphur,	2½	——
Charcoal,	5	——
Cast iron, pulverized,	5	——

Particular Composition.

Saltpetre,	16	parts.
Sulphur,	4	——
Charcoal,	9	——
Antimony,	2	——

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In the old authors on fire-works, there are a variety of formulæ for sky-rockets, which will be found in the following table:

Kinds of Rockets.		Meal powder		Saltpetre		Charcoal		Steel		Sulphur		REMARKS.
		lb.	oz.	lb.	oz.	lb.	oz.	lb.	oz.	lb.	oz.	
Rockets,	4 oz.	1	4	0	4	0	2	0	0	0	0	
Do.	8 oz.	1	0	0	4	0	1½	0	0	0	3	
Do.	do.	1	8	0	0	0	4½	0	0	0	0	
Do.	1 lb.	2	0	0	8	0	2	0	1½	0	4	
Do. in general,		0	0	4	0	1	8	0	0	1	0	
Do.	do.	0	2	4	0	1	12	0	0	1	8	
Do. large fly,		1	0	4	0	0	0	0	0	1	0	
Do. of a middling size		3	0	8	0	0	0	0	0	3	0	
Do.	do.	1	0	3	0	1	0	0	0	2	0	
Do. water,		6	0	4	0	5	0	0	0	3	0	The proportion of charcoal is certainly too great.
Do.	do.	0	0	1	0	0	6	0	0	0	4½	
Do.	do.	0	0	1	0	0	12	0	0	0	4	
Do.	do.	0	0	4	0	1	12	0	0	1	8	
Do.	do.	4	0	4	0	0	0	0	0	2	0	
Do.	do.	0	4	1	0	0	2	0	0	0	8½	
Do.	do.	1	0	3	0	0	8½	0	0½	1	0	Sea-coal, 1 oz. saw-dust, ¾ oz. coarse char. ¼ oz.
Do.	do.	1	12	3	0	0	12	0	0	1	8	Sawdust, 2 oz.
Do.	do. sinking charge,	0	8	0	0	0	12	0	0	0	0	

The charcoal ought not to be pulverized very fine. It should be passed through a coarse wire sieve, and the impalpable powder then separated, by submitting the sifted charcoal to the same operation in a finer sieve. The fine charcoal may be used for small fire-works.

The instructions, heretofore given, for the mixture of compositions must be attended to; as, for instance, when we have weighed the powder, nitre, and sulphur, the whole are to be incorporated in a mortar, and then passed three times through a large sieve. Afterwards add the charcoal, which is mixed thoroughly with the hand. (See the *Mixture of Substances*, part second). With respect to the rammers, the mode of charging, &c. see section iii, of part second.

In charging cases of half an inch caliber, fifteen blows with the mallet must be given; for three-quarters of an inch, twenty blows; for one inch, twenty-five blows; for one and a quarter inches, thirty blows; one and a half inches, thirty-five blows; for two inches, [332] forty blows; and for three inches, fifty blows;—that is to say, the number of blows must be given to each charge put in, which ought to occupy half the interior diameter of the case. The rammer must be frequently taken out, and struck, so as to disengage any of the composition, which may adhere to it. Respecting the accuracy of the charge, see *Table rocket*, in the chapter on *Table fire-works*.

The garnishing, or furniture, should not exceed, in any case, one-third the weight of the rocket. The head is made of pasteboard, first moistened, and then rolled round a conical former. It must enter the mould, and, when inserted, ought to be pasted round the juncture with paper. (See sec. iii, and iv.)

With respect to rocket sticks, as they are used for counter-weights, Morel remarks, that, for rockets up to an inch and a quarter, they may be formed of the branches of light wood, as hazle, elder, &c. and for rockets above that caliber, heavy wood, but perfectly straight and without knots, may be used. As a general rule, the sticks are made ten or twelve times the length of the rocket, and in thickness about one-third of the exterior diameter of the case. In the large end of the stick, there is a gutter or groove, formed to receive the rocket. When branches are used, they must also lie straight, and cut flat at the large end, about half their thickness, so that they may be joined to the rockets with a pack-thread, or fine iron wire. If the stick is too weighty, it may be shaved off the whole length. Rockets, we may remark, that are not well balanced by the stick, will not ascend regularly. If the stick be too light, they will rise in a zigzag direction; but, if too heavy, their accelerated force will be diminished, their motion slow, and, when they arrive at a certain height, they will fall in a semicircular position. (See section v, of this chapter, *on the Dimensions and Poise of rocket sticks.*)

We may further remark, that all rockets are formed and proportioned by the diameter of their orifice. When the height is six and two-thirds diameter, the foot should be one diameter and two-thirds. The choak of the mould, if used, is one diameter and one-third in height, which must be made out of the same piece as the foot, and fit tight in the mould. There must be an iron pin to keep the foot fast. The nipple is half a diameter high, and two-thirds thick, and made of the same metal as the piercer. The height of the piercer is three and a half diameters, and at the bottom one-third of a diameter thick, and from thence tapering to one-sixth of a [333] diameter. The best mode of fixing the piercer in the cylinder, is to make that part below the nipple sufficiently long to go entirely through the foot, and rivet at the bottom. The former or roller, for the cases, is seven and a half diameters from the handle, and its diameter is two-thirds of the bore. The end of the former is one diameter and two-thirds long, and of the thickness given above. The small part, which fits in the hole in the end of the roller, when the case is pinched, is one-sixth and one-fourth of the diameter of the mould thick. The first drift, or rammer, must be six diameters from the handle; and this, as well as all other rammers, must be a little thinner than the former, to prevent the sacking of the paper, when the charge is driven. In the end of this rammer must be a hole to fit over the piercer. Several hollow rammers are used in completing the charge. (See our remarks in part second on *Charging of cases.*)

The diameter of the nipple should always be equal to that of the former. With regard to the thickness of moulds, it is immaterial, provided they are substantial and strong. Solid driving is more expeditious than charging over a piercer; but great labour and attention is required in boring them, an account of which, with the apparatus required, may be seen in *Part second*.

The following table of the dimensions of rocket-moulds, if the rockets are rammed solid, may be useful.

Weight of rockets.		Length of their moulds without their feet.	Internal diameter of the moulds.	Height of the nipples.
lbs.	oz.	Inches.	Inches.	Inches.
6	0	34.7	3.5	1.5
4	0	38.6	2.9	1.4
2	0	13.35	2.1	1.0
1	0	12.25	1.7	0.85
0	8	10.125	1.333 &c.	0.6
0	4	7.75	1.125	0.5
0	2	6.2	0.9	0.45
0	1	4.9	0.7	0.35
0	0½	3.9	0.55	0.25
6	drachms.	3.5	0.5	0.225
4	drachms.	2.1	0.3	0.2

Sec. III. Of the Heading of Rockets. [334]

The heads for sky-rockets must always bear a given proportion to the rockets.

A pointed cap, adapted to the summit, will make a rocket ascend to a greater height, as it serves to facilitate its passage through the air. To these rockets may be added several other things; as a petard, which is a box of tin plate, filled with fine gunpowder, placed on the summit. The petard is put on the composition, at the end, when it has been filled, and the remaining paper of the cartridge is folded down over it, to keep it firm. The petard produces its effect, when the rocket is in the air, and the composition is consumed. We have already remarked, that the upper parts of rockets, that is to say, their *heads*, are generally furnished with some composition, which takes fire, when it has reached its greatest height, emits a considerable blaze, or produces a loud report and whizzing noise. Of this kind are saucissons, marrons, stars, showers of fire, &c. The heads of sky-rockets, are, therefore, furnished with a variety of compositions.

When a rocket is five diameters, and one-sixth in length, the case being cut to this length, after it is filled, the head should be two diameters high, and one diameter $^1/_6$th, and $^1/_2$ in breadth. The perpendicular height of the cone, or cap of the head, must be in diameter, one, and one-third. There is a circular collar, to which the head is fixed, turned out of any light wood; its exterior diameter must be equal to the interior diameter of the head. One-sixth is sufficient for its thickness, and round the outside must be a groove. The interior diameter of the collar should not be quite so wide as the exterior diameter of the rocket. When it is to be glued on the rocket, two or three rounds of paper are to be cut off, which will make a shoulder for it to rest upon. Two or three rounds of paper well pasted, will be sufficient for the head. Put the collar on the mandril, or former, which must fit the inside of the cone when formed; then, with a pinching cord, pinch the bottom of the head into the groove, and tie it with small twine. To make the caps, cut the paper in round pieces, equal in diameter to twice the length of the cone, which is to be made. These pieces, being cut into halves, will make two caps each. Paste over the caps a thin white paper, which must be a little longer than the cone, so as to project about half an inch below the bottom: this projection of paper being matched and pasted, serves to fasten the cap to the head, A conical former is used to shape the head.

Sec. IV. Of the Decorations for Rockets, and the Manner of filling their Heads. [335]

Having, in the preceding section, shown the mode of forming heads, or conical caps, for rockets, we may now remark, that the furniture or decorations for rockets consist of stars of different kinds, such as tailed, brilliant, white, blue, yellow, &c. or gold and silver rain; or serpents, crackers, fire-scrolls, or shining marrons, or small rockets; the kind of the decoration depending entirely upon taste and fancy.

In loading the heads of rockets, a ladleful of powder must be put into each head, along with the decorations. This is absolutely necessary in order to burst the head and disperse the stars, &c.

Various experiments have been instituted, to make rockets, by employing sundry compositions for charging the cases, along with the rocket composition, to produce, like the heads of rockets, when they burst, different appearances. M. Morel informs us, that he made several experiments with that view, but did not succeed. He ascribes the failure to several causes; and, in substance, concludes, that such figures have a greater weight than rockets are able to carry; that their irregular forms and movements produce, in the ascension, a contrariety of effects, which impedes their flight; and that, if they were to succeed, the rapidity, with which the fuse passes through the air, would prevent any thing being distinguished. As such exhibitions are shown with effect, by the bursting of the head of the rocket, after it has ceased to burn; we are of opinion, that the only mode, which can be adopted, with success, is the one already described. For after the rocket has ceased, or finished, the last portion of fire is communicated to the head, containing the decorations, which is blown off, and its contents are inflamed and dispersed. It is true, however, that, in some compositions, stars, previously made, and therefore not mixed with the composition, are put in the cases along with the charge: We have an instance of this in the fire-pump, Roman candle, &c. The cases for these are filled in the following order: first with gunpowder to a certain extent, then a star, then composition; then powder again, then another star, and so on alternately, until the charge is completed; but, in this instance, the star, as well as the gunpowder, is distinct from the composition, which forms the fire-pump. For, while the composition performs one part, the gunpowder acts another, by throwing the stars out, which, by their combustion, give the appearance they are intended to produce. Stars may be formed, or rather exhibited, in this way, [336] which, in fact is much after the manner, in which they are used for the heads of rockets. But the experiments of Morel appear to have been made, with a view to produce that effect from the rocket itself, and altogether by the composition, by varying or otherwise modifying it. Star-composition, it must be observed, is of a greater specific gravity than any ordinary composition, in consequence of the weight, and quantity of metallic and other substances, which enter into it. By arranging stars in cases, in the mode described for the fire-pump, the effect, we have spoken of, always takes place. In rockets, however, which require to be driven with considerable force, and over a piercer, they could not be used.

Sec. V. Of the Dimensions and Poise of Rocket-sticks.

Although we have made some observations on the size, as well as the use of rocket-sticks, in a general way; yet the subject being very important, as rockets, however well made, cannot take a vertical direction without them, we subjoin the following table, which exhibits, at one view, the length, &c. of the stick, compared with the weight of the rocket, and the poise it must necessarily have from the point of the cone. The *centre* of gravity is a necessary consideration.

Weight of the rocket.		Length of the stick.		Thickness at top.	Breadth at top.	Square at bottom.	Poise from the point of the cone.	
lbs.	oz.	Ft.	In.	Inches.	Inches.	Inches.	Ft.	In.
6	0	14	0	1.5	1.85	0.75	4	1.5
4	0	12	10	1.25	1.40	0.625	3	9.
2	0	9	4	1.125	1.	0.525	2	9.
1	0	8	2	0.725	0.80	0.375	2	1.
0	8	6	6	0.5	0.70	0.25	1	10.5
0	4	5	3	0.3750	0.55	0.35	1	8.5
0	2	4	1	0.3	0.45	0.15	1	3.
3	1	2	6	0.25	0.35	0.10	11	0.
0	0½	2	4	0.125	0.20	0.16	8	0.
0	0¼	1	10½	0.1	0.15	0.5	5	0.5

** Transcriber Note: the last three rows of this table have many typos. The rows were probably intended to be as follows:

0	1	2	6	0.25	0.35	0.10	1	1.
0	0½	2	4	0.125	0.20	0.16	0	8.
0	0¼	1	10½	0.1	0.15	0.5	0	5.5

** end of Transcribers Note **

The last column expresses the distance from the top of the cone, where the stick, when tied on, should balance the rocket, so as to stand in equilibrium on the edge of a knife.

Having given the method of preparing sticks, nothing more is necessary on that head, except that they should be cut and planed [337] according to the dimensions in the table. A groove must be made the length of the rocket, and as broad as the stick will allow. Two notches may be cut on the opposite flat side, for the cord which ties on the rocket. The top of the stick should always touch the head. In fixing on the stick, care must be taken to secure it well.

It is the stick which gives a proper counterpoise, without which the rockets would not ascend; and, unless they were of a proper length and weight, instead of taking a vertical or perpendicular direction, they would describe a parabola, or take an oblique course, and fall to the ground.

A rocket stick may be made for any sized rocket, although not expressed in the table, by assuming the data there given, taking care to find the centre of gravity. For the sticks for war-rockets, see *Congreve Rocket.*

Sec. VI. Of the Mode of Discharging Rockets.

Having completely prepared the rockets with all their appendages, we consider in the next place the manner of discharging them; in performing which some care is to be observed. The old and heretofore common manner, of setting them off by hanging them on nails and hooks, has many objections. The best mode is to have a ring made of strong iron wire, large enough for the stick to go in, as far as the mouth of the rockets. Then let this ring be supported by a small iron, at some distance from the post or stand, to which it is fixed; and have another ring fixed in the same manner, to receive and guide the small end of the stick. Rockets, thus suspended, will have nothing to obstruct their flight. The upright, to which the rings are fixed by the small iron, must be exactly vertical.

Two, three, or more sky-rockets may be fixed on one stick, and fired together. Their appearance, in this case, is very striking. Their tails will seem but as one of immense size, and the discharge from so many heads, at the same time, will resemble more the effect of an air balloon. Rockets, for this purpose, must be made alike in every particular. If the rockets are half-pounders, whose sticks are six and a half feet long, then two, or three, or six of these are to be fixed to one stick, the length of which must be nine feet and three-quarters. Cut the top of it into as many sides as there are rockets, and let the length of each side be equal to the length of one of the rockets without its head; and in each of these sides, let a groove be made. From this groove, plane it round, [338] down to the end. The rule is, that the stick at top must be sufficiently thick, when the grooves are cut, for all the rockets to lie as near as possible, without pressing each other. When only two rockets are to be fixed on one stick, let the length of the stick be the last given proportion, but shaped after the common method, and the breadth and thickness, double the usual dimensions.

When several rockets are placed upon one stick, there will be some danger of their flying up without the stick. Cases, when tied on all sides of the stick, cannot be secured to it by rope passing over notches as before mentioned. Instead of which, drive a small nail in each side of the stick, between the necks of the cases; and let the cord, which goes round their necks, be brought close under the nails. A quick match, without a pipe, is to be fixed to the mouth of one rocket, and carried to another. This match will communicate fire at one and the same time.

There is a mode of discharging sky-rockets without sticks, which consists in using balls of lead tied to a wire two or three feet long, and fixing the other end of the wire to the neck of the rocket. These balls answer the purpose of sticks, when made of a proper weight, which is about $^2/_3$ds the weight of the stick. They will balance the rocket at the usual point. To fire rockets, thus equipped, a different mode must be adopted. They are hung, one at a time, between the tops of wires placed for that purpose, letting their heads rest on the wire, and the balls hang down between them. The wires are about three feet long, and inserted in a circle, in a block of wood, which must lie level, and the wires perfectly vertical. The diameter of the circle is two and a half inches; it is divided into three equal parts, and at each one is a rod or wire.

We may introduce here a description of the *stands for sky-rockets*, and the *girandole chests for the flights of rockets*. The first is formed of two rails of wood, of any length, supported at each end by a perpendicular leg, so that the rails lie horizontal; and let the distance from one to the other be almost equal to the length of the sticks of the rockets, intended to be fired. Then in the front of the top rail, drive square hooks at eight inches distance, with their points turning sidewise; so that, when the rockets are hung on them, the points will be below the sticks, and keep them from falling or being blown off by the wind. At the front of the rail at the bottom must be staples, driven perpendicularly under the hooks at top. Through these staples put the small ends of the rocket- [339] sticks. They are fired by applying a lighted port-fire to their mouths. Two or three seconds will expire before they ascend.

The girandole chest is composed of four sides of equal dimensions; but may be made of any size, according to the number of rockets to be fired. Its height must be in proportion to the rockets, and higher than the rockets with their sticks. When the sides are joined, fix in the top, as far down the chest as the length of one of the rockets with its cap on. On this top, make as many square or round holes, to receive the rocket-sticks, as the number of rockets to be fired; but let the distance between them be sufficient to prevent their touching each other. From one hole to another cut a groove of a sufficient size for a quick match to lie in. The top being thus fixed, put in the bottom, at about 1$^1/_2$ feet distance from the feet of the chest. In this bottom, make as many holes as at the top, and all to correspond, but not so large as those in the top.

To prepare the chest, a quick match is laid in all the grooves, from hole to hole. Then take the sky-rockets, and prime them with meal-powder, or priming paste, as before-mentioned, and put a bit of match up the cavity of each, which should project out. Put the sticks of the rockets through the holes in the top and bottom of the chest, so that their mouths may rest on the quick match in the grooves. The rockets will then be fired at once. There should be a door in the side of the chest, and also a cover, to secure the rockets until they are required.

The *fountain of rockets*, an exhibition which frequently accompanies a display of works, is nothing more than a number of rockets discharged at the same time.

There are some improvements on the girandole chest, and on the different modes of discharging a series of rockets.

We may mention one contrivance for this purpose, as described by Morel. It is an oblong box furnished with a double lid, which, when shut, resembles the roof of a house. This box is sixty inches in length, ten inches in breadth, and nine inches in height. It rests upon a frame, and has a bottom in which are one-hundred holes, to receive the same number of rocket-sticks, the rockets resting on the bottom of the box. The lid serves to prevent the access of moisture, and to secure the rockets. No part of the rocket is seen in the box. They are set off by first strewing meal-powder on the bottom, which is then in contact with their mouths, and applying a lighted port-fire. They rise out of the box all together, and at the same time. When fired together, so as to form a *flight* of rockets, the French use them of three-quarters of an inch caliber. [340]

The *girandole* may be considered an assemblage of a large number of rockets of various calibers, arranged in gradation; the largest, occupying the first range, &c. The girandole constitutes, as a fire-work, in the language of Morel, the *feux de gouvernement*.

Similar to this is a contrivance for the same purpose, but not so extensive, and rather differently formed. It consists of a case, in which there are holes to receive the sticks and support the rockets. The case is supported by legs; two of which, working upon a joint, may be extended, and thus the rockets be made to move in any angular direction. The inclination given is hardly ever more than 55 degrees. The legs are pointed, so as to retain their position. If the rockets are to ascend vertically, the two legs, which move in a joint, are closed. They are stuck in the ground at the same place.

For the mode of discharging the *Congreve Rocket*, see the article on *Congreve Rockets.*

Sec. VII. Of the Appendages, and Combinations of Rockets.

We purpose to notice, in this section, some of the modes of arranging, combining, and also of varying the effects of rockets.

When a sky-rocket is fixed with its stick on the top of another, a fresh tail of fire will be observable, when the second rocket takes fire, which will mount to a great height. The preparation of these rockets consists in filling a two pounder only half a diameter above the piercer, (which must be observed in this instance,) and its head with not more than ten or twelve stars; adapting a stick as usual, which must be made a little thicker than customary. This stick must be cut in half the way flat, and in each half a groove, so that, when joined together, they will receive, and be large enough to hold the stick of a half pound rocket. The heading is then performed as before described. The stick of this small rocket is to be fixed in the hollow of the large one, so far that the mouth of the rocket may rest on the head of the two pounder; and, from the head of the two pounder, a leader is to be carried into the mouth of the small rocket.

When sky-rockets are fixed one on the top of another, they are called *towering rockets*, on account of the great height to which they ascend. They are made in the following manner: Fix on a pound rocket, a head without a collar; then take a four-ounce rocket, which may be headed or bounced, and rub the mouth of it with priming paste, or meal-powder and spirits of wine. Put it into the head of a large rocket with its mouth downwards, previously, however, inserting a bit of quick match in the hole made through the clay of the pound-rocket, which match should be of a sufficient length to go a small distance up the bore of the small rocket, to fire it when the large one is burnt out. The four-ounce rocket being too small to fill the head of the other, roll round it as much tow as will make it stand upright in the centre of the head. Then paste a single paper round the opening of the top of the head of the large rocket. The large rocket must have only half a diameter of charge rammed above the piercer; for, if filled to the usual height, it would turn before the small one takes fire, and entirely destroy the intended effect. When one rocket is headed with another, there will be no occasion for any *blowing powder*; for the force with which it flies off will be sufficient to disengage it from the head of the first fired rocket. The sticks for these rockets must be a little longer than for those headed with stars, rain, &c. [341]

The *caduceus rockets* are formed of two rockets. When attached, one on each side at the top of the stick, they form a right angle, their mouths being equidistant from the stick. The sticks, for this purpose, must have all their sides alike, which should be equal to the breadth of a stick, proper for a sky-rocket of the same weight as those intended to be used, and to taper downwards as usual. They must be long enough to balance them, and one length of a rocket from the cross-stick. The cross-stick is that to which the cases are tied, and serves to preserve them steady in that position. Each rocket, when tied on, should form either an angle of 45, or 60 degrees with the large stick, or both together an angle of 90 or 120 degrees. The last, however, is considered a preferable angle. When tying on the rockets, attention ought to be paid to place their heads on the opposite sides of the cross-stick, and their ends on the opposite sides of the long stick. Quick-match is then to be carried from the mouth of one into that of the other. When these rockets are to be fired, suspend them between two hooks or nails, and apply fire to the leader in the middle, and both will take fire at the same time.

The particular effect of this rocket is, that, in rising, it forms two spiral lines, or double worms, in consequence of their oblique position; and the counterpoise in the middle (the stick) causes them to ascend vertically. Rockets, for this purpose, must have their [342] ends choaked close, without either head or bounce; for a weight at top would be an obstruction to their mounting. They do not rise so high as single rockets, because of their serpentine motion, and the resistance they meet with in passing through the air. This resistance is greater than two rockets of the same size fired singly.

Honorary rockets are nothing more than sky-rockets, except that they carry neither head nor report. They are closed at top, to which is attached a cone. On the case, close to the top of the stick, a two-ounce case is tied. This last is filled with a strong charge, and is usually about five or six inches in length, and pinched close at both ends. At the opposite sides, at each end, a hole must be bored, in the same manner as in tourbillons; and from each hole, a leader must be carried into the top of the rocket. When the rocket is fired, and has arrived at its proper height, it will communicate fire to the case at the top, which will cause the rocket and stick to descend very fast to the ground, and, in its descent, will represent a worm of fire.

There are several modes of placing the small case, so as to produce the best effect. One is by letting the stick rise a little above the top of the rocket, and tying the case to it, so as to rest on the rocket. These rockets are not furnished with cones. Another method is also recommended; namely, in the top of the rocket, fix a piece of wood, in which drive a small iron spindle; then make a hole in the middle of the small case, through which put the spindle, and fix, on the top of it, a nut, to keep the case from falling off. The case, by this means, will turn very fast, without the rocket. This method, however, is not preferred.

One-pound rockets are considered the best size for this purpose.

Chained rockets, as they are sometimes called, are another modification of the manner of fixing rockets; for the intention is to make several sky-rockets rise in the same direction, and equally distant from each other. This effect is produced in the following manner: Take six, or any number of sky-rockets, of any size; then cut some strong pack-thread into pieces of three or four yards long, and tie each end of these pieces to a rocket in this way;—after tying one end of the pack-thread round the body of one rocket, and the other end to another, take a second piece of pack-thread, and make one end of it fast to one of the rockets already tied, and the other end to a third rocket; so that all the rockets, except the outside, will be fastened to two pieces of pack thread. The [343] length of thread, from one rocket to the other, is indeterminate. They must all be of a size, and their heads filled with the same weight of stars, or other decorations.

In the mouth of each rocket, a leader is to be fixed of the same length, and when fixed, they may be hung almost close. Tie the ends of the leaders together, and prime them: When this is fixed, all the rockets will mount at the same time, and separate as far as the strings will admit. They will preserve the same order and distance, if they are rammed alike, and equally well made.

The manner of dividing the tail of a sky-rocket, so as to form an arch when ascending, is thus performed. Having some rockets made, and headed according to fancy, and tied on their sticks, get some sheet tin, and cut it into round pieces of about three or four inches in diameter. Then, on the stick of each rocket, under the mouth of the case, fix one of these pieces of tin, sixteen inches from the head of the rocket, and support it by a wooden bracket as strong as possible. The use of this is, that, when the rocket is ascending, the fire will play with great force on the tin, which will divide the tail in such a manner, as to form an arch. If there is a short piece of port-fire, of a strong charge, tied to the end of the stick, it will add greatly to the appearance; but this must be lighted before fire is put to the rocket.

Sec. VIII. Of Swarmers, or Small Rockets.

Although swarmers are nothing more than rockets of a smaller size, as from two ounces downwards, and are charged with the usual rocket composition, which we have described; yet it may be necessary to make some remarks respecting them.

Swarmers are sometimes fired in flights, or in a volley, and in large aquatic fire-works. They are bored in the same manner as large rockets, or pierced in the act of charging them. This is the case with those of one and two ounces. All rockets, however, under one ounce, are not bored, but must be filled to the usual height with composition. The number of strokes for ramming these small swarmers is not material, provided they are rammed true and moderately hard. The necks of unbored rockets must be in the same proportion as in common cases. The composition, with which small swarmers are charged, generally consists of

Meal-powder,	4	oz. [344]
Charcoal, or steel-dust,	¼	oz.

As to the swarmers which are pierced, or bored, *viz.* those of one and two ounces; they are made, we observed, in the same manner as large rockets, with the exception, that, when headed, their heads must be put on without a collar. The number of strokes for driving one-ounce cases must be eight, and for two-ounce, twelve.

Sec. IX. Of Scrolls for Sky-Rockets, and of Strung, Tailed, Drove, and Rolling Stars.

We have given, in a preceding chapter, the composition of various stars, which are used for the decoration of sky-rockets, and other species of fire-works. We shall, therefore, confine ourselves to their application, and the different modes of preparing them for this purpose.

Scrolls are used as furniture, or decorations for sky-rockets, and are so named from the spiral form they assume, when fired very quick in the air. We may put into the head of a rocket, as many of the cases as it will contain. Cases for scrolls should be four or five inches in length, and their interior diameter, three-eighths of an inch. One end of these cases must be pinched quite close before it is filled; and, when filled, the other end must also be closed. Then, in the opposite sides, make a small hole at each end, in the same manner as in tourbillons, and prime them with priming paste, or meal-powder and brandy.

Strung Stars, so named from having a cotton quick match run through them, are formed by taking some thin paper, and cutting it into pieces of about one and a half inches square, and laying on each piece, as much dry star composition as the paper, when folded, will easily contain. The paper, with its contents, is then twisted up as hard as possible. When done, rub some paste between the hands, and roll the stars between them, and afterwards dry them. They are then covered with tow, and primed with a paste composed of meal powder, and brandy, in which they may be rolled in the same manner as described when treating of stars. They are then dried and strung on cotton quickmatch, by piercing a hole through them, taking care to put but ten or twelve on each match, and placing them at the distance of three or four inches apart.

Tailed stars are those which produce a great many sparks, representing a tail like that of a comet. Of these, there are two kinds, [345] the rolled and the drove. The operation for the rolling of stars, we have sufficiently explained; it consists in mixing the composition with brandy, or, if it can be had, with spirit of wine, and either weak gum water, or isinglass size, sufficient to make a thick paste; and then rolling it.

When tailed stars are to be driven, the composition must be moistened with spirit of wine, or if it cannot be had, with fourth proof brandy, without the gum, or gelatin, and not made so wet as for rolling. One or two-ounce cases, rolled dry, are best for this purpose; and when they are filled, unroll the cases within three or four rounds of the charge, and all that is unrolled must be cut off. Then paste down the loose edge; and in two or three days afterwards, cut them in pieces of five or six-eighths of an inch in length; then melt some wax, and dip one end of each piece into it, so as to cover the composition. The other end must be covered with priming paste.

Drove stars are so designated, because the composition is always drove, and used in cases. They are seldom put in rockets, but are chiefly used for air-balloons. They are put in cases, to prevent the composition from being broken, by the force of the blowing powder in the shell. See *Air-Balloons.*

With respect to *rolling stars*, we gave, in our chapter on star compositions, not only the proportion of their constituent parts, but ample instructions for preparing them for use. They are usually about the size of a musket ball; but sometimes they are made an inch in diameter. When very small, they are called *sparks*. See *Stars.*

Sec. X. Of Line-Rockets and their Decorations.

Line-rockets are the same as the *courantines* of the French, or rockets that fly along a rope. If a rocket be attached to an empty case, and a rope passed through the latter, and stretched horizontally; and if the rocket be then set on fire, it will run along the rope, without stopping till the matter it contains is exhausted.

Line-rockets do not differ materially from sky-rockets, as they are made and driven like them; but they are without heads, and the cases are cut close to the clay. They are sometimes made with six or seven changes. Four or five, however, are the most common. We must first have a piece of light wood, turned round, about two and a half inches in diameter, with a hole through the middle, lengthwise, and sufficiently large for a wire to go easily through. If four changes are required, four grooves must be cut in [346] the swivel, one opposite the other, to lay the rockets in.

Having rubbed the mouths of the rockets with wet meal powder, lay them in the grooves, head to tail, and tie them fast. From the tail of the first rocket, carry a leader to the mouth of the second, and from the second to the third, and so on to as many as there are on the swivel, making every leader very secure; but in fixing these pipes, care must be taken, that the quick match does not enter the calibers of the rockets. The rockets being fixed on the swivel and ready to be fired, have a line, 100 yards long, stretched, and fixed up tight, at any height from the ground, but placed perfectly horizontal. This length of line will answer for half-pound rockets, but, if larger, the line must be longer. One end of the line, before it is put up, is to be put through the swivel; and when the line-rocket is fired, let the mouth of that rocket, which is set off first, face that end of the line where the operator stands, and the effect will follow in succession, *viz*: the first rocket will carry the rest to the other end of the line, the second will bring them back, and they will continue running out and in, according to the number of rockets. At each end of the line, there must be a piece of wood for the rocket to strike against, to prevent injury to the line. Let the line be well soaped, and the hole in the swivel very smooth.

In order to vary the appearance, different decorations may be used with the line-rockets; of these, *flying dragons*, *Mercuries*, &c. are the most conspicuous. Another motion may be given to them, that of revolving, in the following manner: Have a flat swivel, made very exact, and tie on it two rockets obliquely, one on each side; which will make it turn the whole length of the line, and form a circle of fire. The charge for these rockets, should be a little weaker than that usually employed.

It is apparent, that a variety of figures may be put in motion, and consequently new appearances formed, by different contrivances. To represent, for instance, two *fighting dragons*, we must have two swivels, made square; and on each swivel, tie three rockets together, on the under side. Then having two flying dragons, made of tin, fix one of them on the top of each swivel, so as to stand upright, and in the mouth of each dragon, put a case of common fire; and another at the end of the tail. Two or three port-fires may also be put on the sides of their bodies to illuminate them Put them on the line, one at each end; but let there be a [347] swivel in the middle of the line, to keep the figures from striking together. Before the rockets are fired, light the cases on the dragons, and, if care be taken in firing both at the same time, they will meet in the middle of the line. They will then turn, and run back with great violence. The line for these rockets, must be very long.

Sec. XI. Of Signal Sky-Rockets.

Signal rockets seldom exceed a pound in weight. Those which are employed in the land and sea service, are sometimes capped, or headed, and contain stars, serpents, &c. Two sorts of signals are used when artificial works are to be exhibited; namely, one with serpents, and the other without. Rockets which are to be bounced, must have their cases made one and a half or two diameters longer than the common proportion, and, after they are filled, a small quantity of clay is put in. Then bounce and pinch them in the usual manner, and fix on each a cap. Signal sky-rockets, without bouncers, are only sky-rockets closed and capped. These are very light, and, therefore, do not require such heavy sticks as those with loaded heads. Signal rockets, with reports, are fired in small flights; and are often, as well as those without reports, used for signals of the commencement of an exhibition of fire-works.

Signal rockets may be seen at a great distance, and observed instantly, when neither flags nor telegraphs could be observed without glasses; and may be so formed, as even to communicate particular orders or intelligence, by varying their decorations, their mode of ascension, as in the caduceus rocket, and by several other means.

CHAPTER VIII.

OF SUNDRY FIRE-WORKS, DENOMINATED AIR-WORKS.

Before we notice the various kinds of wheel-works, and their appendages, we purpose to consider the formation of gerbes, air-balloons, mortars, bombs, tourbillons, aigrettes, and some other works.

Sec. I. Of the Composition and Mode of forming large and small Gerbes. [348]

In preparing cases for gerbes, it is necessary that they should be made strong; as they would be liable to burst, on account of the strength of the composition, which comes out with great velocity. They should be of the same thickness at top and bottom, and the paper well pasted. Their necks should be long, in which case, the iron would have more time to be heated, by meeting with more resistance in its disengagement, than if the neck was shorter; for then it would be burnt too wide before the charge was consumed. Long necks will throw the stars to a greater height, which will not fall before they are spent. They should rise and spread in such a manner as to resemble a wheat-sheaf.

Gerbes are generally made about six diameters long, from the bottom to the top of the neck. Their caliber must be one-fifth narrower at top than at bottom. Their neck is one-sixth diameter, and three-fourths long. There is a wooden foot or stand, on which the gerbe rests. This may be made with a choak or cylinder, four or five inches long, to fit the inside of the case, or with a hole in it to put in the gerbe: both these methods will answer the same end. In the charging of gerbes, there will be no need of a mould, the cases being sufficiently strong to support themselves. Before this operation is commenced, we must be provided with a piece of wood made to fit in the neck. If this precaution is not used, the composition will fall into the neck, and occasion a vacancy in the case, which will inevitably burst it, the moment the fire reaches the air. A weak composition should be put in at first, to the quantity of one or two ladles full. After the case is filled, take out the piece of wood, and fill the neck with slow charge.

Small gerbes, or white fountains, as they are sometimes called, are usually made of four, eight, or sixteen ounce cases, of any length, taking care to paste, and otherwise make them very strong. Before they are filled, however, drive in clay one diameter of their orifice high. When filled, bore a hole through the centre of the clay to the composition. The ordinary proportion will answer for the vent, which must be primed with a slow charge. Large gerbes are made by their diameters, and their cases at bottom one-fourth thick. The interior diameter of a gerbe is found, by supposing the exterior diameter of the case, when made, to be five [349]
inches, by taking two-fourths for the sides of the case, and there will remain two and a half inches for the bore.

Gerbes produce a brilliant fire, and appear remarkably beautiful, when a number of them are fixed in front of a building.

The composition of gerbes is similar to that of the Chinese fire. It is to the cast-iron, which enters into it, that its beautiful effects are to be ascribed. In fact, the composition of Chinese fire differs considerably, as we shall notice, when we treat of it, according to the purpose for which it is employed. It is adapted, for instance, in various proportions of its constituent parts, to calibers of different diameters, cascades, representation of palm trees, as well as for large and small gerbes. The old formula for gerbes is the following.

Composition for Gerbes.

Meal-powder,	6	lbs.		
Beat cast-iron,	2	lbs.	1½	oz.

The present formula, as we remarked when speaking of compositions for calibers from three-quarters of an inch to an inch, is saltpetre 1 oz, sulphur 1 oz, meal-powder 8 oz, charcoal 1 oz, and pulverized cast-iron 8 oz.

The vivid and rapid combustion which ensues, when this composition is inflamed, cannot be accounted for in any other way, than that the nitre is acted upon by the sulphur, the charcoal, and the iron; that the gunpowder, during its combustion, raises the temperature to the degree necessary for the decomposition of the nitre by the substances mentioned; that sulphurous and probably sulphuric acid, as well as carbonic acid, are generated, by the union of the sulphur and carbon with a part of the oxygen of the nitre; that the iron undergoes a combustion, both in contact with the nitre and with atmospheric air; and, lastly, that the *effect*, which characterizes this composition, and other similar compositions, into which cast-iron enters, as in the celebrated Chinese fire, is to be attributed to the iron; and the appearance which iron assumes, when in a state of combustion, is owing to no other cause than its rapid combination with oxygen, by which the metal is oxidized. (See *Iron*, in *Part* I.)

Sec. II. Of Paper Mortars.

It may not be improper, in this place, to give the manner of forming paper mortars. These mortars are necessary for a variety of [350]
exhibitions, as will appear hereafter.

Mortars are made of stout paper; or several sheets are pasted together, and made into pasteboard, in the manner before described. (See *Pasteboard.*) The preparations are various according to the size required. For a coehorn mortar, which is 4 inches and $^2/_5$ths in diameter, roll the pasteboard on the former, on which it is made, $^1/_6$th of its diameter thick, and, when dry, cut one end smooth and even; then nail and glue it on the upper part of the foot. Afterwards cut off the pasteboard at the top, allowing for the length of the mortar, two and a half diameters from the mouth of the powder chamber.

The mortar is then bound round with a strong cord, wetted with glue. The bottom of the foot, it being turned out of elm, is one diameter and two thirds broad, and one diameter high, and the part which goes into the mortar is two-thirds of its diameter in height. The copper chamber for the powder, which is separate from this, is made in a conical form, and is one-third of the diameter wide, and one and a half of its own diameter long. In the centre of the bottom of this chamber, make a small hole, a short distance down the foot; this hole must be met by another of the same size, made in the side of the foot. If these holes are made true, and a copper pipe fitted into both, the mortar, when loaded, will prime itself; for the powder will naturally fall to the bottom of the first hole. By putting a piece of quick match to the side, it will be prepared for firing.

When mortars of a larger size than ten inches in diameter are required, it is better to have them made of brass. See further observations on this subject in section seventh of this chapter, in the article on *fire-pots.*

Sec. III. Of Mortars to throw Aigrettes, &c.

Shells are filled with a variety of pyro-preparations, as stars, rains, serpents, &c. These are put in first, and then the blowing powder, as it is called; but the shells must not be quite filled. They must be introduced into the shells through the fuse hole. Some substances, however, as marrons, being too large to go through the fuse hole, must be put in before the shell is closed. When the shells are loaded, glue and drive in the fuses very tight. With respect to the diameter of the fuse hole; for a coehorn balloon, let the diameter be seven-eighths of an inch; for a balloon, five and a half inches in diameter, make the fuse hole one inch and one-sixth in [351]
diameter; for an eight-inch balloon, one inch and three-eighths; and for a ten-inch balloon, one inch and five-eighths.

Air-balloons are divided, according to the substances they contain, or the effect they are to produce, and are usually of four kinds; namely, 1. Illuminated air-balloons, 2. Balloons of serpents, 3. Balloons of reports, marrons, and crackers, 4. Compound balloons. Balloons and shells, in fire-works, are the same.

In the following view of the different balloons, we have given the number and quantity of each article for the different shells, designating their kind and character:

Coehorn balloon Illuminated.

Meal-powder,	1½	oz.
Grain, do.	½	—
Powder for the mortar,	2	—

Length of the fuse composition, three-quarters of an inch: 1 oz. drove or rolled stars, as many as will nearly fill the shell.

Coehorn balloon of Serpents.

Meal-powder,	1½	oz.
Grain, do.	½	—
Powder for the mortar,	2¼	—

Length of the fuse composition $^{13}/_{16}$ths of an inch: half-ounce cases, driven three diameters, and bounced three diameters, and half-ounce cases, driven two diameters and bounced four diameters, of each, an equal quantity; and as many of them as will fit in easily, placed head to tail.

Coehorn balloons of Crackers and Reports.

Meal-powder,	$1\frac{1}{4}$ oz.
Grain, do.	$\frac{3}{4}$ do.
Powder for the mortar,	2 do.

Length of the fuse composition $\frac{3}{4}$ of an inch; reports 4, and crackers of six bounces, as many as will fill the shell.

Compound Coehorn Balloons. [352]

	oz.	dr.
Meal-powder,	1	4
Corn, do.	0	12
Powder for the mortar,	2	4

Length of the fuse composition $\frac{13}{16}$ths of an inch: $\frac{1}{2}$ oz. cases driven $3\frac{1}{2}$ diameters, and bounced 2, 16; $\frac{1}{2}$ ounce cases driven 4 diameters and not bounced, 10; rolled stars, as many as will complete the balloon.

Balloons illuminated (Republican).

	oz.	dr.
Meal-powder,	1	8
Grain, do.	0	12
Powder for the mortar,	3	0

Length of the fuse composition $\frac{15}{16}$ths of an inch; 2 oz. strung stars, 34; rolled stars, as many as the shell will contain, allowing for the length of the fuse.

Balloon for Serpents, (Republican).

	oz.	dr.
Meal-powder,	1	
Grain, do.	1	8
Powder for the mortar,	3	8

Length of the fuse composition, 1 inch; 1 oz. cases driven $3\frac{1}{2}$ and 4 diameters, and bounced 2, of each an equal quantity, sufficient to load the shell.

Balloons with crackers and Marrons. (Rep.)

	oz.	dr.
Meal-powder,	1	8
Corn powder,	1	4
Powder for the mortar,	3	

Length of the fuse composition $\frac{14}{16}$ths of an inch; reports 12; to be completed with crackers of 8 bounces.

Compound balloons (Republican).

	oz.	dr.
Meal-powder,	1	5
Corn powder,	1	6 [353]
Powder for the mortar,	3	12

Length of the fuse composition, one-inch; $\frac{1}{2}$ ounce cases driven and bounced 2 diameters, 8; 2 oz. cases filled $\frac{3}{8}$ths of an inch with star-composition, and bounced 2 diameters, 8; silver rain falls, ten; 2 oz. tailed stars, 16; rolled brilliant stars, 30. If this should not be sufficient to load the shell, it may be completed with gold rain falls.

Eight-inch balloons Illuminated.

	oz.	dr.
Meal-powder,	2	8
Grain powder,	1	4
Powder for the mortar,	9	

Length of the fuse composition, one inch and $\frac{1}{8}$th; 2 oz. drove stars, 48; 2 oz. cases, driven with star composition, $\frac{3}{8}$ths of an inch, and bounced 3 diameters, 12; and the balloon completed with 2 oz. drove brilliant stars.

Eight-inch Balloons of Serpents.

	oz.	dr.
Meal-powder,	2	0
Corn powder,	2	0
Powder for the mortar,	9	8

Length of the fuse composition, 1 inch and $\frac{3}{16}$ths; 2 oz. cases driven one and a half diameters, and bounced 2, and one-ounce cases driven 2 diameters, and bounced $2\frac{1}{2}$; of each an equal quantity, sufficient for the shell.

We may remark, that the star composition, driven in bounced cases, must be managed in the following manner: First, the cases must be pinched close at one end, then the corn-powder put in for a report, and the case pinched again close to the powder, only leaving a small vent for the star-composition, which is driven at top, to communicate to the powder at the bounce end.

Compound eight-inch Balloon.

	oz.	dr.
Meal-powder,	2	8
Corn powder,	1	12
Powder for the mortar,	9	4

Length of the fuse composition, $\frac{1}{8}$th of an inch; 4 oz. cases, driven with star composition, $\frac{3}{8}$th of an inch, and bounced 3 diameters, 16; 2 oz. tailed stars, 16; 2 oz. drove brilliant stars, 12; silver rain falls, 20; 1 oz. drove blue stars 20; and 1 oz. cases driven and bounced, two diameters, as many as will fill the shell. [354]

Another of eight-inches.

	oz.	dr.
Meal-powder,	2	8
Corn, do.	1	12
Powder for the mortar,	9	4

Length of the fuse composition, 1 inch and $\frac{1}{8}$th; crackers of six reports, 10; gold rains, 14; 2 oz. cases driven with star composition, $\frac{3}{16}$ths of an inch, and bounced 2 diameters, 16; 2 oz. tailed stars, 16; 2 oz. drove brilliant stars, 12; silver rains, 10; 1 oz. drove blue stars, 20; and 1 ounce cases, driven with brilliant charge, 2 diameters, and bounced 3, as many as the shell will hold.

A compound ten-inch Balloon.

	oz.	dr.
Meal-powder,	3	4
Corn powder,	2	8
Powder for the mortar,	12	8

Length of the fuse composition $^{15}/_{16}$ths of an inch; 1 oz. cases driven and bounced 3 diameters, 16; crackers of eight reports, 12; 4 oz. cases, driven $^{1}/_{2}$ an inch with star composition, and bounced 2 diameters, 14; 2 oz. cases driven with brilliant fire 1 and $^{1}/_{4}$th diameters, and bounced 2 diameters, 16; 2 oz. drove brilliant stars, 30; 2 oz. drove blue stars, 3; gold rains, 20; silver rains 20. After all these are put in, fill the remainder of the case with tailed and rolled stars.

Ten inch balloons of three charges.

	oz.	dr.
Meal-powder,	3	0
Corn-powder,	3	2
Powder for the mortar,	13	0

Length of the fuse composition, 1 inch: the shell must be loaded with 2 oz. cases, driven with star composition $^{1}/_{4}$th of an inch, and on that one diameter of gold-fire, then bounced three diameters; or with 2 oz. cases, first filled one diameter with gold fire, [355] then one and one-fourth diameters of brilliant fire. These cases must be well secured at top of the charge, lest they should take fire at both ends: but their necks must be larger than the common proportion. For the manner of forming *balloon cases* of paper, consult the article on that subject, in a preceding chapter.

Balloons, the *bombs* of some, may be formed of different sizes, and made proportionably strong.

Bombs may be formed of wood by turning it round, and hollow, of a sufficient thickness, and in two parts, which fit each other like a common snuff box. The inferior or lower part must be made thicker than the upper, as it rests upon the powder; and for the same reason, that iron bombs are cast thicker at their bottom. One-twelfth of the diameter is considered a sufficient thickness for the under part, and one-fifteenth for the upper part, which is pierced with a hole to receive the fuse. This hole is called the eye of the bomb.

When balloons, or bombs, are to be charged, the decorations may be varied in the same manner as for sky-rockets. Stars, golden rain, and meteors, are considered the best, as they produce the most brilliant effect.

After the addition of the furniture or decorations, we finish the charge by putting in coarse grain powder, which is introduced through the eye. The fuse is then driven in. It is glued, in order to secure it. The bomb is now covered with three or four turns of canvass, and over this some paper, to secure it. In this state, it ought not to be more than $^{1}/_{11}$th of an inch smaller than the caliber of the mortar. This leaves what is denominated the windage.

When the bombs are well dried, the fuse is primed with a double match, and priming paste. A cup, made with two turns of paper, is then attached to the fuse, which receives the double match.

The bomb, thus prepared, is then placed in a cone made of pasteboard, which contains the powder of the charge, or that required for its ascension, and is put into the mortar. One of the matches above described, communicates the fire to the fuse, and the other at the same time to the powder in the cone. The match, it is to be observed, comes out of the mouth of the mortar, and serves to fire it. This mode of discharging the mortar, differs from the one we have previously given.

The following table exhibits the calibers for bombs, the length of the fuse for each caliber, and the weight of the powder required for the charge.

[356]

Caliber for bombs.		Length of the fuse.		Weight of the charge.	
Bombs of	4 in. diam.	1¼	inches.	2 oz.	cannon powder.
----	6 do. —	1⅔	do.	5 oz.	do. —— do.
----	9 do. —	2	do.	6 oz.	do. —— do.
----	12 do. —	2	do.	9 oz.	do. —— do.

Having made some remarks respecting bombs, we will now offer a few observations concerning mortars; and although we have, on a former occasion, mentioned something respecting them, yet we deem a few remarks on this head not improper at this time.

Mortars, from five to six inches bore, are usually made of pasteboard and canvass. The canvass is first soaked in a gelato-amylaceous paste, or paste composed of half glue and half flour; and, when put on, is covered with sheets of pasteboard, which are glued or pasted. For various kinds of paste, see *Pasteboard.*

When the case, or mortar is to be formed, cylinders of wood as *formers* are employed. They are of different diameters, according to the size of the mortars, that are to be made. For four-inch mortars, inch formers; for six-inch, one and a half inch formers, &c. After they are rolled and pasted on the former, they are dried on it. As to their strength, this depends on the thickness of the case. A mortar of four inches in interior diameter, ought to be six inches in exterior diameter, and those of six in interior, should be nine, exterior. The cases being formed, we next have turned as many cylinders of walnut, as cases or pots. These cylinders are short. In each is formed a conical chamber, in the shape of the letter V, which is afterwards lined with tin or brass, to prevent the action of the powder. They are then glued and put into the end of each pot, about the length of an inch, and further secured by nails.

The chamber is designed to receive the powder, and its conical form enables it to act with all its force immediately on the bomb. A flat bottom would not have this advantage, as the powder in that case would have more room, and consequently its force be divided. They are sometimes, however, made flat.

The charge for these mortars, as a general rule, is $^{1}/_{30}$th part of the weight of the bomb.

When mortars are to be larger than the sizes we have mentioned, it is necessary to have them of metal, and for this purpose copper is generally employed. Its thickness should be one-fourth of an inch, for a nine-inch mortar; and half an inch, for twelve- [357] inch mortars. A cone of copper is to be made in the same way as above mentioned. This is secured, and made solid by means of lead.

In experiments and exhibitions, the powder, we may observe, must be of the same strength.

We find then, that mortars, for the discharge of bombs, or balloons, are differently made from those which are used for throwing iron-shells. In fire-works, the design of mortars is to project the balloon in a vertical direction, which, being furnished with a fuse as in ordinary shells, receives the fire from the gun-powder; and at a given time, according to the length of the fuse, the fire is communicated to the balloon, which bursts and scatters its contents in the atmosphere. The furniture for balloons being various, and in a larger quantity than could be contained in the heads of rockets, (except the Congreve,) the appearance is more grand and impressive. It is obvious, that, when they burst, fire is communicated to the whole at the same time; and the quantity of powder is usually sufficient, not only to burst the shell, but also to throw the contents to some distance. The height, to which balloons ascend, depends, of course, on the quantity of gunpowder put in the mortar. The quantity is generally regulated.

We find, also, that two modes are used for discharging the mortars. The one consists in having a communication from without to the bottom of the cone, which contains the powder, and applying the match to this vent, on the same principle as that for firing a cannon, or common mortar. The other, by firing a quick-match in the conical cavity, and putting in the charge with the balloon; letting the match, however, be of a sufficient length to come out of the mouth of the mortar, and fall over its side. This match, when fired, will communicate fire to the powder in the cone, and produce the same effect. Metallic cylinders, and especially copper, however small, are certainly preferable to those made in the usual manner.

Sec. IV. Of making Balloon Fuses.

Wood, particularly beech, is generally employed for forming fuses, which is turned of the shape required. If made with pasted paper, they will answer for the purpose of fire-works. The diameter of the former for fuses for coehorn balloons must be half an inch; for a republican fuse, five-eighths of an inch; for an eight-inch fuse, three-fourths of an inch; and for a ten inch fuse, seven- [358] eighths of an inch. Having rolled the cases, pinch and tie them almost close at one end; then drive them down, and let them dry. Before they are filled, mark on the outside of the case, the length of the charge required, allowing for the thickness of the bottom; and when the composition is rammed in, take two pieces of quick-match about six inches long, and lay one end of each on the charge, and then a little meal-powder, which is to be rammed down loose. The loose ends of the match, double up, and place in the top of the fuse. This top must be covered with a proper cap to keep it dry. When the shells are put into the mortars, uncap the fuses, and pull out the loose ends of the match, and let them hang on the sides of the balloon. The use of the match is to receive the fire from the powder in the chamber of the mortar, in order to light the fuse. When the shell is put in the mortar, its fuse must be uppermost, and exactly in the centre. Some meal-powder is usually sprinkled upon it.

Fuses of wood are longer than those of paper, and not bored through, but left solid about $^{1}/_{2}$ an inch at bottom; so that, when used, this end is cut off. They are sawed, however, at a proper length, measuring the charge from the cup at top. On the subject of *Fuses*, see the last part of the work.

Fuses for bombs, Morel remarks, are formed of five thicknesses of paper, or of pasteboard, made of that thickness; and the former, on which the fuse case is rolled, should be one-third diameter. The composition is put in with a spoon, and each charge is driven with twenty strokes of a moderate size mallet.

Composition for the fuses of bombs or balloons.

1.	Meal powder,		12 oz.
	Sulphur,		4 —
	Charcoal,		6 —
2.	Saltpetre,	1 lb.	10 —
	Sulphur,		8 —
	Meal powder,	1 lb.	6 —
3.	Saltpetre,	1 lb.	8 —
	Sulphur,		8 —
	Meal powder,	1 lb.	8 —

Sec. V. Of the Mosaic and Common Tourbillon.

The *tourbillon de feu* of the French, or whirlwind of fire, is the same as the *soleil montant*; because it ascends in full illumination, [359] and scatters fire in various directions. The tourbillon, therefore, receives its name from the effect it produces. It raises itself very high, and forms a whirl of fire and terminates in two coronal figures, or crowns, which descend in what are called parasols. It does not, however, produce crowns, except when it is charged with Chinese fire.

There are two kinds of tourbillons, which we will describe, namely, the mosaic and the common. The mosaic produces a tail of some length, and after whirling round, finishes with a report. This effect is owing to its particular structure and formation, as it differs from the common tourbillon. In preparing the cases for mosaic tourbillons, pasteboard, formed of five sheets of paper, is used. They are made seven inches in length upon a roller or former $^{5}/_{12}$ths of an inch in diameter. Their thickness, when rolled, is $^{1}/_{8}$th of an inch. They are choaked in the usual manner, and the excess of the string is cut off. After having put a quarter of an inch of earth into a case, and beating it with ten or twelve blows with the mallet, we mark the height of the earth on the outside of the case. We then load it to the height of $^{7}/_{12}$ths with the composition heretofore mentioned. Another quarter of a spoonful of earth is then put in. We then choak, and bind the case in this place. Two fingers of grain powder are now added; we again choak, and bind it above this. We put in the same composition, after the last operation, to the height of $^{7}/_{12}$ths of an inch. The choaking, it is to be observed, must not wholly close the case; so that the composition can set fire to the powder.

We now introduce a spoonful of earth, and choak and bind as before. It is then finished by charging it with $^{7}/_{12}$ths of an inch of composition. The remainder of the case is cut, and the composition primed.

Cases, thus prepared, are afterwards treated in the following manner: We pierce three holes in the sides of each, one a little above the last choak, another through, or into the case, to penetrate the last charge, and the third through the first charge. These holes have a communication with each other by means of quickmatch; so that, when the match is set on fire, the two extremes are inflamed at the same time, and being opposed to each other, give a rotary motion to the tourbillon, which, when the powder inflames, terminates by an explosion. The holes ought to be covered with three or four turns of pasted paper. It is then ready to be put into the *pots de chasse*. When completed, the tourbillon should not exceed $^{10}/_{12}$ths of an inch in diameter. [360]

The *pots de chasse* (mortars somewhat similar to those described) should be made of pasteboard, prepared with eight thicknesses of paper, and moulded upon a roller of $^{11}/_{12}$ths of an inch in diameter. They are mounted in the same manner as *fire-pots*, and are also primed in the same way.

Into each pot there is put four drachms of broken grain powder, and a slip of pasteboard, pierced with five or six holes, which is introduced by means of a stick. A little meal-powder is then put into the pot, and afterwards the tourbillon, the primed end of which must be above the *chasse*. It is then closed with paper, made into a wad or ball, and the pot is secured with a slip of pasteboard, pasted on it.

Composition of Mosaic Tourbillons.

1.	Meal powder,	16	oz.
	Charcoal,	3 or 4	dr.
2.	Meal powder,	16	parts.
	Charcoal,	3⅓	——

Common tourbillons differ in many respects from the mosaic, although their motion is the same. There are two methods of forming them as well as their appendages, both of which we purpose to describe. The first is the following: Having filled some cases within about 1$^{1}/_{2}$ diameters, drive in a handful of clay, prepared, of course, in the manner described in the first part of the work; then pinch their ends close, and drive them down with a mallet. Then find the centre of gravity of each case; where you nail and tie a stick, which should be $^{1}/_{2}$ an inch broad at the middle, and run a little narrower to the ends; these sticks must have their ends turned upwards, so that the cases may turn horizontally on their centres. At the opposite sides of the cases, at each end, bore a hole close to the clay, with a gimblet the size of the neck of a common case of the same nature. From these holes, draw a line round the case, and, at the under part of the case, bore a hole with the same gimblet, within half a diameter of each line, towards the centre; then from one hole to the other, draw a right line. This line divide into three equal parts, and bore a hole near to each of the ends; then from these holes to the other two, lead a quick-match, over which paste a thin paper.

It is to be observed, that there is a stick about the length of the case, which goes across it, and is securely fastened by a cord, [361] that the whole lies flat upon a table before it is fired, and hence, it is sometimes named the *table tourbillon*; and, that the leader should be carried from one side hole to the other, the holes being made at the opposite sides, as before mentioned. When tourbillons are fired, they must lay upon a smooth table, with their sticks downwards, the leader being set on fire in the middle with a port fire. They should spin two, three, or four seconds round the table, before they rise, which is about the time the composition will be burning from the side holes to those at the bottom.

Reports, or detonating cases, may be fixed to tourbillons, if so required. In this case, we make a small hole in the centre of the case at top, and in the middle of the report make another. Then place them together, and tie on the report, and, with a single paper, secure it from fire. By this method, small cases of stars, rains, &c. may be fixed on tourbillons, being careful, nevertheless, that they are not overloaded.

One-eighth will be a sufficient thickness for the sticks, and their length equal to that of the cases.

The other mode of forming common tourbillons, is the following: They are made with cases of an inch, which are choaked and bound in the usual manner. In filling, we make two wads of paper of the same size, and put one of them into the case, and ram it with fifteen or twenty blows. We then mark upon the case, the height of this wad, which is afterwards driven with the composition, given at the end of this section. To each charge, thirty strokes of a moderate size mallet, will be required; and each charge should not be more in height in the case than nine exterior diameters. We mark, on the outside of the case, the height of this charge, and put in a wad of the same kind and size as the former one. We drive this in the same manner as the first, and then choak and bind the case. After cutting off the excess of the ligature, with which we bound the case, we again introduce the rammer, and give it eighteen blows with the mallet, in order to flatten the choak.

We afterwards divide the case parallel to each end, into four equal parts, and mark the height of the wads. That of the middle, which becomes in fact the bottom of the case, (from the manner it is fixed for ascension), we divide into five equal parts from one point to the other, and pierce a hole in each division to the composition. We then make, on a level with the wads, upon the lateral lines, two similar holes; one upon one side, and the other on the other side, at the opposite ends. These holes are so made as that [362] the case has four holes on one line, and one upon each of the other two. Each hole is then primed with a piece of quick match, and priming paste. One of these matches must pass over all the other holes; so that the fire may be communicated from one to the other at the same time. The matches are then covered with a band of pasted paper. To hold the tourbillon in a horizontal position, we procure a hoop of the same thickness and diameter as the length of the case; and on the plate, we make a groove for the match of communication, which is supported between the four holes with an iron wire. If the case whirls round with a uniform motion, it is well balanced.

The four holes beneath, serve to raise it in the air, and the two lateral apertures give it a revolving motion.

When tourbillons are to be set off, they must be balanced either by a cross stick, as in the first instance, or some other contrivance. The effect is the same as before described.

Composition for Tourbillons, or Table Fusées, of different Calibers.

Substances.	Calibers of ⅓d of an inch.	Of ⅔ds of an inch with Chinese fire.	Of ⅚ths of an inch with Chinese fire.
Saltpetre,	8 oz.	16 oz.	16 oz.
Sulphur,	4 oz.	8 oz.	8 oz.
Meal-powder,	16 oz.	18 oz.	16 oz.
Charcoal,	1 oz.		
Pulverized cast iron,		10 oz.	12 oz.

Another composition for a caliber of half an inch, of common fire.

Saltpetre,	16	oz.
Sulphur,	4	—
Meal-powder,	7	—
Charcoal,	4	—

The following formulæ are sometimes used;

For four-ounce tourbillons.

Meal-powder,	2 lbs.	4 oz.
Charcoal,	—	4½ —

For eight-ounce tourbillons. [363]

Meal powder,	2	lbs.
Charcoal,	4¾	oz.

For large tourbillons.

Meal-powder,	2	lbs.
Saltpetre,	1	do.
Sulphur,	8	oz.
Beat-iron,	8	oz.

As a general rule, we may remark, that the larger tourbillons are made, employing, if necessary, different coloured fires, the weaker must be the charge; and, on the contrary, the smaller, the stronger their charge.

Sec. VI. Of Mortars for throwing Aigrettes, and the manner of loading and firing them.

Pots of aigrette, when inflamed, exhibit the appearance of an aigrette, or cluster of rays, such as are produced by diamonds, when they are arranged in a particular way. The aigrette takes its name from a bird, whose feathers serve to make up an ornament for the head. It was given in diamonds, as a particular mark of distinction, by the Grand Signior, to Lord Nelson, after the battle of the Nile. There are aigrettes made of glass.

For the purpose of throwing aigrettes, the mortars are generally made of pasteboard, of the same thickness as balloon mortars, and two and a half diameters long in the inside from the top of the foot. The latter must be made of elm without a chamber, but flat at top, in the same proportion as those for balloon mortars. These mortars must be bound round with a cord as before mentioned. Sometimes eight or nine of these mortars, of about three or four inches in diameter, are bound altogether, so as to appear as one; but when they are prepared for this purpose, the bottom of the foot must be of the same diameter as the mortars, and only one-half a diameter high. Having bound the mortars together, fix them on a heavy solid block of wood. To load them, place over the inside bottom of each, a piece of paper, and spread on it one and a half ounces of meal and grain powder mixed; then tie the serpents up in parcels with quickmatch, and put them in with their mouths downwards. Care must be taken, that the parcels do not fit too tight in the mortars, and that all the serpents have been well primed, or wetted with the paste of meal powder and spirit of wine.

On the top of the serpents, in each mortar, lay some paper or tow; then carry a leader from one mortar to the other, and from all [364]
the outside mortars to that in the middle. These leaders are to be put between the cases and the sides of the mortar, down to the powder at bottom. In the centre of the middle mortar, fix a fire pump, or brilliant fountain, and sufficiently long to project out of the mouth of the mortar. Then secure the mortars, by pasting paper over their tops.

The *nest of serpents* (as mortars thus prepared are called) is fired by lighting the fire-pump, which, when consumed, will communicate to all the mortars at once by means of the leaders.

Single mortars are called *pots des aigrettes*. If the mortars, when loaded, are sent to any distance, or liable to be much moved, the firing powder should be secured from getting amongst the serpents, which would endanger the mortars, as well as injure their performance. To prevent this accident, the mortars are to be loaded in the following manner; First, put in the firing powder, and spread it equally; then cut a round piece of blue touch paper, equal to the exterior diameter of the mortar, and draw a circle on it equal to its interior diameter, and notch it as far as that circle: then paste that part, which is notched, and put it in the mortar close to the powder, and stick the pasted edge to the mortar. This will secure the powder at the bottom, so that it may be moved and carried without receiving any damage.

For mortars of six, eight, or ten inches diameter, the serpents should be made in one and two-ounce cases, six or seven inches long, and fired by a leader, brought out of the mouth of the mortar, and turned down the outside; its end being covered with paper, to prevent the sparks of the other works from setting it on fire. For a six-inch mortar, let the quantity of powder for firing be two ounces; for an eight-inch, two ounces and three-quarters; and for a ten-inch, three ounces and three-quarters. Care must be taken in these, as well as small mortars, not to put the serpents in tight, for fear of bursting the mortars. These mortars may be loaded with stars, crackers, &c.

Sec. VII. Of Making, Loading, and Firing Pots des Brins.

These are formed of pasteboard, and must be rolled pretty thick. They are usually made three or four inches in diameter, and four diameters long; and pinched at one end like common cases. A number of these are placed on a plank in the following manner: [365]
Having fixed on a plank two rows of wooden pegs, cut, in the bottom of the plank, a groove the whole length, under each row of pegs. Then through the centre of each peg, bore a hole down to the groove at bottom, and, on every peg, fix and glue a pot, whose mouth must fit tight on the peg. Through all the holes, run a quick-match, one end of which must go into the pot, and the other into the groove, having a match laid in the groove from end to end, and covered with paper; so that, when lighted at one end, it may discharge the whole almost at the same instant. In all the pots, put about one ounce of meal and grained powder. Then in some put stars, and in others rains, snakes, serpents, crackers, &c. When they are all loaded, paste paper over their mouths. Two or three hundred of these pots being fired together, make a brilliant appearance by affording so great a variety of fires.

Sec. VIII. Remarks respecting Fire Pots.

Fire pots, called also *pots of ordnance*, in pyrotechny, are nothing more than vessels used in, as well as for, the exhibition of artificial fire-works. They are generally formed of thick pasteboard, made by pasting together six or eight sheets of paper, of two inches interior diameter, three inches exterior diameter, and fifteen inches long. They are always placed upon a solid block or plank, and preserved in a firm position. There is a stopper or plug made of wood, which goes one inch into each case or pot, and is there glued and secured by nails. This plug is turned with a screw, which enters the plank, and preserves the pot in a steady position. The plank, on which the pots rest, is usually three inches wide, an inch and a half thick, and sufficiently long to receive twelve pots, placed at the distance of half an inch apart. Before the pots are fixed on, a hole is made through each plug in its centre, to receive a quick match, which passes through to the composition. A groove is also made in the plank, in its length, one-third of an inch square; and in such a manner, that the holes, which communicate to the interior of the pots through the plugs, must come in the middle of the groove. When the quick-match is put through the plugs, to communicate with the interior of the pots, we must leave about two inches on the outside. At each hole, also, we put some priming paste, and then permit it to dry.

If it is required to discharge them all at once, this may be done by making a communication through the groove, by means of leaders in the manner before mentioned; and covering the leaders with four or five bands of paper, and setting the match or leader on fire. If, on the contrary, they are to go off in succession, the groove is filled with bran, which is pressed with the fingers, and is then covered with paper. The match of communication with the pots must, however, be preserved. The bran causes the fire to communicate gradually from one to the other. [366]

Pots are charged in the following manner: We first make the *sacs of powder*. For this purpose, we have as many squares of paper as there are pots, which are made into cylinders on the same roller that formed the pots. Into each is put about an ounce of the charge-composition, hereafter mentioned, with two pieces of match, sufficiently long to come out an inch. They are then closed and tied, and the excess is cut off. One of these sacs is put into each pot, having previously pierced it with several small holes, and sprinkled it with meal powder. After this, the garnishing, furniture, or decoration is added, always observing to put the primed part downwards. A wad of paper is then put over the whole, and the mouth is closed with pasted paper.

Composition of the charge for fire pots.

Gunpowder, in broken grains,	16	oz.
Charcoal,	3	—

Fire pots are discharged in the way we have described, which is considered the best and most certain; or they may be fired by communicating the fire with a match, passing out of the mouth, and hanging over the sides. Another mode may be used, similar to that for discharging balloons or bombs, but on a scale proportionate thereto. Pots may be discharged in any direction; hence two pieces, or sets, may be fired adversely, like rockets from the regulated rocket case. Their effect depends, as we have frequently observed, on their furniture or decorations.

The strength of fire pots is also to be considered. If they are made three inches in interior diameter, it is prudent to cover them with stout canvass, or small cord, wrapped round and covered with a coat of glue, in the same manner as for tourbillons.

Fire pots are calculated to throw serpents, &c. in the air. Mortars, it will be recollected, are designed to discharge shells or balloons, which are thrown to a considerable height, by the powder placed in the conical cavity; whereas fire pots, although their contents are thrown out by blowing powder, are differently made at the bottom, and merely designed to project serpents, stars, [367] &c. to a small distance. Being primed, they take fire as they pass out of the pot. The charge is sometimes gunpowder, and, as above, composed of gunpowder and charcoal, to lessen the power of the former. The principle, on which they are discharged, is the same. Fire pots are called pots of ordnance, because they are used for discharging sundry substances, by means of gunpowder.

CHAPTER IX.

OF PARTICULAR COMPOSITIONS.

Sec. I. Of Fire-Jets, or Fire-Spouts.

Fire-jets are produced by certain compositions, which are employed in cases, and are charged solid. They are formed and used according to taste or fancy.

The jets are made with a caliber of from one-third of an inch, to one inch and one-third, in interior diameter. They are seven or eight exterior diameters in length, and are charged in the usual manner with the composition, hereafter mentioned, driving each charge with twenty blows with a small mallet. The first charge must be the common fire composition.

Some of the compositions in the following table have already been mentioned, when treating of certain fire-works; but we deem it of importance to notice them in a connected manner, so that we may have the formulæ in one view.

Fire-jets, it must be remembered, are calculated as well for turning, as for fixed pieces.

Common Fire for calibers of one-third of an inch.

Meal-powder,	16 oz.
Charcoal,	3 —

Common Fire for calibers of five-twelfths to half an inch.

Meal-powder,	16 oz.
Charcoal,	3 — 4 dr.

Common fire for calibers above half an inch.

Meal-powder,	16 oz.
Charcoal,	4 —

Brilliant fire for ordinary calibers. [368]

Meal-powder,	16 oz.
Filings of iron,	4 —

Another, more beautiful.

Meal powder,	16 oz.
Filings of steel,	4 —

Another, more brilliant, for any caliber.

Meal powder,	18 oz.
Saltpetre,	2 —
Filings of steel,	5 —

Another, very brilliant, for two-thirds of an inch caliber, and above.

Meal powder,	16 oz.
Saltpetre,	1 —
Sulphur,	1 —
Filings of steel,	7 —

Brilliant fire, more clear, for any caliber.

Meal powder,	16 oz.
Filings of needles, or of needle steel,	3 —

Silver-rain for calibers above two-thirds of an inch.

Meal powder,	16 oz.
Saltpetre,	1 —
Sulphur,	1 —
Filings of steel, fine,	4 — 4 dr.

Grand jessamine, for any caliber.

Meal powder,	16 oz.
Saltpetre	1 —
Sulphur,	1 —
Filings of spring steel,	6 —

Small jessamine, idem.

Meal powder,	16 oz.
Saltpetre,	1 —
Sulphur,	1 —
Filings of steel, the best,	5 —

White fire, idem.

Meal powder,	16 oz.
Saltpetre,	8 —
Sulphur,	2 —

White fire, idem.

Meal powder,	16 oz.
Sulphur,	3 —

Blue fire, for parasols and cascades. [369]

Meal powder,	8 oz.
Saltpetre,	4 —
Sulphur,	6 —
Zinc,	6 —

Another blue fire, for calibers of half an inch, and upwards.

Saltpetre,	8 oz.
Meal powder,	4 —
Sulphur,	4 —
Zinc,	17 —

The cases charged with this composition are only employed for furnishing the centre of some pieces, the movement of which depends on other cases; for these, having no force, would not move the piece.

Blue Fire, for any caliber.

Meal powder,	16 oz.
Saltpetre,	2 —

Sulphur,	8 —

Radiant Fire, idem.

Meal powder,	16 oz.
Filings of pins, (*d'epingles*)	3 —

Green Fire, idem.

Meal powder,	16 oz.	
Filings of copper,	3 —	2 dr.

Aurora Fire, idem.

Meal powder,	16 oz.
Gold powder, (*Poudre d'or*)	3 —

For Italian roses or fixed stars.

Meal powder,	2 oz.
Saltpetre,	4 —
Sulphur,	1 —

Another, for the same.

Meal-powder,	12 oz.
Saltpetre,	16 —
Sulphur,	10 —
Antimony,	1 —

The jets of fire, which are various according to the composition employed, may appear under several forms, sometimes in one [370] and sometimes in another; and hence they may put on an asteroid appearance, or that of a fountain, or water spout, or the form of rain. The effect, however, is very elegant; and, in conjunction with other species of fire-works, cannot fail to change the general appearance, by modifying the whole, or rendering it more various.

These compositions are generally used in the manner before mentioned, in cases of different sizes; but they may, under particular circumstances, be employed otherwise. In fact, the *forms* which may be given to the flame of gunpowder, or the substances which compose it, either by increasing or retarding its combustion, or changing the appearance of the flame, and giving it the form of jets, stars, rain, &c. are so numerous, that it furnishes alone an important branch of Pyrotechny. These effects will be detailed, when we treat of the formation of compound works.

Sec. II. Of Priming and Whitening Cases, and Remarks concerning Spunk and Touch Paper.

When the cases are charged, we pierce them with a small awl, or make a hole with a gimblet in the end, if it should be stopped with clay, or *probe* them with a drill, as fire-workers call it, in the hole which had been filled, in which we put some more of the composition. This precaution is considered necessary, in order that the earth should not cover internally the hole of the piercer. A piece of match is then introduced, which extends on the outside, and is secured there with a plug of wood.

Brown paper, made either of linen or cotton, but not of woollen cloth, when soaked in a concentrated solution of saltpetre, is, we have said, rendered very combustible, and will convey fire for small works with much facility. It is this paper, called touch, or more properly match, paper, that is used for capping, &c. Paper of this kind may sometimes be used, as for *crackers*, *serpents*, &c. Cotton quick-match, however, is used more generally; and, for large works, when employed as a leader, it is usually confined in a proper tube, the better to preserve it entire, and to keep it dry. Spunk, made by soaking certain species of fungus in a solution of saltpetre, takes fire very readily by the least spark, and, therefore, is used for collecting and preserving the fire from flint and steel. This spunk, when well made, and particularly of the proper kind of fungus, may be cut into slips, and employed [371] advantageously in some fire-works. In all cases, however, the object is the same, to communicate fire with facility to the powder, or composition; and this object may be attained by all those methods, which we have had occasion frequently to mention. See *Pyrotechnical Sponge.*

To *whiten* cases is an operation, which merely consists in covering them with paper, and is performed in the following manner. We procure as many half-sheets of paper as we have cases, and put them on a table one upon another. We paste the paper, and roll each case in one of these sheets, which is named the covering. The paper is cut in such a manner, that it passes over the end of each case an inch and a half. There is no particular use in this covering, the case being made sufficiently strong without it; it makes, however, a handsome finish. In the Chinese fire-works, their cases are covered with different coloured papers, and frequently ornamented with gilding. In all that I have seen, with some of which I have made experiments, the match of communication is nothing more than twisted match-paper. The figures are made of paper, painted, and ornamented in the same way; some resembling animals, &c. but on a small scale. The leaders are fixed in the usual manner, and the works are fired in the same way. Tourbillons, serpents, and crackers are chiefly the kind which we have seen.

Sec. III. Of Chinese Fire.

The composition for producing this fire, as it is peculiar, and therefore distinct from all others, was invented by the Chinese, and hence bears that name. The substance, which produces the peculiar effect is cast or crude iron. See *Iron.*

It was the brilliant light, produced when iron filings are thrown into the fire, that gave rise to an improvement in the fire of rockets, rendering it much more beautiful, than when gunpowder, or the substances of which it is composed, are alone employed. The Chinese have long been in possession of a method of rendering fire brilliant, and variegated in its colours. Cast-iron, reduced to a powder more or less fine, is called iron-sand, because it answers to the name given to it by the Chinese. They use old iron pots, which they pulverize, till the grains are not larger than radish seed; and these they separate into sizes or numbers, for particular purposes.

It should be observed, that rockets, into the composition of which, iron-filings and iron-sand enter, cannot be long preserved, [372] owing to the change which the iron undergoes in consequence of moisture.

It may be proper to introduce here two tables, which exhibit the proportions of the different ingredients for rockets of this kind from 12 to 33 lbs.

For Red Chinese Fire.

Calibers.	Saltpetre.	Sulphur.	Charcoal.	Pulv. cast iron. No. 1.	
lbs.	lbs.	oz.	oz.	oz.	dr.
12 to 15	1	3	4	7	0
18 — 21	1	3	5	7	8
24 — 36	1	4	6	8	0

For White Chinese Fire.

Calibers.	Saltpetre.	Meal-powder.	Charcoal.		Pulv. cast iron. No. 2.	
lbs.	lbs.	oz.	oz.	dr.	oz.	dr.
12 to 15	1	12	7	8	11	0
18 — 21	1	11	8	0	11	8
24 — 36	1	11	8	8	12	0

These substances are incorporated together in the manner already stated.

The cast-iron, we observed, is reduced to a fine powder, or rather *sand*, as the French fire-workers call it, and is then passed through a sieve. For the method of reducing it to powder, consult the article on *Iron*. That the brilliancy of the fire is owing to the iron in its crude state, without being converted into soft or malleable iron, a process which carries off a large quantity of carbon, oxygen, &c. and increases its specific gravity,—is very evident from the effect produced. Wrought iron will occasion scintillations, somewhat of the same appearance, and steel, also, in greater abundance; and hence both are employed in sundry compositions. But the particular character, beauty, and brilliancy of Chinese fire must be attributed, first to the iron, and secondly to its peculiar state of combination with carbon and oxygen; for, we have said, that malleable iron, (which is deprived in a great measure of these substances in the operation required for its preparation), produces an effect far inferior to cast iron. This difference then can only arise from the quality, character, composition, or properties of these two kinds of iron. Steel, on the contrary, having a more vivid effect than wrought iron, owes its properties to another state of combination of the iron and carbon. [373]

Hence we account for the difference in the appearance of the flame, and consequently the effect, in the different mixtures of crude iron, malleable iron, and steel. We have already remarked, in treating of iron, and in explaining the action of bodies in the process of combustion, in the section on the theory of fire-works, that the effect of some substances was to produce sparks, stars, &c. In the present instance, namely, the effect of the composition of the Chinese fire by combustion, the iron is first ignited by the powerful heat created by the combustion of the powder, nitre, charcoal, and sulphur, and in this state, is thrown out with violence, and is itself consumed. The combustion of iron is nothing more than its oxidizement, during which a brilliant fire, which characterizes so pre-eminently the Chinese fire, is produced. This oxidizement of the metal, in proportion as it is more rapid, necessarily gives rise to the phenomena of combustion, which, in this, and the generality of instances, presupposes a combination with oxygen. The fire is, therefore, more brilliant, as the combustion is more rapid, and the metal may be oxidized in a greater or lesser degree, but not to a maximum. From the effect taking place in the air, as it does not ensue, or is not seen, in the case, it follows, that the iron receives for the support of its combustion the oxygen of the air.

We have said, that the substances which compose cast-iron, are iron, carbon, and oxygen, in a peculiar state of combination. We may also conclude, therefore, that, as carbon, by combustion in oxygen gas, or in atmospheric air, which contains about twenty-two per cent. produces carbonic acid, the carbon of the iron during its combustion, is changed, by its union with oxygen, into this acid. The products, then, are oxide of iron, and carbonic acid, the latter existing in the gaseous state. With respect to the other products of combustion, arising from the gunpowder, saltpetre, sulphur, and charcoal, we have before noticed them. See *Gunpowder*, and the *General Theory of Fire-Works.*

We may remark, at the same time, that the intense heat, produced as well by the combustion of the gunpowder, as by the combustion of charcoal and sulphur, in contact with the nitrate of potassa, brings the metal almost to a state of fusion; which, being thrown off in this state, and considerably divided, is acted upon by the oxygen on all sides, causing the effect to be uniform and general.

The quantity of iron, it will be seen, which enters into the different compositions, is various, according to the particular purpose [374] to which the composition is applied. The *effect*, therefore, may be varied, as we employ more or less of the iron; and the state of ignition may be affected, as the proportions of nitre and charcoal are increased or diminished. These facts are obvious, by referring to the respective formulæ, and the application of the several compositions. It is, besides, no less true, that as much care is required in selecting pure materials for every kind of artificial fire, as scrupulous accuracy, in following the proportions prescribed. Nor is this all; the mixture must be intimately made, or the effect would be doubtful and uncertain.

There is a particular manner required for preparing the composition of Chinese fire. All the substances must be passed three times through a sieve, except the sulphur, and the pulverized cast-iron. These are mixed by themselves, and afterwards with the other substances. They are turned over frequently with the hand. Cases are filled with it in the same manner as other compositions.

In order to make the mixture of the sulphur with the iron more intimate, the latter may be wetted occasionally with spirit of wine, which should contain no water, as water would tend to rust the metal, and injure its effect. The sulphur would then mix with more freedom, and the composition be more perfect. The spirit of wine, acting merely as a vehicle, afterwards evaporates; and, as it has no chemical action on either the sulphur or the metal, they would remain unaltered.

By proceeding in this manner; namely, first mixing the other substances by themselves, and afterwards the iron and sulphur, and then the whole, we form an intimate mixture throughout.

The composition, prepared in this way, makes the fire more brilliant; giving it a greater lustre than by proceeding in a contrary manner.

We are informed, that spontaneous combustion has frequently taken place, by suffering the iron and alcohol, or spirit of wine, to remain in contact; and, although this appears an anomaly, which we will not attempt to explain, yet that it is a fact, and that it has occurred at Paris, we have the authority of M. Morel.

When the cast-iron is reduced to powder, or *sand*, it is divided into several sorts, which are proportioned to the caliber employed. These sorts are marked or numbered, and are used as follows: For calibers under $^{7}/_{12}$ths of an inch in diameter, No. 1; [375] for those of $^{7}/_{12}$ths to $^{10}/_{12}$ths, No. 2; and for larger calibers, No. 3.

In charging with the composition, care must be taken to turn it over repeatedly at every other ladle full; because the iron, which is the heaviest substance, is liable to fall to the bottom. If the composition be not equally diffused, the fire would be irregular, and go out by puffs. This is a defect which ought to be guarded against.

The mixture of the composition for *Jessamine* is made in the same manner.

Chinese fire, in cases, is commonly employed in garnishing, as it is called, the circumference of a decoration, or in forming pyramids, galleries, yew trees, cascades, palm trees, or in short, in producing a variety of figures, according to taste and fancy. They are often employed in turning pieces for their last fire, in consequence of the brilliancy of their effect.

We are told, that nothing is more elegant than Chinese fire; and that it forms, in its descent, flowers of variegated beauty, which, being scattered about by the rotation of the piece, resemble the *hydraulic girandole* in the rays of the sun.

Chinese fire, however, has little force; and hence, when it is used, it is accompanied with other fire, as two or more jets of white fire. The latter is only employed, when the Chinese fire is to be exhibited on wheels, or turning pieces. When it is on fixed pieces, there is no occasion for them. Cases of Chinese fire, when burnt alone, will not turn a wheel.

As the effect of Chinese fire on wheels depends greatly on the motion of the wheel, its velocity should therefore be accelerated; which, although the duration of its effect would be shorter and more brilliant, may be produced by employing several cases of white fire, and communicating their fire one to the other by leaders in the usual manner.

There is no doubt, that the accelerated motion of the wheel causes the composition to burn more rapidly, in the same way as a bellows excites the heat of a blast-furnace; and, therefore, the increased brilliancy of the fire may be attributed to the greater rapidity of the combustion, which necessarily produces, in a shorter time, the oxidizement of the iron, and, at the same time, the combustion of the other substances.

With respect to the comparative force of compositions, or that power by which cases, as rockets, &c. ascend, or which gives motion to vertical and horizontal wheels, we may observe generally, that these effects depend on the compositions employed; and that the *recoil*, in such instances, is proportionate to the impelling power; for the resistance with which the fire meets from the air, [376] in the immediate vicinity of the caliber of the case, causes a reaction, which produces the recoil, and consequently the motion of the wheel. That this effect depends, in a greater or less degree, on the composition we use, and the manner the case is charged, is very evident. (See *General Theory of Fire-Works.* Part 1.)

Composition of Chinese Fire for calibers under ten-twelfths of an inch.

Meal-powder,	16 oz.
Saltpetre,	16 —
Sulphur,	4 —
Charcoal,	4 —
Pulverized cast iron,	14 —

Another of the same.

Meal-powder,	16 oz.
Sulphur,	3 —
Charcoal,	3 —
Pulverized cast iron,	7 —

Another, for Palm-trees and Cascades.

Saltpetre,	12 oz.
Meal-powder,	16 —
Sulphur,	8 —

Charcoal,	4 —
Pulverized cast iron,	10 —

Another, white, for calibers of eight and ten-twelfths of an inch.

Saltpetre,	16 oz.
Sulphur,	8 —
Meal-powder,	16 —
Pulverized cast iron,	12 —

Another, for Gerbes of ten, and eleven-twelfths and one inch caliber.

Saltpetre,	1 oz.	
Sulphur,	1 —	
Meal-powder,	8 —	
Charcoal,	1 —	[377]
Pulverized cast iron,	8 —	

It may be proper to remark, that the above formulæ are all approved; as they have been used in France, and are given on the authority of Morel and Bigot. We are informed, indeed, that these proportions produce the most perfect fire, which surpasses the fire of the Chinese. From the many experiments made in France, instituted with the view of determining the best proportions, and leading, in fact, to the improvement of the original composition, we do not hesitate to give them the preference over all others.

In the composition of wheel-cases, Chinese fire is sometimes used, and then only for decoration; but in nearly all the compositions employed, in wheel-works, for standing or fixed cases, sun-cases, &c. steel-dust forms a constituent part. The proportion it bears to other substances is various: *viz.* to meal-powder, as one to five, one to ten, &c. In one of the formulæ for brilliant fire, the proportion is still greater, and in another less; but by mixing seven and a half ounces of steel-dust with meal-powder, saltpetre, and sulphur in the proportion of eleven pounds, one pound two ounces, and four ounces respectively, a composition is formed, calculated to produce a brilliant fire. But as this subject will be considered, when we treat of wheel-works, standing pieces, &c. and the different compositions appertaining thereto, we would only observe, that Chinese fire should always be preferred, where the object is decidedly appearance, with brilliancy and splendour.

Sec. IV. Of Bengal Lights.

We have had occasion to mention heretofore, that metallic as well as the crude, or sulphuret of, antimony, entered as a component part into some compositions, in order to vary the effect and appearance of the flame. That this is the effect, in the composition, which constitutes the Bengal lights, is a fact well known, and to which its particular character is owing.

Bengal lights, in consequence of the whiteness and brilliancy of their flame, are considered as highly important in fire-works. The composition was a long time kept secret, and artists were at a loss to compound it, for those who possessed the secret, it appears, would not divulge it. Simple as it is, it was not known, until many experiments were made, which proved its identity with [378] the original Bengal composition; and, since that time, it has been confirmed by the original formula. Morel assures us, that he purchased the secret.

Composition of Bengal Lights.

Saltpetre,	3 lbs.
Sulphur,	13 oz. 4 dr.
Antimony,	7 oz. 4 dr.

They are pulverized and mixed in the usual manner, and passed three times through a hair sieve. Any quantity may be made at one time. The composition is usually put in earthen vessels, without decorations. They may be of different sizes, and, in fact, as broad as they are high, sufficiently large, however, to contain the composition. A small quantity of dry meal-powder is scattered over its surface, and a sheet of paper is tied on to secure it. It is primed with port fire match.

The *effect* of this mixture is evidently that of the combustion of the sulphuret of antimony, as well as of the sulphur. The nitre furnishes the oxygen to both, and, as the combustion is rapid, the metal is oxidized, probably forming the antimonic acid, as the antimony may be oxidized to the maximum. There is another view, in which this combustion may be considered. According to the present theory of the formation of sulphuric acid, by the combustion of sulphur, and nitre in leaden chambers, it appears, that sulphurous acid is first produced, and nitric oxide gas, (deutoxide of azote), is also formed; and that the latter by uniting with the oxygen of the air is changed into nitrous acid, which is *then* acted upon by the sulphurous acid, and is decomposed. Part of its oxygen combines with the sulphurous acid, changing it into the sulphuric, and deutoxide of azote is reproduced. In all probability, then, in the combustion of the composition of Bengal lights, the nitric oxide itself may affect the combustion of the antimony, which, as it would be enveloped in nitrous acid vapour, arising from the union of nitrous gas and oxygen, may present, in a measure, one of those cases of combustion, in which nitric oxide acts as a supporter, affording on that account a particular phenomenon. Reasoning *a posteriori*, this may be affected again by the formation of sulphuric acid; for a part of the sulphurous acid may be changed into sulphuric, not by its immediate union with the oxygen of the nitre, according to the old theory, but by the decomposition of the vapour of nitrous acid. This conclusion, however, is sufficient, that the nitre is decomposed, and during [379] its decomposition, the sulphur and antimony are brought into action; that a large quantity of caloric and light is evolved, whether from the oxygen gas of the atmosphere, or the substances themselves we will not stop to inquire; and, that, in the act of combustion, the sulphur and antimony are acidified, forming new products.

It will be seen, by examining the formulæ for the composition of the white and blue-lances, that they both contain antimony, but in different proportions: thus, in the white lance, the proportion of antimony is as one to eight of sulphur, as one to sixteen of saltpetre, and as one to four of meal-powder; and in the blue-lance, as it is composed only of saltpetre and antimony, the proportion of the latter to the former is as eight to sixteen. In the composition of Italian roses, or fixed stars, the proportion of antimony is still smaller, and is as one to ten of sulphur, one to sixteen of saltpetre, and one to twelve of meal-powder. Now, by comparing these proportions with those which constitute the Bengal light composition, they will be found to differ from those compositions, into which the same substances enter; for, in the Bengal lights, the proportion of the antimony to the sulphur is as five to nine, and to the saltpetre, as five to thirty-two, or thereabout.

The inference we draw, therefore, is, that the white lance composition differs from the blue, in containing meal-powder and sulphur, and the latter from the former, in containing no sulphur, but eight times as much antimony; that the white-lance composition varies from the Bengal light, by containing one-half less of saltpetre, one-fifth less of antimony, and one-ninth less of sulphur; and that the Bengal composition differs from the blue lance composition, in having double the quantity of saltpetre, nine parts of sulphur, (the blue-light having none,) and nearly one-third less of antimony. If we attend to these proportions of the antimony, with the other ingredients, in the respective preparations, we will find, that the difference, in the proportions of the antimony, produces, with the presence or absence of the meal-powder and sulphur, and the difference also in the quantity of the latter, the phenomena or effects which characterise them. It is thus, therefore, with this, as with other preparations; only vary the proportions, and institute new equivalents, as it were, in any particular preparation, and adopt some and reject other substances, and the effects are varied agreeably thereto; and, if improvements are to be made in any composition, they can only be effected by experiment, and the investigation of the effects of new proportions, a comparison of which, with the effect of any particular [380] composition, prepared according to a given formula, can alone determine the relative value of any new formula.

Sec. V. Of Roman Candles.

Roman candles are formed on a roller seven-twelfths of an inch in diameter, and are generally fifteen inches in length. They are choaked at one end, and tied in the usual manner. According to the nature of the charge, which we shall mention, their effect is to throw out brilliant stars, to the height of one hundred and more feet, and when arranged with marrons, they finish with a report.

After the cases are formed, and ready to be filled, the operation is performed with expedition, by tying a number of them together, and charging them in that manner. The cases are charged with the rocket composition, heretofore described, in the following way: A ladleful of composition is put in, and rammed, using seven or eight blows with the mallet; a small spoonful of powder is then added, and afterwards a moulded star. This star should fit the caliber of the case. More of the composition is then added, then meal-powder, and afterwards a star, and these are repeated in the same order, till the case is completely charged. Care must be taken in observing this order, otherwise the effect would be destroyed. In striking with the mallet, attention must also be paid, that the blows are not too violent, or the star might be destroyed. When the cases, or candles, are charged, we untie them, and roll some coarse paper round each end of them, at the extremity, and round the choak.

We may remark, that in the charging of Roman candles, as their effect depends greatly on the appearance of the stars, which issue out in succession, too much care cannot be used in preserving the star composition entire. To do this, much art is required in putting in, and ramming, the rocket composition, so as not to injure or break it. The quantity of gunpowder to each star must be small, otherwise it might burst the case. Roman candles may be fired singly or several at a time, according to the effect required. To fire one in a chandelier, for instance, it is only necessary to prime it with priming paste; but, if we wish to form batteries in an artificial fire-work, in order to produce a variety, or to mount them on fixed or moveable pieces, we may, if necessary, terminate their effect with marrons, which may be effected by uniting them in such a way as to make the fire of the one, at a given time, [381]
communicate to the other. This communication is usually made through the choak, by attaching a match, which is carried to the mouth of the marron; so that, when the candle has burnt out, the last portion of the fire may pass to the marron, the effect of which is instantaneous. If necessary, priming paste may be used to facilitate the communication of the fire. The marron may be fixed directly under the bottom of the candle, by making the whole solid by a paper cylinder, which fits over the ends of both.

The mosaic candles, as well as mosaic simples, are formed in cases of the same thickness as sky-rockets, from which they differ in the introduction of stars along with the composition. We may remark, also, that they are rolled without pasting; and although Morel recommends choaking the cases, yet a writer of more recent date, M. Bigot, whose practical knowledge must be great, recommends *plugging* them on the stick or roller. This is done by merely turning the end down about half an inch, and then beating it. Before the composition is added, he advises, also, the introduction of two or three fingers' thickness of clay, which is rammed very solid. This answers for a base, and supersedes the necessity of choaking. If, as we before remarked, it is necessary to communicate fire from this end to a marron or any other case, the clay must be bored to the composition, and quickmatch inserted; or, instead of this, the case itself, above the clay, may be perforated, and a communication in this way made.

Besides the ordinary Roman candles, intended expressly for exhibition, there is another preparation, which goes under the name of the incendiary Roman candle, used for the purposes of war. This preparation is composed of three parts of sulphur, four parts of saltpetre, one part of antimony, and half a part of meal-powder; but this, together with the incendiary stars, we purpose to consider when we treat of *Military Fire-works*.

Sec. VI. Of Mosaic Simples.

Mosaic simples are in reality nothing more than a variety of the Roman candle, being formed in the same manner, and of the same composition, except that the moulded stars are different, and produce another effect. The mosaic simples produce merely a tail, or spout of fire; whereas the Roman candle throws out a brilliant star. They may be used with marrons in the same manner as the Roman candle. The length of the case is fifteen inches, and seven-twelfths of an inch in diameter. Mosaic simples are very [382]
appropriate to terminate a piece. A number of cases may be used by placing them in such a manner, that their fires may cross each other, an effect more striking than the ordinary mode of exhibition. This may be accomplished by arranging them, two and two, to a horizontal stick, observing that their mouths are up, and that they cross each other. They are lashed to the stick, and leaders are carried from the mouth of one to the mouth of another. This communication is so managed, that two pieces discharge at the same time. They may be employed in a variety of ways, according to fancy.

Sometimes pyramids forty or fifty feet high are furnished on each side, with cases of mosaic simples, with a star at the summit, and white and coloured lances differently dispersed.

The curtain of fire, produced by so many cases, the height to which it rises, the appearance of the star with the variegated and diversified effect of the coloured lances, all contribute to the splendour of this arrangement.

Composition of the Mosaic Moulded Stars.

Saltpetre,	4	oz.
Sulphur,	4	dr.
Meal-powder,	16	oz.
Charcoal,	3	—

Or in proportional parts: saltpetre, four parts; sulphur, half a part; meal-powder, sixteen parts; and charcoal, three parts.

These substances, being finely pulverized, and intimately mixed in the usual manner, are combined with gum-water, &c. as directed for preparing *stars*, and cut into lozenges, which are then rolled in priming powder, and dried in the shade.

Sec. VII. Of Mosaic Tourbillons.

We may merely remark, as we have mentioned tourbillons heretofore, that the cases for the mosaic tourbillons, by which name they are designated, are seven inches in length, five-twelfths of an inch in interior diameter, and nine-twelfths in exterior diameter; and that the composition with which they are charged, is composed of sixteen parts of meal-powder, and three and a half parts of pulverized charcoal. See *Tourbillon.*

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Sec. VIII. Of Hydrogen Gas in Fire-Works.

M. Diller, some years since, exhibited at the pantheon of Paris, artificial fire produced by the combustion of hydrogen gas. From the short account we have of this exhibition in the *Dictionnaire de l'Industrie*, vol. iii, p. 39, it seems, that he employed three different airs, or gases, and produced three different flames: viz. white, blue, and green, which were made by the mixture of the three gases; and that he represented very perfectly, suns, stars, triangles, the cross of Malta, and sundry figures of animals in motion.

We may remark, that, if hydrogen gas be pure, the flame is of a yellowish-white; but this, however, is seldom the case, as the gas is always more or less impure, and, according to the substances it may hold in solution, so is the flame tinged. It is most usually reddish, because the gas holds in solution a little charcoal. In Cartwright's fire, ether is always mixed with the whole, or a *part* of the gas, which is brought to the state of vapour by the application of a gentle heat, or even by immersing the bladder of gas, which contains the liquid ether, in hot water.

When combined with arsenic, in the form of arsenuretted hydrogen gas, hydrogen burns with a blue flame; combined with phosphorus it takes fire spontaneously, producing a white flame with a beautiful corona, caused by the formation of water; and when combined with sulphur, forming sulphuretted hydrogen or hepatic gas, it burns with a bluish-red flame, and a quantity of sulphur is deposited. Various mixtures of hydrogen with other gases, in due proportions, will produce different coloured flames; so that, by paying attention to this circumstance, the same variety of appearances may be produced, as in Diller's exhibition.

Bladders, (or sacks made of oiled silk, which are preferable), when filled with gas, and connected with tubes, revolving jets, &c. bent in different directions, and formed into various figures, and pierced with holes of different sizes, will, when pressure is applied, allow the gas to pass through the different tubes, jets, &c. which, when inflamed, will represent the sun and stars. If to this be added, triangular tubes, tubes in the form of the cross of Malta, or any other figure, they being pierced in their sides with a great number of holes not larger than the point of a pin; it is obvious, that fixed pieces may be represented, as well as revolving ones. In this manner, Diller must have made his exhibition.

Hydrogen gas is usually made, by pouring on zinc, or iron filings, in a gas bottle, sulphuric acid diluted with six times its weight [384]
of water. The latter is decomposed; its oxygen unites with the metal, and while the oxide is taken up by the acid, the hydrogen passes off in the form of gas. The gas may be received directly in the bladder or bag.

The *inflammable air pistol* is nothing more than a hollow metallic cylinder, or an instrument in the shape of two cones joined base to base, and furnished with a touch-hole, and handle. This pistol is filled with a mixture of hydrogen and oxygen gases, or in lieu of the latter, atmospheric air; a plug or stopper is put in the caliber, and, when the touch-hole is brought in contact with a lighted taper, an explosion will take place, and the plug be sent out with much force. The same effect may be shown by passing the electric spark over the touch-hole, and hence, on an insulated stool, a person, charged with electricity, may set it off by the finger or nose. This pistol is usually called the Voltaic pistol, from Volta, who is said to have invented it.

M. Biot (*Traité de Physique Experimentale*, &c. tome ii, p. 435) describes the Voltaic pistol as a metallic vessel of a spheroid shape, furnished with an aperture and pipe, and with a conductor for the electric fluid, which passes through the middle of the vessel. This conductor is insulated, as it goes through a glass tube, and extends to within an eighth of an inch of the middle; and directly opposite to this conductor is a metallic wire, having, like the first conductor, a small metallic ball on its end. This conductor is placed a short distance from the first; so that, when the electric fluid is conducted, it passes from one ball to the other within the pistol, and hence inflames the hydrogen gas. With respect to the form of the pistol, it is of no moment whether it be cylindrical, conical, or globular, as the effect is the same, provided that it contain a sufficient quantity of gas, and the spark is conveyed through the gas, or the gas is inflamed by a vent. The air pistol described by Brande (*Brande's Chemistry*) is cylindrical, or rather in the shape of a cannon, and, where the touch-hole should be, there is an insulated conductor, which conveys the spark to the interior.

The *Voltaic lamp* is also a contrivance by which hydrogen gas is inflamed by the electric spark, which sets fire to a taper. The original lamp has been greatly improved, and simplified. The eudiometer of Volta is another contrivance by which hydrogen gas is burnt, in a strong tube, by the electric spark.

The detonation of inflammable air may be shown over a pneumatic tub, by filling metallic gas-holders with a mixture of hydrogen [385] gas and atmospheric air. When flame is brought in contact with the mouth of the gas-holder, an explosion will immediately take place. Soap-bubbles, blown with hydrogen gas, mixed with atmospheric air, will take fire, on presenting a lighted taper, and give a slight explosion. The ascension of these bubbles demonstrates, that the gas is lighter than atmospheric air, and it is its extreme levity that fits it for the purpose of filling balloons. It may be made twelve times specifically lighter than atmospheric air, by passing it over dry muriate of lime, in order to absorb the moisture it may contain, provided the gas be free from carbon, or carbonic acid.

Light carburetted hydrogen gas, or *fire-damp* of miners, is that gas, which so often formerly produced many dreadful accidents by its explosion. The invention, by Sir H. Davy, of the safety-lamp prevents this effect.

The principle of this most valuable discovery, appears to be altogether in the fine metallic gauze case, which surrounds the flame of the lamp; so that, as it is found by numerous and repeated experiments, the inflammable air, if present, cannot take fire outside of the gauze; in other words, the flame, in the interior of the case, is prevented from setting fire to the exterior atmosphere, however explosive it may be.

Hydrogen gas, in combination with carbon, is not only generated in mines and coal pits, (in the latter of which, it is the most abundant), but is frequently found on the surface of springs in the form of bubbles, usually however combined with sulphur; and in many places on the surface of the earth. It may be inflamed by a candle. The burning springs consist of this gas which is set on fire, and the combustion is kept up by a constant supply of gas from the same source. In the East, this gas is very often conveyed under ground through hollow reeds, and is constantly kept burning. At other times, it is conveyed to the sacred temples, as with the Zoroasters, and burnt as *holy fire*; and in some countries, it is so abundant, that the natives employ it as fuel for boiling their pots. It is found in different parts of the United States. A striking incident, showing its effects, occurred lately near Cincinnati, in the state of Ohio. It appears, that, in making an excavation, and boring for salt water, the workmen penetrated their augur into a cavity, which contained an abundance of gas, and which, with the water, made its way to the excavation. Not suspecting that the gas was inflammable, or being unacquainted with it, and apprehending no danger, they brought a lighted taper; and the gas, being [386] mixed with atmospheric air, exploded with a noise so considerable, that it was heard several miles in the neighbourhood. The men were much burnt, some of them dangerously.

The gas was afterwards inflamed by applying a taper, as it rose in bubbles from the surface of the water.

The philosophical candle is nothing more than hydrogen gas set on fire as it proceeds from a capillary tube, being formed in a bottle to which the tube is attached. The most brilliant flame, however, is produced by hydroguret of carbon, or olefiant gas.

Inflammable air is often generated in the stomachs of dead persons, for, on applying a lighted candle, the *vapour* has been known to take fire. Dr. Swediaur relates some instances of the same kind, but in living persons, in which the *urine* of the by standers was made use of. According to several authorities, combustion has been known to take place spontaneously in living persons. Lair, however, is of opinion, that, in these cases, it must have occurred by some slight external cause, such as the fire of a candle, taper, or pipe. There can be no question as to the developement of hydrogen gas.

Morse, (*Universal Geography*, article Persia, p. 588), after mentioning the Persian *guebres*, the disciples and successors of the ancient magi, and followers of Zoroaster, speaks of a combustible ground about ten miles distant from Baku, a city in the north of Persia, as the place for their devotion. This ground contains several old temples, and is remarkable for the quantity of inflammable air it emits, which is employed to produce the *sacred flame of universal fire*. If the ground be penetrated with a stick, there will issue out such a prodigious quantity of inflammable air, as, when lighted, will burn for a considerable time. This gas, we remarked, is employed there for lighting, cooking, and other purposes. The naphtha districts, in Persia, furnish this gas in abundance. See *Naphtha*.

A Sandusky (Ohio) paper states, that, about one mile and a quarter from Milan, is a place just in the edge of the water of Huron river, where there is a current of inflammable gas, that burns with a clear bright blaze, and is in sufficient quantity to light ten houses.

CHAPTER X. [387]

OF THE MANNER OF FIXING AND ARRANGING FIRE-WORKS IN GENERAL FOR EXHIBITION.

Having already treated of the formation of various kinds of fire-works, we come now to consider their arrangement in fixed and moveable pieces.

It is obvious, that the order of arrangement, the manner of disposing the work, or establishing pieces for exhibition, may be greatly varied according to taste and fancy. The great variety of fixed and moveable pieces, consisting of suns, moons, stars, &c. which may be either made permanent, or to revolve on, or round a centre; or of wheels, double, single, or treble, either moving round other wheels, or by themselves in a vertical or horizontal order, together with the arrangement of fire-pots, and coloured lights, the management of rockets, the formation of aerial stars, serpents, tourbillons, &c. and the imitation of cascades, girandoles, and water-falls, all depend on the taste and fancy of the artist.

It is our intention, therefore, in the different sections of this chapter, to give the order and arrangement of pieces, as adopted in Europe, and particularly in France; so that the manner of fixing any one piece, or combination of pieces, to produce effects of different kinds, may be seen at one view. The moveable pieces are generally made of wheel-work, the wheel always turning upon an axle, which may pass entirely through and be kept on by a nut or pin. They should revolve without much friction, and, for this reason, the spindle should be of metal, and oiled or greased. Black lead, along with tallow, will diminish the friction very considerably. As to the formation of the wheel, whether it be solid, or formed of spokes and a band or hoop, or made with several concentric bands, placed at given distances apart, &c. the observations on this head will be found under the respective articles, and, generally, on all other pieces for exhibition.

We purpose, in a subsequent chapter, to notice particularly the works, made in and on water, usually denominated *aquatic fire-works*; as their arrangement, in many respects, differs from those on the land. Aquatic works furnish a variety, both in character and effect, and, therefore, are calculated to produce, in conjunction with land works, a brilliant spectacle. Of this, we have an instance, mentioned in the introduction to this part of our work, in the splendid exhibition at the *Pont Neuf* in Paris. [388]

Sec. I. Of the Composition of Wheel-Cases, standing and fixed.

It may not be improper, before noticing the arrangement of wheel-cases, to give in this place the compositions, which are used for charging them, reserving, however, the notice of some preparations, when we treat of such works, in which they are particularly employed.

Wheel-cases from two ounces to four pounds.

1.	Meal-powder,	2	lbs.			
	Saltpetre,	4	oz.			
	Iron-filings,	7	—			
2.	Meal-powder,	2	lbs.			
	Saltpetre,	12	oz.			
	Sulphur,	4	—			
	Steel-dust,	3	—			
3.	Meal-powder,	4	lbs.			
	Saltpetre,	1	—			
	Sulphur,	8	oz.			
	Charcoal,	4½	—			
4.	Meal-powder,	8	oz.			
	Saltpetre,	4	—			
	Sawdust,	1½	—			
	Sea-coal,	¾	—			
5.	Meal powder,	1	lb.	4	oz.	
	Sulphur,	4	—	10	dr.	
	Saltpetre,	8	—			
	Glass-dust,	2½	—			
6.	Meal-powder,	12	oz.			
	Charcoal,	1	—			
	Sawdust,	½	—			
7.	Saltpetre,	1	lb.	9	oz.	
	Sulphur,	4	—			
	Charcoal,	4½	—			
8.	Meal-powder,	2	lbs.			[389]
	Saltpetre,	1	—			
	Sulphur,	½	—			
	Sea-coal,	2	oz.			
9.	Saltpetre,	2	lbs.			
	Sulphur,	1	—			
	Meal-powder,	4	—			
	Glass-dust,	4	oz.			
10.	Meal-powder,	1	lb.			
	Saltpetre,	2	oz.			
	Steel-dust,	3½	—			
11.	Meal-powder,	2	lbs.			
	Steel-dust	2½	oz.			
	Beat iron,	2½	—			
12.	Saltpetre,	2	lbs.	13	oz.	
	Sulphur			8	—	
	Charcoal,			4	—	

Slow fire for wheels.

1.	Saltpetre,	4	oz.		
	Sulphur,	2	—		
	Meal-powder,	1½	—		
2.	Saltpetre,	4	oz.		
	Sulphur,	1	—		
	Antimony,	1	—	6	dr.
3.	Saltpetre	4½	oz.		
	Sulphur,	1	—		
	Meal-powder,	1½	—		

Dead fire for wheels.

1.	Saltpetre,	1¼	oz.

	Sulphur,	¼	—
	Lapis calaminaris, (prepared calamine,)	¼	—
	Antimony,	2	dr.

Standing, or fixed cases.

1.	Meal-powder,	4	lbs.			
	Saltpetre,	2	lbs.			[390]
	Sulphur and charcoal, (together,)	1	—			
2.	Meal-powder,	2	lbs.			
	Saltpetre,	1	—			
	Steel-dust,	8	oz.			
3.	Meal-powder,	1	lb.	4	oz.	
	Charcoal,	4	oz.			
4.	Meal-powder,	1	lb.			
	Steel-dust,	4	oz.			
5.	Meal-powder,	2½	lbs.			
	Sulphur,	4	oz.			
	Seacoal,	6	—			
6.	Meal-powder,	3	lbs.			
	Charcoal,	5	oz.			
	Sawdust,	1½	—			

Sun cases.

1.	Meal-powder,	8½	lbs.		
	Saltpetre,	1	—	2	oz.
	Steel-dust,	2	—	10	—
	Sulphur,			4	—
2.	Meal-powder,	3	lbs.		
	Saltpetre,	6	oz.		
	Steel-dust,	7½	—		

Crowns or globes.

1.	Saltpetre,	6	oz.
	Sulphur,	2	lbs.
	Antimony,	4	oz.
	Camphor,	2	—

This view of the compositions used in fixed and turning pieces, exhibits the various compounds which *have been* employed, and, therefore, may be relied upon. Notwithstanding they are considered the standard formulæ; yet we must observe, that in some, particularly in the turning sun, with variations, changes are required, in order to produce a variety in the effect. This is [391] accomplished, by making, in the first place, a particular composition, and mixing a given quantity of it with meal-powder, which forms the second change. Of this second composition, combined in a given proportion, with meal-powder, we form a third change; and, in like manner, we employ the third along with more powder, to form a fourth, and the fourth to form a fifth. The particular manner of making these changes will be described in a future section.

Sec. II. Of Single, Vertical, Horizontal, Spiral, and other wheels.

Of the different kinds of *vertical wheels*, we may mention, that some have their fells of a circular form, others, in the form of a hexagon, octagon, or of a figure of a greater number of sides, according to the length of the cases designed for the wheels. The spokes being fixed in the nave, nail slips of tin, with their edges turned up, so as to form grooves for the cases to lie in, from the end of one spoke to another. Then tie the cases in the grooves head to tail, in the same manner as those on the horizontal water-wheel; so that the cases successively taking fire from one to another, will keep the wheel in an equal rotation. Two of these wheels are very often fired together, one on each side of a building, and both lighted at the same time, and all the cases filled alike to make them keep time together. This may be accomplished in the following manner. In all the cases of both wheels, except the first, and on each wheel, drive two or three ladles full of slow fire, in any part of the cases, but be careful to ram the same quantity in each case; and in the end of one of the cases on each wheel, one ladle full of dead-fire composition, which must be very lightly driven. Many charges of fire may be made by the same method.

The hole in the nave of the wheel may be lined with brass, and made to turn on a smooth iron spindle. On the end of this spindle, let there be a nut to screw off and on. When we have placed the wheel on the spindle, screw on the nut, which will keep the wheel from flying off. Let the mouth of the first case be a little raised.

Vertical wheels are made from ten inches, to three feet in diameter, and the size of the cases must vary accordingly. Four-ounce cases will be sufficient for wheels of fourteen or sixteen inches in diameter, which is the proportion generally used. The best wood for wheels of all kinds, is the light and dry beech.

Horizontal wheels are more perfect, when their fells are made circular. In the middle of the top of the nave must be a pintle, [392] turned out of the same piece as the nave, two inches long, and equal in diameter to the bore of one of the cases of the wheel. There must be a hole bored up the centre of the nave, within half an inch of the top of the pintle. Nail at the end of each spoke, of which there should be six or eight, a piece of wood with a groove, cut in it to receive the case. Fix these pieces in such a manner, that half the cases may incline upwards, and half downwards, and that, when they are tied on, their heads and tails, or extremities, may come very near together. From the tail of one case to the mouth of the other, carry a leader, which is necessary to be secured with pasted paper. Besides these pipes, a little meal-powder must be placed in the inside of the pasted paper, to blow off the pipe, that there may be no obstruction to the fire from the cases. By means of these pipes, the cases will successively take fire, burning one upwards, and the other downwards. On the pintle, fix a case of the same sort as those on the wheel. This case must be fired by a leader from the mouth of the last case on the wheel, which case must play downwards. Instead of a common case in the middle, we may put a case of Chinese fire, sufficiently long to burn a given time, or as long as two or three cases on the wheel.

Horizontal wheels are often fired two at a time, and made to keep time, like vertical wheels, only they are prepared without any slow or dead-fire. Ten or twelve inches will be sufficient for the diameter of wheels with six spokes.

With respect to *spiral wheels*, we may remark, that they are only double horizontal wheels, made in the following manner: The nave must be thicker than that of the single sort; and, instead of the pintle at top, a hole is usually made for the case to be fixed in. There are two sets of spokes, one set put near the top of the nave, and the other, near the bottom. At the end of each spoke, cut a groove, in which the cases are to be tied, there being no fell. The spokes should not be more than three and a half inches long from the nave, so that the wheel may not be more than eight or nine inches in diameter. The cases are placed in such a manner, that those at top play down, and those at the bottom play up; but let the third or fourth case burn horizontally. The case in the middle may begin with any of the others. Six spokes will be sufficient for each set; so that the wheel may consist of twelve cases, besides that on the top; the cases six inches each.

Plural wheels are different from the former. They are made to turn horizontally, and consist of three sets of spokes, placed six at [393] top, six at bottom, and four in the middle, which must be a little shorter than the rest. Let the diameter of the wheel be ten inches. The cases must be tied on the ends of the spokes, in grooves, cut on purpose, or in pieces of wood, nailed on the ends of the spokes, with grooves cut in them as usual. In clothing these wheels, make the upper set of cases play obliquely downwards, the bottom set obliquely upwards, and the middle set, horizontally. In placing the leaders, we must so arrange them, as that the case may turn thus: namely, first up, then down, then horizontally, and so on with the rest. But another change may be made, by driving in the end of the eighth case two or three ladles full of slow fire, to burn till the wheel has stopt its course. Then let the other cases be fixed the contrary way, which will make the wheel run back again. For the case at top, we may put a small gerbe, and the cases on the spokes may be short, and filled with the strong brilliant charge.

For forming the *illuminated spiral wheel*, we must proceed thus: First have a circular horizontal wheel, made two feet in diameter, with a hole quite through the nave; then take three thin pieces of light board, three feet long each, and three-fourths of an inch broad. One end of each of these pieces, nail to the fell of the wheel, at an equal distance from one another; and the other end, nail to a block with a hole in its bottom, which must be perpendicular to that in the block of the wheel, but not so large. Plane a hoop down very thin and flat, and nail one end of it to the end of the wheel, and wind it round three sticks in a spiral line, from the wheel to the block at top. On the top of this block, fix a case of Chinese fire. On the wheel may be placed any number of cases, which must incline downwards, and burn two at a time. If the wheel should consist of ten cases, we may let the illuminations and Chinese fire begin with the second cases. The spindle for this wheel must be a little longer than the cone, and made very smooth at top, on which the upper block is to turn, and the whole weight of the wheel to rest.

For making the *double spiral wheel*, the block, or nave, must be as long as the height of the worms, or spiral lines; but must be very thin, and as light as possible. In this block fix several spokes, which must diminish in length from the wheel to the top, so as not to exceed the surface of a cone of the same height. To the ends of these spokes nail the worms, which must cross each other, several times. These worms clothe with the same illuminations as those on the single wheels, but the horizontal wheel may be [394]
clothed according to fancy. At the top of the worm, place a case of slow fire, or an amber light.

Balloon wheels turn horizontally. They are usually made two feet in diameter without any spokes, and very strong, with any number of sides. On the top of the wheel, range and fix in pots of three inches in diameter, and seven inches high each, as many as there are cases on the wheel. Near the bottom of each pot, make a small vent; and into each of these vents, carry a leader from the tail of each case. Some of the pots may be charged with stars and some with serpents, crackers, &c. As the wheels turn, the pots will be fired in succession, and throw into the air a great variety of fires.

Fruiloni wheels are made with a nave, nine inches long, and three inches in diameter. Near the bottom of this nave, fix eight spokes with a hole in the end of each, sufficiently large to receive a two or four-ounce case. Each of these spokes may be fourteen inches long from the block. Near the top of this block, fix three more of the same spokes, exactly over the others, but not so long by two inches. As this wheel is to run horizontally, all the cases in the spokes, must play obliquely upwards, and all those in the spokes at bottom, obliquely downwards. This being accomplished, have a small horizontal wheel, made with eight spokes, each five inches long from the block. On the top of this wheel, place a case of brilliant fire. All the cases on this wheel must play in an oblique direction downwards, and burn two at a time; and those on the large wheel, four at a time; i. e. two of those on the top set of spokes, and two of those in the bottom set of spokes.

The four first cases on the large wheel, and the two first on the small, must be fired at the same time, and the brilliant fire at the top, at the beginning of the last cases. The cases of the wheels may be filled with a gray charge. When these wheels are completed, we must have a strong iron spindle, four feet six inches long; and fixed perpendicularly on the top of a stand. On this, we put the large wheel, whose nave must have a hole quite through from the bottom to the top. This hole must be large enough to turn easy round the bottom of the spindle, at which place there must be a shoulder, to keep the wheel from touching the stand. At the top of the spindle, put the small wheel, and join it to a large one with a leader, in order that they may be fired both together.

Pin wheels, as they are called, are formed by rolling some paper into pipes of about fourteen inches in length. The paper should [395]
be thin, and rolled of three thicknesses. When they are thoroughly dried, procure a tin tube, twelve inches long, to fit easy into the pipes. At one end of this tube, fix a small conical cup, which cone is called a funnel; then bend one end of one of the pipes, and put the funnel in at the other, as far as it will reach, and fill the cup with composition. Draw out the funnel gently, shaking it up and down, and it will fill the pipe, as it comes out. Having filled some pipes, procure some small blocks, about one inch in diameter and half an inch thick. Round one of these blocks, wind and paste a pipe, and to the end of this pipe, join another, which must be done by twisting the end of one pipe to a point, and putting it into the end of the other with a little paste. In this manner, join four or five pipes, winding them one upon another, so as to form a spiral line. Having wound on the pipes, paste two strips of paper across them to hold them together. The pipes must also be pasted together.

The other method of making these wheels is described thus: wind on the pipes without paste, and stick them together with sealing wax at every half turn; so that, when they are fired, the end will fall loose, every time the fire passes the wax, by which means the circle of fire will be considerably increased.

The formers for these pipes are made from $1\frac{1}{2}$ to $\frac{4}{16}$ths of an inch in diameter. They may be fired on a large pin, and held in the hand with safety.

Composition for Pin-Wheels.

Meal-powder,	8	oz.
Saltpetre,	2	—
Sulphur,	1	—
Steel-filings, or the powder of cast-iron,	¼	—

The ingredients are to be well mixed, and dry. The mixture need not be very fine, or it will adhere to the funnel.

Sec. III. Of Revolving Suns.

From what has been said in the preceding section, it is obvious, that revolving or turning suns may be formed, or any piece put in motion, in the manner already described. The most common mode of forming a sun, is to attach to three naves, which proceed [396]
from a hub, that revolves on a spindle, from three to six cases, placing them in such a way, that they may be fired successively. The jets, or spouts, proceeding from the cases, constitute the *rays*, the sun being in the centre, which revolves with the cases on an axis. The arrangement of these cases should be such, as that the six (as that number is usually employed,) might form the perimeter.

The cases may be charged with one, or with different compositions, given in the following table. They are attached in such a way, that the head of the first is nearly in contact with the *ray* of the second, and that to the third, &c. When the first case is finishing, it must, therefore, communicate fire to the second, that to the third, and so on in succession. These cases must be attached firmly by wire; and leaders are used to communicate the fire, as in other works. The end must be enclosed in the neck of the first case, and the other end in that of the second, &c. They are secured in their respective positions, by tying them securely to the cases.

With respect to the composition employed, it may be varied according to pleasure. In most instances, however, the ordinary sun-composition is used; but, in other instances, this is varied according to circumstances. Morel has adopted the following composition for a sun of six cases, the cases being eight-twelfths of an inch in diameter. These cases are mounted on the arms of the sun in the same manner as before described.

Composition for a sun with variations, the cases of which are eight-twelfths of an inch in caliber.

No. 1, first change,		
Saltpetre,	16	oz.
Sulphur,	6	—
Meal-powder,	3	—
No. 2, second change,		
Composition No. 1,	2	oz.
Meal-powder,	2	—
No. 3, third change,		
Composition No. 2,	1	oz.
Meal-powder,	1	—
No. 4, fourth change, [397]		
Composition No. 3,	1	oz.
Meal-powder,	1	—
No. 5, fifth change,		
Composition No. 4,	1	oz.
Meal-powder,	1	—
No. 6, sixth change,		
Meal-powder alone, for two changes.		

It appears evident, that the changes thus produced are owing to the diminution of the quantity of saltpetre and sulphur, or, in other words, to the increase of the quantity of powder; and that the fourth change must contain but a small quantity of each, whilst the sixth or last change contains none, except that which is in the composition of the powder. The effect, therefore, must be proportionate; for, it must be apparent, that this diminution of nitre and sulphur, and the increase of powder, must render each charge more explosive, or, in other words, the combustion more instantaneous, and that this effect characterizes each of the changes in succession, is a result which necessarily follows.

The instructions given by Morel for employing these changes, in the charging of cases, are thus: We take the above composition for the third case of the sun. The first case is of common fire; the second of silver rain; the third of two charges of common fire, and afterwards a charge of No. 1, the second two charges of No. 2, the third three charges of No. 3, the fourth four charges of No. 4, the fifth four charges of No. 5, and two charges of No. 6. The fourth case is composed of brilliant fire; the fifth the same as the third, and the sixth of large or grand jessamine.

We may merely remark, that the sun must be supported very firmly, and that it ceases to revolve at the fourth, fifth, and sixth numbers.

Sec. IV. Of Fixed Suns.

Fixed suns are so called, because they remain stationary, and exhibit the appearance of a sun with innumerable rays. A fixed sun is formed by putting eight or more strips of board across each other, so that each arm may proceed from a common centre, in which a sun is painted on silk. To the extremities of these arms are attached, to each one in succession, a case of brilliant fire, [398] which, by means of bodies fixed in the usual manner, go off together. The two arms below, forming right angles with each other, are longer than the rest; so is also the upper and vertical arm. This, however, depends upon fancy. The cases are tied to these arms; and, after the leaders are fixed from the mouth of one case to that of the other, they terminate at the bottom and hang below the vertical arm. Fire is first communicated to the hanging match.

Fixed suns are usually employed as a decoration for other works. They are sometimes sixty feet in diameter, and variously decorated. They are commonly, however, ten feet. The fire extends a considerable distance, sometimes, it is said, to the distance of thirty feet; but this must depend on the size of the cases.

Sec. V. Of Fixed Suns with Transparent Faces.

Fixed suns may be made with transparent faces in the following manner: Two rows of cases must be fixed in radii from the face of the sun, the sun being in the centre; and these cases, being placed alternately one above the other, and preserving the same distance all round, present what is called a double glory, and make the rays strong and full. The frame or sun-wheel is made thus: Have a circular flat nave, made very strong, 12 inches in diameter, and fix six strong flat spokes, proceeding from the circle that contains the sun's face to the extremity of the wheel, and also two other hoops, placed between it and the sun. To these, and the external wheel, the cases are tied. When the cases are tied on, leaders are attached from the upper to the under cases. The front of these spokes supports a circular fell, five feet in diameter. Within this is another fell, smaller in diameter by the length of one of the sun cases; and within this also is a third fell, whose diameter must be less than the second by the length of one case and one third. The fells are divided into as many equal parts as we employ cases, which may be from twenty-four to forty-four. At each division, fix a flat iron staple. These staples must be made to fix the cases and hold them fast on the wheel. The staples must be so placed, that one row of cases may lie in the middle of the intervals of the other. There is a spindle in the centre of the block of the sun, to which a small hexagonal wheel is put. The cases of this wheel must be filled with the same charge as the cases of the sun. Two cases must burn at a time, and begin with them on the fells. The pipes of communication are to be carried from one to the [399] other, and from one side of the sun to the wheel in the middle, and from thence to the other side of the sun. They will hold the wheel steady, when the sun is fixing up.

A sun thus made is called a brilliant sun, as there appears nothing but sparks of brilliant fire, the wood-work being covered with fire from the wheel in the middle. A transparent face is usually made with pasteboard, by cutting out the eyes, nose, and mouth, for the sparks of the wheel to appear through. A face may be painted on oiled paper, or Persian silk, put over a hoop, and supported by three or four pieces of wire at six inches distance from the wheel in the centre. The silk may be painted according to fancy.

As to the size of cases for a sun of five feet in diameter, half-pound cases, filled ten inches with composition, is considered a good proportion.

Sec. VI. Of the Rose-Piece and Sun.

This exhibition may be made in such a manner as to produce a pleasing effect. A rose-piece may be used for a mutation, or change of a regulated piece, or fixed by itself. It makes the best appearance, when made large. If its exterior diameter be six feet, it will be a good size. Let the exterior fell be made of wood, and supported by four wooden spokes. All the other parts, on which the illuminations are fixed, must be made of strong iron-wire. On the exterior fell, place as many half pound cases of brilliant charge, as will be sufficient; but the more, the greater will be the effect, for the nearer the cases are placed, the stronger will be the rays of the sun. The illuminations should be placed within three inches of each other. They must all be fired together, and burn some time before the sun is lighted, which may be done by carrying a leader from the middle of one of the illuminations to the mouth of one of the sun cases.

Sec. VII. Of the Manner of changing a Horizontal to a Vertical Wheel, and representing a Sun in front.

In order to produce this change, the wheel for this purpose should be about three feet in diameter, and its fell circular, on which tie sixteen half-pound cases, filled with brilliant charge. Two of these cases must burn at a time. On each end of the nave is to be a tin barrel of the same construction as those on the regulated piece. We must then have a stand, made of any height, about three or [400] four inches square, and saw off from the top a piece two feet long. This piece is then to be joined again, at the place where it was cut, with a hinge on one side, so that it may lift up and down in the front of the stand. Then fix on the top of the bottom part of the stand, on each side, a bracket, which must project, at right angles with the stand, one foot from the front, for the short piece to rest on. These brackets are to be placed a little above the joint of the post, so that, when the upper stand falls, it may lie between them at right angles with the bottom stand; which may be done by fixing a piece of wood one foot long between the brackets, and even with the top of the bottom stand. Then, as the brackets rise above the bottom stand, they will form a channel for the short post to lie in, and keep it steady without straining the hinge. On the side of the short post, opposite the hinge, nail a piece of wood of such a length, that, when the post is perpendicular, it may reach about one and a half feet down the long post; to which, being tied, it will hold the short stand upright. The stand being thus prepared, in the top of it, fix a spindle ten inches long. On this spindle put the wheel; then fix on a brilliant sun, with a *single glory*. The diameter of this sun must be six inches less than that of the wheel. When we fire this piece, attention must be paid to light the wheel first, and let it run horizontally till four cases are consumed. Then, from the end of the fourth case, carry a leader into the tin barrel that turns over the end of the stand. This leader must be met by another, brought through the top of the post, from a case filled with a strong port-fire charge, and tied to the bottom post, with its mouth facing the pack thread, which holds up the stand; so that, when this case is lighted it will burn the pack thread and let the wheel fall forward, by which means it will become vertical. Then from the last case of the wheel, carry a leader into the barrel, next the sun, which will begin as soon as the wheel is burnt out.

Sec. VIII. Of Caprices and Fire-Wands.

Caprices are so called from the particular motion they assume, and are regulated according to the order and manner of their firing.

A perpendicular shaft, or post, is first provided, in which are placed two sets of spokes at some distance from each other. At the [401] extremities of these spokes, joints are made, on which the cases are fixed. These cases communicate with each other by leaders. The first which takes fire, discharges upwards; the second, vertically; the third, horizontally; and the fourth, fifth, sixth, and seventh, go off at the same time; *viz.* the fourth, upwards; the fifth, vertically, a little inclined; the sixth, horizontally; and the seventh, vertically. The match of communication is fixed by a port-fire.

The arrangement of this piece, to produce the effect, depends on the construction of the wood work.

The great falling caprice differs from the foregoing in the following particular, that it separates itself in the midst of its fire into three parts. It is formed of three wheels, which appear as one; but at a certain time after the fire is communicated, they separate and occupy certain positions.

Mercury's Wand, as it is called, is formed by placing, across each other, two pieces of wood, and at the extremity of each four lances parallel to each other, and one obliquely. These lances of illumination must be connected by leaders. Circular bands are attached to the extremity of each leg, which terminates in the centre, and the wings or legs move in opposite directions. The double crescents, thus formed, produce, in turning, a variety of figures.

Sec. IX. Of Palm and other Trees.

The representation of trees is considered an elegant fire-work. Palm trees are shown by fixing an upright piece, which serves as a trunk, and attaching to it a number of pieces, resembling in effect the branches of a tree. The extremities or branches are decorated with gerbes, and sometimes with marrons, arranged in such a manner that they may go off together.

For Yew trees, cases of brilliant fire, jessamine, or Chinese are used. In making this representation, the upright piece is usually four feet in length, two inches in breadth, and one inch thick. At the top we fix, on the flat side, a hoop fourteen inches in diameter, and round its edge and front, place illuminations, and in its centre a five-pointed star. At a foot and a half from the edge of the hoop, two cases of brilliant fire are usually placed, one on each side. These cases should be one foot long each. Below these are usually fixed two more cases, at such a distance that their mouths may almost meet those at top. Two other cases are sometimes added, which ought to be parallel with the last. The cases are then clothed with leaders, so that they, with the illuminations and [402]
stars at top, may all take fire together.

Fire trees may be formed by placing cases at an angle of 45 degrees, inclining upwards from the trunk, and at certain distances from each other. The two last cases may incline downwards. Cases may also be placed on the trunk itself, so that the whole will resemble a body of fire. Fire trees are commonly made about six feet long and three inches in diameter. The cases are generally fixed to pegs. At the top of the tree, a four-inch mortar is fixed, which is loaded with stars, rains, or crackers. In the middle of this mortar, we may place a case filled with any sort of charge, which must be fired with the other cases. Brilliant fire is generally employed. The fire is communicated, as in other works, by means of leaders, which are fired at the bottom.

There is also another exhibition often made with the so called *illuminated yew-tree*. The middle piece or stem on which the branches are placed, is generally eight feet six inches high. The branches all incline downward, and shorten as they go up. The number of branches on each side is six, and their length is determined according to judgment. When the branches are fixed, place illuminating port-fires on the top of each, as many as are required. Behind the top of the stem, fasten a gerbe or fountain of Chinese fire, which must be fired at the beginning of the illuminations on the tree.

Fires are often made to intersect each other, which has a good effect. For this purpose a perpendicular post is provided, of any thickness, so that it is sufficiently strong to hold the cases. There are two pieces of wood which go across the post, two feet six inches apart and two feet in length. On the end of each of these pieces there is usually a five-pointed star. Six stars are mostly employed. Pegs are fixed to the post in such a way that two of them incline upwards and two downwards, both forming an angle of ninety degrees, or forty-five degrees with the post. To these pegs are fixed half pound cases of brilliant fire. All the cases and stars must be fired at once. It is obvious that by this arrangement of the cases, the fires must cross, and thus by intersecting each other afford a greater variety.

Sec. X. Of the Pyramid of Flower Pots.

This piece is formed by attaching to a post, ten or twelve feet high, and placed perpendicularly in the ground, four rails or [403]
pieces, two feet apart, which must diminish in length, so as to represent a pyramid. The bottom rail must be six feet long. On the bottom rail fix five paper mortars, each three and a half inches in diameter. Let one be opposite the post, and the other four equally distant on each side. Load these mortars with serpents, crackers, stars, &c. In the centre of each mortar fix a case of spur-fire. On the second rail fix four mortars so as to stand exactly in the middle of the intervals of those on the bottom rail. On the third rail, place three mortars, on the fourth, two; and on the top of the post, one. All the mortars must incline a little forwards, that they may easily discharge; and the spur-fire rammed exactly alike, that the mortars may all be fired at the same time. The pipes of communication being prepared, carry them from one spur-fire to the other.

Sec. XI. Of the Dodecaedron.

The piece, required in forming a twelve sided figure, is prepared in the following manner: A ball must be turned out of solid wood, fourteen inches in diameter, and its surface is to be divided into fourteen equal parts. In each division bore holes of a half inch in diameter, perpendicular to the centre, so that they may all meet in the middle. In the inside of each hole, let there be turned a female screw. To all the holes but one must be made a round spoke, five feet long, with four inches of the screw at one end to fit the holes. In the screw end of all the spokes, bore a hole five inches up, which must be bored slanting so as to come out at one side a little above the screw. From these holes cut a small groove along the spoke, within six inches of the other end, where another hole through to the other side of the spoke is made. To this end fix a spindle, on which put a small wheel of three or four sides, each side six or seven inches long; these sides must have grooves cut in them, large enough to receive a two or four-ounce case. When these wheels are clothed put them on the spindles, and at the end of each spindle attach a nut to keep the wheel from falling off.

The wheels being thus fixed, carry a pipe from the mouth of the first case on each wheel through the hole in the side of the spoke, and from thence along the groove and through the other hole, so as to hang out at the screw end about an inch. The spokes being all prepared in this manner, a post must be provided on which the piece is to be fired, having an iron screw in the top of it to [404]
fit one of the holes in the ball. On the screw attach the ball and then in the top hole of the ball put a little meal-powder, and some loose quick-match. After this, screw in all the spokes, and in one side of the ball bore a hole, in which put a leader and secure it at the end. By this leader the powder and match in the centre are fired, which will light the match at the end of the spokes all at once, and by which all the wheels will be lighted at the same time. There may be an addition to this piece by fixing a small globe on each wheel, or one on the top wheel only. Gray charge may be used for the wheel cases.

Sec. XII. Of Cascades of Fire.

Cascades of fire may be made of any size, and with cases from a half pound to a pound, or more. Half pound cases are usually the size employed. Cascades may be made either fixed, or turning. The former are an assemblage of pieces of wood, furnished with cases charged with Chinese fire, and placed one above the other. The distance may be more or less; sometimes from eight to fifteen feet. The latter, or turning cascades, are constructed about four feet in diameter. The wheel is made to turn on a pivot, and is put in motion by attaching to it, in the usual manner, cases of white fire. These play horizontally. The cases of Chinese fire, which play downwards, are fixed to the wheel, or to another wheel below this, or above it, according to fancy, and are placed with their mouths downwards. Sometimes in fact they play upwards, and for that purpose are made to incline outwards. In the centre, there is a case or two of brilliant fire.

It is obvious, that this arrangement not only gives a motion to the wheel, and to the cases of Chinese fire, but produces in effect a circular sheet, which falls like a cascade.

By having an upright piece, stuck in the ground, on which are fixed three or more horizontal wheels, or segments of a circle, made permanent, and at about three feet from each other, diminishing, however, as they go up, and also in their diameter, a frame will be formed capable of holding a great number of cases. The first segment may be four feet in diameter. The top pieces may be of any length, so as to hold the cases at a little distance from each other. All the cross pieces are to be fixed horizontally, and supported by brackets. The bottom cross piece, or segment, should be about one foot six inches broad in the middle; the second, one foot; the third, nine inches; and the top piece, four inches. The cases may be made of any length, but must be filled with a [405]
brilliant charge. Bits of wood ought to be nailed on the edges of the cross pieces, having a groove cut in each piece, and sufficiently large for a case to lie in. These bits of wood are fixed, so as to incline downwards, and that the fire from one tier of cases may play over the other. Leaders are carried from one to the other, as before mentioned. Let there be a pipe, hung from the mouth of one of these cases, covered at the end with a single paper, which is burnt to fire the cascade. Nine cases generally form the first tier; seven, the second, four, the third; and three, the last. These cases play downwards, except the three at top, one of which is vertical and the other two inclining at an angle of about forty-five degrees. The arrangement may be varied at pleasure. The only thing to be attended to is, to fix the cases in such a way, that the fire which proceeds from them may pass over the tier immediately underneath, that the effect may be general and uniform. Chinese fire may be used, as in the former instance.

Sec. XIII. Of Chinese Fountains, and Parasols.

The manner of constructing the wood work of a Chinese fountain is as follows: Procure a perpendicular piece of wood, seven feet long, and two and a half inches square. At sixteen inches from the top, fix on the front a cross piece, one inch thick, and two and a half inches broad; with the broad side up. Below this, fix three more pieces of the same width and thickness, at sixteen inches from each other. Let the bottom rail be five feet long, and the others of such a length as to allow the fire-pumps to stand in the middle of the intervals of each other. The pyramid being thus made, fix in the holes, made in the bottom rail, five fire-pumps, at equal distances: on the second rail, place four pumps; on the third, three; on the fourth, two; and on the top of the post, one. Place them all, however, to incline a little forward, so that when they throw out the stars, they may not strike against the cross rails. The fire-pumps are to be clothed with leaders, in order that they may all be fired together.

Cases for *Fire-pumps* are made in the same manner as those for tourbillons. See *Fire-pump*, and also *Fire-pots* of various kinds.

The effect of these cases depends entirely on the star-composition. Stars, previously moulded, are introduced into them along with meal-powder.

Parasols are also formed with Chinese fire. A horizontal wheel is provided, and its circumference is clothed with eight or ten [406] cases of that fire. These cases may be five-sixths of an inch in diameter, and, when inflamed, should throw their fire horizontally. The fire, in this instance, is made to resemble a *sheaf*; but the ordinary composition is generally used. The cases, however, should play horizontally. To make the wheel turn on its pivot, two cases of white fire are attached to it. The parasol, produced by the fire, is from twenty-five to thirty feet in diameter. It is formed in consequence of the fire coming in contact, and producing a concave sheet in its fall, resembling a parasol when extended.

Sec. XIV. Of Wings or Cross Fire.

Nearly similar to one of the pieces described, that of the representation of a tree, is the cross-fire, or *wings*, a name given to it, because it resembles the sails, or wings of a windmill.

In forming this piece, two sticks, eight feet in length, are provided, and through the centre of each, a square hole is made, to receive a piece of iron of the same size, through which is a hole to admit a pivot.

When these sticks are put together, there must be a sufficient distance between them to prevent their rubbing each other. Five cases, charged with the composition of brilliant fire, are fixed to each extremity, proceeding towards the centre, at a short distance apart, and making in all twenty cases. Four of these cases are placed at each end, nearly horizontally, resembling the rounds of a ladder, the sticks being nearly vertical; and the one nearest the centre is placed almost vertically, or rather obliquely. The cases, being connected with leaders, when fired, turn with the sticks in an *opposite* direction to each other.

When three wheels are each furnished with two rounds of white and coloured fire, and are so arranged, that the periphery of each should pass over in succession at the distance of ninety degrees of the perimeter, this piece is then called by the whimsical name of the *love-knot*.

Sec. XV. Of Galleries of Fire, and Batteries of Roman and Mosaic Candles.

Galleries of fire are formed by attaching, to long strips of wood, at convenient distances from each other, cases of Chinese fire, [407] which go off together. At the end of each case, is put a marron, which, when the case is burnt, ends with an explosion.

To form batteries with marrons, in connection with Roman candles, they are tied at two feet distance from each other, on long sticks, leaders being attached. These batteries, like the fire gallery, usually accompany other fire-works.

We may here remark, that *thunder* is imitated by marrons, which are fixed in the same way two feet apart. To produce the effect, and increase the report, it is necessary to use them of different sizes, from a quarter of an inch to three inches caliber. They should be preceded by flashes of *lightning*, which is imitated either with powdered rosin, or lycopodium, in the manner described in our chapter on *Theatrical Fire-Works*.

Sec. XVI. Of Girandoles, and their Modifications.

Girandoles, for the purpose here noticed, are nothing more than wheels which turn on a pivot. They are made of light wood, with a rim similar to that of a sieve, and are clothed with cases. Two cases are fired at a time, which burn in an opposite direction.

Girandoles may be made to imitate a parasol, by placing, horizontally, cases charged with the blue-fire composition, or with that of the Chinese fire. Cascades may be formed, by arranging them vertically, horizontally, and some at an angle of ten or fifteen degrees from the horizon. The *bunch of flowers* is represented by using, at the same time, cases of $^{10}/_{12}$ths, $^{11}/_{12}$ths, and one inch, charged with Chinese composition, as given in the table for calibers of that diameter. See *Chinese Fire.* Crackers are formed by attaching Roman candles and Mosaic simples, and the sheaf is shown by fixing in the centre some empty cases, on which are strung small rockets, which are fired by the last case.

There are different modes of varying the effect of the girandole. They may imitate the fire-rain, by employing cases charged with that composition, which is given in the chapter on *Theatrical Fire-Works.*

Sec. XVII. Of Cracking Caprices.

For this piece, a circular table is formed about twenty inches in diameter, and one inch and a quarter thick. There is a hole made in the centre, which is furnished with a pivot.

Twelve inches from the circumference, and at equal distances, eight holes are to be bored, to receive the same number of pots, [408] of two inches caliber; and, in the immediate vicinity of the centre hole, which receives the pivot, four more are made, for four other pots.

Eight arms, three inches long, project from the table at equal distances, on which is fastened a hoop one inch in width. The fire-pots are now put in the different apertures, which are made sometimes to screw in; and the frame, of which we have spoken, is furnished with cases of brilliant fire.

It is necessary that this piece should go off at three fires; but the order of firing may be varied according to circumstances.

Sec. XVIII. Of the Projected Regulated Piece of Nine Mutations.

A regulated piece, if well executed, is considered as curious in its effect as any other in pyrotechny. It consists of fixed and moveable pieces on one spindle, representing various figures, which take fire successively one upon another, without any assistance after lighting the first mutation.

I. Names of the mutations, with the colour of fire, and size of the case, belonging to each.

First Mutation.—This is a hexagon vertical wheel, illuminated in front with small port-fires, tied on the spokes. This wheel must be clothed with two-ounce cases, filled with black charge. The length of these cases is determined by the size of the wheel, but each must burn singly.

Second Mutation.—This is a fixed piece, called a golden glory, by reason of the cases being filled with spur fire. The cases must stand perpendicular to the block, on which they are fixed, so that, when burning, they may represent a *glory* of fire. This mutation is generally composed of five, or seven two-ounce cases.

Third Mutation.—This is moveable, and is only an octagon vertical wheel, clothed with four-ounce cases, filled with brilliant charge. Two of these cases must burn at a time. In this wheel, we may make changes of fire.

Fourth Mutation.—This is a fixed sun of brilliant fire, consisting of twelve four-ounce cases. The necks of these cases must be a little larger than those of four-ounce wheel cases. In this mutation, may be made a change of fire, by filling the cases half with brilliant charge, and half with gray.

Fifth Mutation.—This is a fixed piece called the *porcupine quills*. This piece consists of twelve spokes, standing perpendicular to [409] the block in which they are fixed. On each of these spokes, near the end, must be placed a four-ounce case of brilliant fire. All these cases must incline either to the right or left, so that they may all play one way.

Sixth Mutation.—This is a standing piece called the cross fire. This mutation consists of eight spokes fixed in a block. Near the end of each of the spokes, must be tied two four-ounce cases of white charge, one across the other; so that the fires from the cases on one spoke may intersect the fire from the cases on the other.

Seventh Mutation.—This is a fixed wheel with two circular fells, on which are placed sixteen eight-ounce cases of brilliant fire, in the form of a star. This piece is called a fixed star of *wild fire*.

Eighth Mutation.—This is a beautiful piece, called a brilliant star piece. It consists of six spokes, which are strengthened by two fells of a hexagon form, at some distance from each other. At the end of each spoke, in the front, is fixed a brilliant star of five points; and on each side of every star is placed a four-ounce case of black or gray charge. These cases must be placed with their mouths sidewise, so that their fires may cross each other.

Ninth Mutation.—This is a wheel piece. It is composed of six long spokes, with a hexagon vertical wheel at the end of each.

These wheels run on spindles in front of the spokes. All the wheels are lighted together. Two-ounce cases will be sufficient for these wheels, and may be filled with any coloured charge.

II. With respect to the proportion of these mutations, with the method of conveying the fire from one to the other, and the distance they stand from each other on the spindle, the following general remarks will be sufficient.

The *first mutation* must be a hexagon vertical wheel fourteen inches in diameter. On one side of the block, whose diameter is two and one-fourth inches, is fixed a tin barrel. This barrel must be a little less in diameter than the nave. Let the length of the barrel, and block be six inches. Having fixed the cases on the wheel, carry a leader, from the tail of the last case, into the tin barrel, through a hole, made on purpose, two inches from the block. At the end of this leader, let there be about one inch, or two, of loose match; but be careful to secure the hole, in which the pipe is put, to prevent any sparks falling in, which would light the [410] second mutation before its time, and confuse the whole.

The *second mutation* is thus made. Have a nave, turned two and a half inches in diameter, and three long; then let half an inch of that end, which faces the first wheel, be turned, so as to fit easy into the tin barrel of the first mutation, which must turn round it without touching. On the other end of the block, fix a tin barrel No. 2. This barrel must be six inches long, and only half an inch of it to fit on the block. Round the nave, fix five spokes, one inch and a half long each. The diameter of the spokes must be equal to a two-ounce former. On these spokes, put five seven-inch two-ounce cases of spur-fire, and carry leaders from the mouth of one to the other, that they may all light together. Then, from the mouth of one of these cases, carry a leader through a hole bored slantwise in the nave, from between the spokes to the front of the block, near the spindle hole. The end of this leader must project out of the hole into the barrel of the first mutation; so that, when the pipe, which comes from the end of the last case on the first wheel, flashes, it may take fire and light the second mutation. To communicate the fire to the third mutation, bore a hole near the bottom of one of the five cases to the composition; and from thence carry a leader into a hole, made in the middle of the barrel. This hole must be covered with pasted paper.

The *third mutation* may be either an octagon or hexagon wheel, twenty inches in diameter. Let the nave be three and a quarter inches in diameter, and three and a half in length. One and a half inches of the front of the nave must be made to fit in the barrel No. 2. On the other end of the block, fix a tin barrel No. 3. This barrel must be six and a half inches in length, one inch of which must fit over the block. The cases of this wheel must burn two at a time, and, from the mouths of the two first cases, carry a leader through holes in the nave, into the barrel of the second mutation, after the usual manner. But besides these leaders, let a pipe go across the wheel from one of the first cases to the other. Then, from the tail of one of the last cases, carry a pipe into a hole in the middle of the barrel No. 3: at the end of this pipe, let there be some loose quick match.

Fourth and Fifth Mutations.—Their naves are made of one piece, which, from the barrel of the fourth, to the commencement of the sixth, is fourteen inches. The block of the fourth is four inches in diameter, having ten or twelve short spokes, on which are fixed eleven inch eight-ounce cases. The front of this block must fit easy in the barrel of the third wheel. Clothe the cases, so that [411] they may all light together; and let a pipe be carried through a hole in the block into the barrel No. 3, in order to receive the fire from the leader, brought from the last case on the wheel. The nave of the fifth mutation must be four and a half inches in diameter, and furnished with ten or twelve spokes, eighteen inches in length each. These spokes must stand seven inches distant from the spokes of the fourth mutation, and, at the end of each spoke, tie a four-ounce case as No. 5. All these cases are to be lighted together, by a leader brought from the end of one of the cases on No. 4.

Sixth and Seventh Mutations.—The blocks of these two mutations are turned out of one piece of wood, whose length from the barrel of the fifth wheel, to the block of the eighth wheel, is fifteen inches. The block of the sixth wheel is five inches in diameter, having eight spokes, each two feet four inches long. At the end of each spoke, tie two four-ounce cases, as in No. 6. All these cases must be fired at the same time, by a pipe brought from the end of one of the cases on the fifth mutation. Let the distance between the spokes of the sixth, and those in the fifth mutation, be seven inches. The nave of the seventh mutation must be five and a half inches in diameter, and furnished with eight spokes. On the front of them, two circular fells, one of four feet eight inches in diameter, and the other, three feet eleven inches, are to be fixed. On these fells, tie sixteen eight-ounce cases, or pound cases, as in No. 7, and carry leaders from one to the other, so that they may be fired at the same time. This mutation must be fired by a leader, brought from the tail of one of the cases on the sixth mutation.

Eighth and Ninth Mutations.—The blocks of these may be turned out of one piece, whose length from the barrel of the seventh mutation to the block of the ninth, must be twelve inches. The block of the eighth, six inches in diameter, must contain six spokes, each three feet in length, and strengthened by an hexagon fell, within three or four inches of the ends of the spokes. Close to the end of each spoke, in the front, fix a five-pointed brilliant star, and seven inches below each star, attach two ten-inch eight-ounce cases, so that the upper ends of the cases may rest on the fells, and their ends on the spokes. Each of these cases must be placed parallel to the opposite fell.

Ninth Mutation.—The block of the ninth mutation is seven inches in diameter, and holds six spokes, six feet long each, with holes [412] and grooves for leaders, as those in the dodecaedron. At the end of each spoke in the front, fix a spindle for a hexagon vertical wheel, ten inches in diameter, as in No. 9. When these wheels are on, carry a leader from each into the block, so that they may all meet. Then lead a pipe from the end of one of the cases of the eighth mutation, through a hole bored in the block of the ninth, to meet the leaders from the vertical wheels, in order that they may be fired together.

Having thus given a brief description of this complicated work, the performance of which depends so much on the accuracy of its parts, we will now add a few remarks respecting the formation of spindles.

For the larger pieces, the spindles should be made very strong and exact. The instructions on this head are, that for a piece of nine mutations, let the spindle be, at the large end, one inch in diameter, and continue that thickness as far as the seventh mutation, and from thence to the fifth, let its diameter be three-quarters of an inch. The other proportions, then, are, from the fourth to the second, half an inch; and from the second to the end, three-eighths of an inch. At the small end must be a nut, to keep on the first wheel, and at the thick end, a large nut; so that the screw part of the spindle being put through a post, and a nut screwed on tight, the spindle will be held fast and steady. The wheels, however, ought to run easy and without sticking. The fixed pieces are made on different blocks, and the leaders must be joined, after they are fixed on the spindle. The best method of preventing the fixed mutations from moving on the spindle, is to bore a hole a little larger than the diameter of the spindle; and, at each end of the block, over the hole, fasten a piece of brass, with a square hole in it to fit the spindle.

Similar to this piece of nine mutations is the *Pièce Pyrique* of the French, which consists of a great variety of fixed and moving pieces, that are fired alternately, but in regular succession. This piece we purpose to describe in the following section.

Sec. XIX. Of the Pyric or Fire-Piece.

This, we have remarked, is a combination of pieces, calculated, like the one we have described, to produce a variety of fires, variously arranged and distributed.

The pyric piece commonly commences with a turning sun. This sun consists of three cases, fixed to three arms proceeding from [413] the centre. They are attached by means of a string, and have leaders which go from one to the other of the cases. See *Sun.* This sun communicates its fire to a fixed sun, formed of eight or nine strips of board, crossing each other, or as many spokes from a hub, to which are attached, lengthwise, as many cases, whose mouths are made to communicate fire by means of leaders; so that each case presents the appearance we have before described. Then follows a wheel consisting of two or more concentric circles, and round which are placed eight cases, with their mouths inclining a little upwards. These cases are generally charged with brilliant fire. They communicate with each other in the usual manner, and afterwards with a fixed star, placed on a stick, proceeding from the horizontal axis. This star is made of two cases, charged with Chinese fire, with their mouths upwards, and forming, with each other, an angle of forty-five degrees. This fire is then communicated to another wheel, and from that to one, on which, at certain distances, are fixed six smaller wheels, furnished with six cases each; so that the whole are put in motion at one time, the fire being communicated at the same period. The appearance of these smaller wheels, as the cases may be charged with the coloured fire-composition, is such as to exhibit the motion of a screw; which, however, depends on the structure of the wheel. The fire from this may then communicate to other wheels of the same kind, to cases of brilliant fire, to marrons and the like, differently arranged according to fancy. Cylinders of copper or tin, called *barrels* by some, are used in the arrangement, in the manner already described. In fact, the remarks we have before made on the regulated piece of nine mutations, the manner of forming as well as of executing it, will apply to the Pyric-piece.

Sec. XX. Of Sundry Illuminated Figures.

There are various illuminated pieces, some of which we purpose to notice in this section.

The illuminated pyramid, with Archimedean screws, a globe, and vertical sun, may be exhibited in the following manner: Let a pyramid be made twenty-one feet in height, and the height of the pedestal six feet, and breadth nine feet, having a space between the rails of six inches. They must be made as thin as possible, and in all put port-fires at intervals of four inches. The Archimedean screws are placed on the pedestal. They are nothing more than double spiral wheels, on which the cases are placed, but [414] horizontally instead of obliquely. The vertical sun, placed four feet below the top of the pyramid, may consist of twelve rays. The globe on the top may be made in proportion to the pyramid. The leaders must be prepared and arranged in such a manner, that all the illuminating port-fires, or lances, screws, globe, and sun may take fire together.

Transparent stars with illuminated rays are formed, by making a strong circular block or body for the star, two feet in diameter, and attaching to it illuminated rays. In the centre of the front of the body, fix a spindle, on which put a double triangular wheel, six inches in diameter, clothed with two-ounce cases of brilliant charge. The cases on this wheel must burn only one at a time.

Round the edge of the body, nail a hoop made of thin wood or tin, which must project in front six or seven inches. In this hoop, cut three or four holes to let out the smoke from the wheel. The star may be cut out of strong pasteboard or tin in the following manner: Cut a round piece of pasteboard, two feet in diameter, on which draw a star, and cut it out. Over the vacancy, paste Persian silk, and paint the letters yellow; and also four of the rays yellow, and four red. This transparent star is to be fixed to the wooden hoop by a screw, to take off and on. The illuminated rays are made of thin wood, with tin sockets, fixed on their sides, within four inches of each other. In these rockets, put the illuminating port-fires, or lances; and behind the point of each ray, attach a half pound case of gray, black, or Chinese fire. The illuminated rays are to be lighted at the same time as the triangular wheel, or after it is burnt out. This may be done by a tin barrel, in the manner described in the regulated piece. Into this barrel, carry a leader from the illuminated rays, through the back of the star, which must be met by another leader, brought from the tail of the last case on the wheel.

The regulated illuminated spiral piece, with a projected star wheel, also illuminated, is made by procuring a block, eight inches in diameter, and putting in six iron spokes, which serve for spindles for the spiral wheels. These wheels are made one and a half feet in diameter, and three feet in height. The spindles must be of sufficient length to keep the wheels four or five inches from one another. At the end of each spindle, put a screw nut. On these spindles, the wheels, that hang downwards, are to run. On the spindles, which stand upwards, must be a shoulder, for the blocks of the wheels to run on. The projected star wheel turns on the [415] same spindle on which the large block is fixed. This spindle must be long enough to admit the star-wheel to project a little before the spiral wheels. The exterior diameter of the star wheel is five feet five inches. On this wheel, three circles of iron wire are to be fixed, to which attach either port, or other illuminating fires. On the block, place a transparent star, or a large five-pointed brilliant star. The cases on this wheel may burn four at once. The cases on the spiral wheels must be placed parallel to their fells and burn two at a time.

In order to make a figure-piece, with five-pointed stars, illuminated, all that is necessary is to have a vertical wheel about one foot in diameter, and furnished with six four-ounce cases of different coloured charge, which must burn double. On the frame of the figure piece, fix five-pointed brilliant or blue stars, rammed four inches with composition. Let the space between each star be eight inches, and, at each point, fix a gerbe or case of Chinese fire. The gerbe, stars, and wheel are to be lighted at the same time.

The illuminated star wheel may be formed by procuring a fell about four feet in diameter, and placing, within this fell, three circles of iron wire, one smaller than the other, so that the diameter of the least may be about ten inches. Place the port, or other fires on these fells, with their mouths inclining outwards, and the port-fires on the points of the star, with their mouths projecting in front. The exterior fell must be clothed with four-ounce cases of gray charge. They must burn four at a time and be lighted at the same time with the illuminations.

The illuminated regulating piece as it is called, consists of flat wooden spokes, each five feet long, and at the end of each, a vertical wheel, ten inches diameter, and clothed with six four-ounce cases of brilliant fire. These cases burn one at a time. On two of the spokes of each wheel, two port-fires are attached, which must be lighted with the first case of the wheel. On each spoke, behind the wheels, place six cases of the same size with those on the wheels. These cases must be tied across the spokes with their mouths in one direction, and be made to take fire in succession.

The diameter of the large wheel must be two and a half feet, and its fell made of wood, which is to be fixed to the large spokes. Twenty-four cases of the same kind are fixed on this wheel, and burn four at a time. On the circles of iron-wire, already mentioned, illuminating port-fires are attached. The star-points on the large spokes may be made of thin ash-hoops. The diameter of these [416] points, close to the centre wheel, is usually eleven inches. On these, port-fires are placed, three and a half inches distant from each other.

The illuminated double cone-wheel is nothing more than a double cone, formed of a number of hoops, and supported by three or four pieces of wood, in the manner of the spiral wheels. The wheel to which the cones are attached, base to base, is two feet six inches in diameter, and the height of each cone is three feet six inches. Port-fires, or lances, are tied to each of the hoops, in a horizontal direction, with their mouths outwards. The cases are eight-ounce, and play horizontally, two at a time. The spindle for this piece must rise three feet above the point of the cone at top; so that its length will be ten feet four inches from the top of the post, in which it is fixed, allowing four inches for the thickness of the block of the wheel. The whole weight of the wheel and cones must be made to bear on a shoulder in the spindle, on which the block of the wheel is to turn. On the top of the spindle, fix a sun, composed of sixteen four-ounce cases of brilliant fire. These cases must be stuck into a block, six inches in diameter. In the front of this sun, put a circular vertical wheel, sixteen inches in diameter. On the front of this wheel, form a spiral with wire, to which attach illuminations in the usual manner. This wheel is to be fired, when the cones are burnt out, which may be done as before described. The sun must not be fired, until the vertical wheel is burnt out. Three vertical wheels illuminated, which turn on their own naves upon a horizontal table, is a piece readily formed. It consists in having a table, three feet in diameter fixed horizontally on the top of a post, with three wheels that turn round on it. There are three spokes, joined to a triangular flat piece of wood, in the middle of which, a hole is made to fit easily over a spindle placed in the centre of the table. There are three pieces of wood four or five inches long, and two inches square, fixed on the under sides of the spokes. In these pieces, holes are made lengthwise, to receive the thin parts of the blocks of the wheels, which, when in, are prevented from coming out by a small iron pin that runs through the end of each. The three vertical octagon wheels, each eighteen inches in diameter, have blocks sufficiently long, for three or four inches to rest on the table. Round these a number of sharp points of wire are driven, (which must not project out of the blocks more than $^1/_{16}$th of an inch), and the clothing is affixed in the usual manner. The use of the points is this, that, when the [417] blocks turn round, they will stick in the table and assist in giving a uniform motion to the wheel. On the front of the wheels, make four or five circles of strong wire, or flat hoops, and tie, on these circles, as many illuminations, as they will hold, at two inches from each other. Spiral lines may be made instead of circles. When illuminations are fixed in a spiral line, in the front of a wheel, they ought to be placed on the slant. The cases for these wheels may be filled with any coloured charge, but must burn only one at a time. A globe, or spiral wheel may be put on the spindle, so that its fire may play over the vertical wheels. The wheels must be lighted at the same time, and the illuminations, after two cases of each wheel are consumed.

The vertical scroll wheel is formed by taking a block of a moderate size, and fixing in it four flat spokes, and, on them, a flat circular fell of wood. Round the front of this fell, port-fires are placed; and on the front of the spokes a scroll is formed either with a hoop or strong iron-wire. On this scroll, tie cases of brilliant fire in proportion to the wheel, head to tail. When the first case near the fell is lighted, the fire is communicated in succession. The grand volute, with a projected wheel in front, is made in the following manner: Two hoops are formed of strong iron wire, one of six feet in diameter, and the other of four feet two inches. These hoops must be joined to scrolls, formed according to fancy, of the same kind of wire. On these, tie, with iron wire, as many illuminating port-fires, as they will carry, at two inches distance. Prepare then a circular wheel of four spokes, three feet six inches in diameter, and, on its fell, tie as many four-ounce cases, head to tail, as will complete the circle, only allowing a sufficient distance between the cases, that the fire may pass free. On each spoke, fix a four-ounce case, about three inches from the fell of the wheel. These cases are to burn one at a time, and the first of them to begin with those on the fell, of which four are to burn at a time. On the front of the wheel, form a spiral line with strong wire, on which tie port-fires, with their mouths to face the same way as the cases on the wheel. All these port-fires must be fired with the second cases on the wheel.

The spokes of the wheel must be formed of wood, and made to screw into a block in the centre, and each spoke should be four feet six inches in length. In the top of each, fix a spindle, and, in each spindle, put a spiral wheel of eight spokes. The blocks of [418] these wheels must have a hole at top for the centre cases, and the spindle must be furnished with nuts, screwed on their ends, which should fit in the holes at the top of the blocks. The cases of these wheels are to burn double; and the method of firing them, is by carrying a leader from each down the spokes into the block in the centre, as in the dodecaedron; but the centre cases of each wheel must begin with the two last cases as usual. The large circular wheel in front ought to have a tin barrel on its block; into which a pipe must be carried from one of the second cases on the wheel. This pipe, being met by another from the large block, in which the eight spokes are screwed, will fire all the spiral wheels, and the illuminating port-fires at the same time. The cases of the projected wheel may be filled with a white charge, and those of the spiral wheels with a gray.

Sec. XXI. Of the Spiral or Endless Screw, and Waved Fire.

This piece is formed in the same manner as the single and double cones; and, in fact, is the same as the Archimedean screw, which we have already described. The serpentine form which characterizes the spiral piece, is given to it by the particular arrangement of the lances of illumination. The cone receives its motion from the cases of white-fire; the fire of which is communicated by leaders to the cases of port-fire, or lances of illumination. They must burn the same length of time.

The waved fire is produced by having two wheels of a similar size, turning in a contrary direction on the same axis, and furnished with cases, which are inclined about 45 degrees from the level of the table. These wheels carry four cases each, and burn at the same time. They have been made to carry forty-eight cases, and furnished, at their centres, with lances, bent in a particular manner, so as to represent the motion of serpents.

Sec. XXII. Of the Decoration of Wheels.

Wheels, we have seen, may be made of different dimensions, according to the purpose to which they are applied. The most common are three or four feet in diameter, with a nave of hard wood, and spokes of light wood. They are sometimes surmounted with a fell, and frequently by several concentric hoops, placed at different distances from each other. [419]

Wheels, in general, are furnished with cases, and various decorations. Some have two, three, four, and more fires; but, if they are *finished* too much, the weight they thus acquire would retard the velocity of the wheel. Their centres may be finished in several ways; as, for instance, by attaching, to the inner fells or circles, cases filled with white lance-composition, placed at the distance of two inches from each other, or alternately, white, blue, and yellow, or Chinese gerbes, or cases of blue fire. We may also attach small turning suns, the axes of which being placed upon the spokes. They may also be made to resemble a mirror, by furnishing all the spokes with white lances; and for the last fire, we may attach four cases to the centre, or in its vicinity, placed in such a manner, that their fire may issue from the interior of the wheel. To this, we may add, two other cases, which may cross the former. Leaders are fixed, and they are lighted at the same time.

Automatons with all their joints, or articulations, have been added to exhibitions of this kind, and with particular effect. They are clothed with cases after the usual manner.

Sec. XXIII. Of Globes, with their Various Decorations.

The first we purpose to treat of are the illuminated globes with horizontal wheels.

The hoops for these globes may be made of wood, tin, or iron wire, about two feet in diameter. For a single globe, take two hoops and tie them together, one within the other, at right angles; then have a horizontal wheel made, whose diameter must be a little wider than the globe, and its nave six inches long; on the top of which, the globe is fixed so as to stand three or four inches from the wheel. On this wheel may be put any number of cases, filled with any of the ordinary charges, as the white fire composition. Two of these cases must burn at a time. They may be placed horizontally, or inclining downwards. When the wheel is clothed, fix on the hoops as many illuminations as will stand, within two and a half inches of each other, which are fastened on the hoops with small iron wire. Attach the pipes of communication, and arrange them so as to carry the fire to all at the same time, with the exception of one or two, which are to receive their fire for the last. The spindle, on which the globe is to turn, must go through the block of the wheel up to the inside of the top of the globe; at this place must be fixed a bit of brass or iron, with a hole [420] in it, to receive the point of the spindle, on which the whole weight of the wheel is to bear. When the globe is to be stationary and the wheel to run by itself, the block of the wheel must not be so long, or the spindle any longer than to raise the globe a little above the wheel.

We may remark, that, while the cases of white fire composition give to the piece a rotary motion, those of the lance or illuminating port-fire produce the effect, which characterizes in particular this fire-work.

With respect to fire globes, there are two kinds; namely, one with projected cases, and the other with concealed cases. If we have a globe made of wood, of any diameter, and divide its surface into twenty-four equal parts, and bore a perpendicular hole in each of these divisions to the centre, we may then represent this piece in the following manner: In every hole, except one, put a case filled with brilliant or any other charge, and let the mouths of the cases be even with the surface of the globe. Then cut in the globe a groove from the mouth of one case to that of another for leaders, which must be carried from case to case, so that they may all be fired together. The globe is then covered with a single paper and painted.

Fire globes with projected cases are made in the following way: Prepare a globe with fourteen holes, and fix in every hole except one, a case, and let each case project from the globe two-thirds of its length. Then clothe all the cases with leaders. It must be supported by a spindle made to fit the hole in which there is no case.

The *bursting-globe* is nothing more than a globe prepared in a particular way. It turns on a pivot, and is made by uniting four segments. These segments or parts are fixed to hinges, which open on the inside, and, when brought together, are kept in their place by a match which goes round the globe. The globe, it is to be observed, is furnished in the inside with several steel springs, which, unless the globe itself were tied, would force it open. When the match is burnt, this effect follows and the globe separates into four parts. It is furnished with lances and cases in the same manner as those already described. The last effect is that we have noticed.

Globes, which leap or roll on the ground, may be formed by procuring a wooden globe, furnished with a cylinder; and, having loaded it with the composition hereafter mentioned, introduce into it four or more petards loaded with grain powder to their [421] orifices, which must be well stopped with paper or tow. If a globe prepared in this manner be fired by means of a match at the mouth of the cylinder, it will leap about as it burns on a smooth horizontal plane, according as the petards are set on fire. The petards may be affixed to the exterior surface of the globes, which they will cause to roll and leap as they catch fire.

Composition.

Grained powder,	1	lb.
Saltpetre,	32	—
Sulphur,	8	—
Scraped ivory,	1	oz.
Sawdust, (boiled in saltpetre and dried,)	8	lbs.

Sec. XXIV. Of the Representation of the Moon and Stars.

The moon and stars are represented in the following manner: Make a wheel eighteen inches in diameter, by fixing eight or more spokes in the nave; and then adapt a fell to it. To the fell fasten eight cases of the black or gray composition, and let the fire communicate from one to the other. These cases give motion to the wheel. Furnish the spokes of this wheel with cases charged with the white lance composition. Make now a crescent of iron and attach it to the spokes, or a little before the spokes of the wheel. In order to fix stars to this piece, eight strips of wood, seven feet in length, are made to cross each other at equal distances, and nailed to each other in the middle; so that when this frame is put behind and secured to the moon-piece, its arms will extend some distance beyond the perimeter of the wheel. These projections are furnished with five-pointed stars, eight inches apart, and there is usually in all thirty-two. They are made to communicate with each other by means of the cotton match, as before described. The light of the lances renders the moon very apparent, and the fixed stars resemble those in the firmament. The representation of the moon and seven stars may be performed by procuring a smooth, circular board, six feet in diameter. Out of the middle of it cut a circular piece twelve or fourteen inches in diameter, and cover the hole formed with Persian silk, on which is to be painted a moon's face. Also cut out of the board stars of four or five inches in diameter. These stars are cut out with five points and covered with oiled silk. On the front of the large circular board draw a seven-pointed star, as large as the circle will [422] admit, and on the lines which form this star, make several perforations, in which six-pointed stars are to be fixed. A wheel of brilliant fire is placed behind the moon, which renders the moon and stars transparent. They will disappear when the wheel is burnt out; but then in consequence of the communication of the fire to the large star in front, which is formed of pointed stars, the appearance of this star succeeds, and finishes the piece.

A large fixed star may be made thus. To each extremity of the pieces of wood, arranged so as to cross each other, attach two cases of the black charge. Their fire must communicate. Near these cases, on each arm, place a turning sun of three cases. These five suns are fixed at the same time, and when they cease, the cases commence. These cases form the star.

The representation of flaming stars, with brilliant wheels, is made in the following manner. After procuring a circular piece of wood, about one inch thick, and two feet in diameter, fix round it eight points, each two feet and a half long, four of which must be straight and four waved, or flaming. These points being joined on very strong, and even with the surface of the wood, nail tin or pasteboard on their edges, from the wood to the end of each, where they must be joined. This tin is to project in front eight inches, and be joined where they meet at the block. Round the front of the wood, fix four pieces of thick iron wire, eight inches long each, equally distant from each other. Cut a piece of pasteboard round, two feet in diameter, and draw on it a star; then cut out this star, and on the back of it, place oiled paper. Paint half red and half yellow, lengthwise. The body of the star must be left open in which must be seen a brilliant wheel. This wheel is formed by having a block turned nine inches long, and fixing in it six spokes. At the end of each spoke, put a two-ounce case of brilliant fire. The length of these cases is made in proportion to the wheel, and the diameter of the wheel, when the cases are on, must be less than the diameter of the body of the small star. The cases on the spokes in front must have their mouths inclined outwards, and those on the inside spokes, placed so as to form a vertical circle of fire.

Carry the first leader, from the tail of one of the cases in front, to the mouth of one of the inside cases, and from the tail of that to another in front, and in the same order to all of them. Put on a spindle in the centre of the star. This spindle must be furnished with a shoulder at bottom, to keep the wheel at a little distance from the block, which is kept on the spindle by a nut at the end. [423] Having fixed on the wheel, fasten the transparent star to four pieces of wire. When fired, a common horizontal wheel will only be seen; but when the first case is burnt out, it will fire one of the vertical cases, which will show the transparent star and fill the large flames and points with fire. It will then appear like a common wheel, and represent the same appearance for twelve changes.

With respect to the formation of stars for regulated pieces, we may remark, that they are made of different sizes according to the work for which they are intended. They are prepared with cases from one ounce to one pound; but, in general, with four-ounce cases, four or five inches long. The cases should be rolled with paste, and twice as thick of paper as a rocket of the same caliber. Having rolled a case, let one end of it be pinched quite close; then drive in half a diameter of clay, and, when dry, fill it with composition to two or three inches of the length of the case. At the top of the charge, drive some clay; as the ends of these cases, being seldom pinched, would be likely to take fire. Divide the case, when filled, at the pinched end close to the clay, into five equal parts; then bore five holes with a gimblet, about the size of the neck of a common four-ounce case, into the composition. From one hole to another, carry a quick match, and secure it with paper, in the same manner as the ends of wheel cases; so that the hollow part, which projects from the end of the case, may serve to receive a leader from any other work, to give fire to the points of the stars. These stars may be made with any number of points.

Sec. XXV. Of the Representation of Sundry Figures in Fire.

Animals and various figures may be represented in fire by the following method: Take sulphur, reduced to a very fine powder, and, having formed it into a paste with starch, cover the figure of the thing to be represented, with this mixture, having first coated it with clay to prevent it from being burnt. After the figure is covered with paste, it must be sprinkled, while moist, with gunpowder; and, when the whole is perfectly dry, arrange about it several small matches, that the fire may be speedily communicated to it on all sides. In this way, all sorts of garlands, festoons, and other ornaments may be imitated by fire of different colours.

A shower of fire may be connected with this representation, by using cases of one-third of an inch in diameter, charged with any [424] of the following compositions. These cases should be two inches and a half in length. They must not be choaked, it being sufficient to twist the end of the cartridge. The effect of these cases is to fill the surrounding air with an undulating fire. The compositions are similar to those already noticed; viz. for *Chinese Fire*, take gunpowder one pound, sulphur two ounces, pulverized cast-iron of No. 1. five ounces; for *ancient fire*, meal-powder one pound, charcoal two ounces; and for *brilliant fire*, meal-powder one pound, and iron filings four ounces. Sparks are also sometimes employed. These are made in the usual manner.

Besides the common mode of forming sparks, as they differ from stars only in their size and duration, (being formed into small balls about the size of peas), they may be made by the following method: Take sawdust of fir, poplar, &c. and boil it in water, in which saltpetre has been dissolved. When the water has boiled some time, it is to be poured off, that the sawdust may remain in the vessel. When nearly dry, spread it out on a table, and sprinkle it with sulphur, sifted through a very fine sieve, to which may be added a little meal-powder.

If it be required to accompany the exhibition with bearded rockets, (*fusées chevelues* of the French), so called from the circumstance, that, when they fall, they make small undulations in the air like frizzled hair, we may form them in the following manner: Fill the barrels of some goose-quills with the composition of sky-rockets, and place upon the mouth of each a little moist gunpowder, both to keep in the composition, and to serve as a match. If a flying-rocket be then loaded with these quills, they will produce, at the end, a beautiful shower of fire.

Sec. XXVI. Of the Representation of Flat Stars, with a large Body of Fire.

A star of five points, about two feet from point to point, is to be made, and, in its centre, is placed a turning sun, composed of three cases, and altogether not more than six or eight inches in diameter. To this star five branches are fixed, each of which is three feet in length; and, to the extremity of each, are attached seven cases, with their mouths outwards, and inclining about thirty-five degrees. One case is then attached lengthwise, and forms the very extremity of each projection. On each leg or branch, nearer, however, the centre of the star, must be three cases, fixed in an hexangular form. The border of the large star is decorated [425] with Italian or fixed stars. The fire is communicated to the star by means of a leader, then to the sun and the cases on the branches.

Sec. XXVII. Of the Single, Double, and Triple Table Wheel.

We have spoken of an arrangement of fire-works, which moves a wheel on a circular board. That contrivance is similar to the one we now purpose to describe.

The table-wheel is a kind of girandole, which turns circularly on a round table, by having its axis connected with a perpendicular pin, fixed in the table; so that its motion is vertical, while it moves in a circular position round the table.

The table, as well as the wheel, may be of any size, according to fancy. Eight or nine cases are usually attached to the fell of the wheel, and in the direction of the fell. These cases turn it with great velocity. The centre of the wheel may be decorated with lances, or illuminating port-fires. When double or treble wheels are to be arranged on the same table, this is done by having the iron so lengthened, as to extend over the table, and receive another wheel of the same size; and by using a contrivance of iron, having three projections, at equal distances apart, and turning in the same manner on a pivot, or pin, fixed in the centre of the table, three wheels may be put in motion at the same time. When two wheels are employed, we may decorate one with blue lances, and the other with yellow. When three wheels form the same piece, it is usual to illuminate them, severally, with white, blue, and yellow lances. The wheels of coloured fire augment the beauty of the exhibition. In the centre of the table, may be placed a pyramid, decorated in the usual manner. Spiral wheels, globes, &c. may be attached, if so required.

Sec. XXVIII. Of Decorations, Transparencies, and Illuminations.

Cut-work, as it is called, is often employed in decorations. Various figures, letters, garlands, &c. may be represented. This may also be accomplished in tambour-work. Several methods have been used to produce the same effect. Cut-work, made in pasteboard, and the pasteboard blackened and suspended in a frame, will, by the aid of lights placed behind it, exhibit the design [426] very perfectly. A figure of a sun cut out of pasteboard, either fixed or made to revolve in the manner before described, and illuminated by fixed lights or revolving cases, is considered to be the best mode of forming such pieces. In all instances, the more brilliant the fire, the more perfect is the representation. Tambour decorations are variously arranged; and, frequently, in the termination of an exhibition, six or more are shown at once, and sometimes with cascades, and turning suns.

In the place of cut-work, painted transparencies, made with fine colours, and on Florence Taffeta, are usually employed. Transparent paintings however, are not preferred by some, as the effect, it is said, is not so perfect as when cut-work is employed. Morel gives a preference to the latter.

Transparencies may be formed with silk, or fine linen, and even with paper, if previously prepared, by means of the spirit of turpentine. The colours are painted in turpentine, and transparent varnish is then applied.

Transparent screens may be prepared, by spreading white wax, dissolved in spirits of turpentine, over thin muslin. A screen, thus prepared, will roll up without injury. A clearer screen may be produced, by having the muslin stretched upon a rectangular frame, and prepared with turpentine instead of wax.

In the *Œuvres de Diderot*, t. xv, p. 349, are observations respecting transparencies, and the manner of preparing them. The process described is nothing more than we have noticed. It consists in using the oil of turpentine, and sometimes a solution of wax in turpentine. The colours are prepared mostly with turpentine. Canada balsam, thinned by the addition of the spirit, is also employed. Moveable transparencies were exhibited with great effect in Paris. Transparent figures were made to move continually in every direction, which had a singular appearance. Artificial fire-works were very accurately imitated, by producing a variety of movements with different pieces of transparencies, variously coloured. The sun, moon, and stars, revolving wheels, &c. composed a part of this exhibition.

With respect to decorations in white and coloured lances, we may observe, that artificial fire-works are usually terminated by some decoration, which corresponds with the subject. For this purpose, triumphal arches, fronts of palaces, colonades, rocks, &c. are formed, and represented in wood-work. These are usually clothed, and painted in water-colours. From the rocks, water is made to issue, forming cascades, and a number of figures are put in motion. The jets of water are terminated by jets of Chinese fire, or brilliant fire-rain. [427]

The furniture, or decorations, may be various, either with white or coloured lances of illumination, hung four inches apart, and attached to different parts of the figure, or building. If it is in front of a temple, the columns are ornamented with emblems, &c. the fire-work being thus arranged: *viz.* blue lances are attached to the columns, white lances to their entablature, and to the emblems, yellow lights. This however, depends on taste.

Decorations are also made with matches; but this mode is not preferred, because so much smoke is thereby produced.

Figures, cut in paper, are illuminated in the manner before described. But for this purpose, muslin is first stretched on a frame, and its sides are covered with two or three thicknesses of paper, which are pasted on. It is then blackened. After tracing the design, or the subject of the illumination, and cutting it out with exactness, the frame is put in a case, sufficiently deep to contain a number of lights.

Illuminations, as an expression, of public feeling for some event or memorable occasion, are by no means a recent thing. Various modes have been adopted to render such exhibitions more elegant, as well as more expressive. Hence, with the usual display of lights, arranged according to taste and fancy, transparencies, decorations, such as we have described, &c. have been more or less customary.

We mentioned, in the first part of our work, something in relation to the antiquity of illuminations; but, as this subject may be interesting, we deem the following brief remarks not irrelevant.

Beckman assures us, (*History of Inventions*), that the origin of illuminations is very ancient. The feasts, or holy-days were celebrated in the days of antiquity, in various ways, among which, that with lamps was very common in Egypt. It was called the feast of the lamps, (*Fête des Lampes*), and the inhabitants of some cities in Egypt were obliged to illuminate, with a great number of lamps, placed before their houses. Herodotus (*lib.* ii, *chap.* 62), remarks, that, at a particular festival of the Egyptians, lamps were placed before all the houses throughout the country, and kept burning the whole night. During the *festum encæniorum*, the Feast of the Dedication of the Temple, which, according to common opinion, was celebrated in December, and continued eight days, a number of lamps were lighted before each of their houses. Such illuminations were used, also, in Greece and Rome, and were called *Lampadaria*. An infinite number of lamps were burnt in honour of Minerva, Vulcan, Prometheus, Bacchus, &c. On the last occasion, the illumination was called *Lampericæ*. It seems that the lighting of streets had not been adopted at that period.[25] At Rome, the forum was lighted, when games were exhibited in the night-time; and Caligula, on a like occasion, caused the whole city to be lighted. As Cicero was returning home late at night, after Cataline's conspiracy had been defeated, lamps and torches were lighted in all the streets, in honour of that great orator. The emperor Constantine caused the whole city of Constantinople to be illuminated with lamps and wax candles on Easter-eve. The first christians often illuminated their houses on idolatrous festivals, in a more elegant manner than the heathens. This was dictated by policy. The houses of the ancients were illuminated on birth-days, by suspending lamps from chains. [428]

For illuminations at the present day, tallow is chiefly used. It is clarified, for the making of candles, by means of alum. M. Olaine in 1710 presented to the academy of sciences an apparatus for the manufacture of candles. The *bougie economique* of the French is described in the *Journal de Paris* for 1782. The outline of the process for preparing them is as follows: Take eight parts of suet, and melt it with one quart of water; and after straining it, and returning it to the same boiler, add the same quantity of water, in which was dissolved half an ounce of saltpetre, as much sal ammoniac, and one ounce of alum. The boiling is continued to evaporate the water. The wick is made of cotton or flax, and rolled in a solution of camphor in petroleum, and afterwards covered in the usual manner with the above composition. [429]

In using tallow generally, quicklime is recommended to be added to it in fusion. When the quicklime subsides, it is poured off. Another mode recommended is to melt the tallow with vinegar, and to add to it a decoction of rosemary, sage, laurel, and a small quantity of turmeric; the whole being boiled until the water is evaporated. This communicates, it is said, an agreeable odour, and a yellow colour. Different modes of preparing tallow for candles have been used. See *sal ammoniac.* With respect to ancient lamps, some account of them has been published in the *Antiquities*, by Montfaucon and by Passeri; and the *Journal des Savants* 1682 and 1685 mentions the two lamps of Boyle and Sturmius, and some account of the celebrated lamp of Callimacus in the temple of Minerva. On the formation of lamps, and the purification of oil, sundry patents have been granted both in France and England. The argand lamp for burning its own smoke, which it effects by a glass cylinder placed over the flame, is one of the best improvements of the kind. The principle of these lamps is the same, although variously modified in shape and structure. For chemical purposes, an iron cylinder is substituted for glass. A lamp, for the burning of tar and turpentine, with steam, has lately been invented by Mr. Morey, (*see Silliman's Journal Vol. II.*) Mr. E. Clarke obtained a patent for a lamp calculated to burn tallow; the principle of which is, that by the heat of the flame, the caloric is conducted to the tallow by means of a piece of iron, which is heated by it, and the tallow melts as it is wanted. This lamp may be economically used, when common lamp oil is scarce and high in price. A lamp is described in the *Repository of Arts*, to burn tallow.

As a wick, besides cotton, several substances have been recommended. The filaments of amianthus, for instance, while they perform the office of a wick, are incombustible. The *Journal de Verdun* for 1748, announced incombustible wick by sieur Lespar. Touch wood, the *tussilago sarfara*, and the *verbascum tapsus* of Linnæus, are also recommended. In 1783, Leger announced, in the *Journal de la Blancherie*, that he had invented a match which would burn without smoke and odour. [430]

Lamps have been furnished with fixed and moveable mirrors, to throw the light forward by reflection. The reverberatory lamps, revolving lights for light houses, &c. are of this kind. Many patents have been obtained for such contrivances, which we have not room to notice.

The inflammable air lamp for the table, described in the *Dictionnaire de l'Industrie*, is nothing more than a spirit of wine lamp, and used in lieu of hot bricks, or vessels filled with boiling water for the warming of dishes, &c. In 1780, M. Ehrman, in his *Description et usage de quelques lampes à air inflammable*, describes a chafing dish with inflammable air, invented by Nevet, which operates by the combustion of hydrogen gas.[26]

Fixed illuminations are more brilliant and more magnificent; as the lights are more numerous, as well as more diversified. Wax, spermaceti, or tallow candles, or oil burnt in tin lamps, or in glass cups suspended by wire, are all used for the purpose. If the wick be dipped in spirit of turpentine, it will take fire instantaneously. It is unnecessary to make any remarks as to the arrangement of lights.

Large dishes containing melted tallow, and a wick proportionally thick and suspended by means of a simple contrivance of tin, are recommended for the same purpose. Coloured lights afford a variety. The appearance of coloured flame may be produced by burning the oil in coloured glasses, so disposed as to let the light pass through the glass, or by placing lamps behind bottles filled with coloured water.[27] [431]

The coloured glasses which are sold in Paris for the purpose, are formed with facets on the outside, which not only produce the appearance of coloured flame, but also, according to the number of facets, the refraction and reflection of the light. Arches, pyramids, obelisks, &c. are lighted up in this manner.

The Pont Neuf, and the Seine in 1739, were illuminated at the time of the splendid exhibition of fire-works. It is unnecessary, however, to particularize on this head. We all remember the splendid illuminations in all our cities during the late war, which were indeed a true expression of our national and individual feeling. Illuminations, in this country, before that time were very rare; none we think since the peace of 1783, and the union under the federal compact.

Phosphuret of lime, of the size of peas, thrown into water, will afford, at short intervals, a brilliant flame of fire; for the phosphuretted hydrogen gas thus produced has the property of inflaming spontaneously in atmospheric air. Alcohol, containing sundry salts in solution, will give a flame of various colours, according to the salt it holds in solution. See *Alcohol.*

Illuminated works are much admired by the Italians, and particularly the *Illuminated chandelier*, which is considered a great addition to a collection of works. An illuminated chandelier is formed of thin wood with arms extending on each side. Holes are bored in the front of the branches and in the body, and also in the eagle (if it be added,) at top, and distant from each other about three inches. In these holes, we put illuminations, filled with white, blue and brilliant charge. Having fixed in the port-fires, they must be clothed with leaders, so that the chandelier and eagle may light together.

We may also observe, that, for the speedy lighting of a number of lamps, at one and the same time, quick-match enclosed in paper tubes has been used. This quick-match is sometimes made to communicate its fire to a sulphur match, prepared by dipping [432] strands of cotton in melted sulphur, and from this to the lamp. Several methods are recommended for this purpose; one of which consists in dipping cotton wick in the oil of spike, and arranging it along the wicks of the different lamps, so that when inflamed the fire may pass rapidly from one lamp to another. In 1772, M. Renault, a Parisian, announced in the public papers, that he possessed a secret, by which he could light 2000 lamps in five minutes, by means of a match of communication.

We have some experiments and observations on coloured flame, by Mr. Morey, in his essay on heat and light, in the second volume of Silliman's *Journal of Science and Arts*, p. 120. The experiments are curious, and worthy of remark. If water, he observes, be put into one cylinder, and made to boil, and the steam be led to the bottom of another included cylinder, containing spirits of turpentine, the steam, when let out under a moderate pressure, carries off with it a sufficient quantity of the spirit to burn with a pleasant *white* flame, free from smoke; but if the pressure be increased, the flame will become in part or wholly blue. "Here," he adds, "as in many other experiments, I have noticed, that different coloured flames may be produced from the same materials—are the products of combustion different?" He further observes, that "if the steam of water, containing a small proportion of the vapour of rosin, be driven against iron, at or below a red heat, it burns with a pleasant *blue* flame, which will be extended some way back into the column of the vapour, intermixed with innumerable sparks of very white flame, evidently particles of the rosin. If the vapours, when the proportion of the rosin is very small, are made to pass between two plates of iron, at or near a red heat, they can be inflamed on the opposite sides of the plates, and will then, sometimes, burn with an entirely *blue* flame, although the vapour can not be inflamed, without the intervention of the plates." He states other experiments, made with tallow and steam, producing a *blue* flame. The *blue* colour seems to be owing to the pressure made use of; for, in his second communication, (page 122, of the same volume), he mentions white flame being produced by the vapour of water; and when it is in a sufficient quantity, there is *no smoke*. If too great, combustion ceases. Speaking of the colour of the flame, produced by mixed vapours, (of the combustible and water), such as blue, blue and white, white and intense white, he adds, that they may be imitated, at pleasure, with the patent lamp stove, by burning tar, pitch pine, or mineral coal and water. Newly made charcoal will take up about three [433] times its weight of water. "Sand, ashes, or fine clay," he observes, "answers well for mixing with the tar, &c. If the latter be made into a paste with equal parts of spirit of turpentine and water, and cold lumps of it, of a conical form, be placed on a table, and a flame applied, the vapours burn without smoke for a short time, &c. If enclosed in a tin cylinder, and the vapour be made to issue through small holes at the top, placed as before stated, or on a plate over a chafing dish of coals, it burns with a very bright light, free from smoke. If the cylinder be tight at the top and the vapour be led from the inside at the top, down and through the bottom, and there be made to issue in an oblique direction, and from a number of small openings, it will burn with a beautiful flame and supports and regulates, very accurately, its own evaporation. The oblique direction carries the heat, in part, beyond the cylinder, when the evaporation is too great.

"Every effect may be produced in consuming the smoke, and giving an intense white flame, by using a certain proportion of water, intimately blended or mixed with these vapours, that can be from an access of oxygen furnished, by creating a very strong current of air, with a high flue." The description of Morey's lamp stove, may be seen in the same work. The steam, he observes, may be furnished by a small tin boiler, and directed to or near the bottom of the tar. An *intense white flame free from smoke*, may be thus produced from tar, rosin, rough turpentine or the spirit, alcohol, oil, fat, tallow, mineral coal, pitch pine wood, and the knots, birch bark, and pumpkin, sun-flower, flax, and other seeds. With regard to pine wood, he adds, it is the easiest managed, evaporates at a lower temperature, consumes a greater proportion of water in its combustion, contains the water within itself, and gives a brighter light than common candles or lamps, and without smoke. The more volatile parts are evaporated at a temperature below that of boiling water, and burn well with three parts of the vapour of water; the flame then, however, is nearly *blue*. Observations on the application of this mode of producing light and heat, may be seen in Silliman, p. 131, &c. It appears, that Gay-Lussac (*Annales de Chimie*, for June, 1819,) has commented on Mr. Morey's plan.

Professor Hare (*Silliman's Journal*, vol. 2d, p. 172) also observes, that the flame of hydrogen gas is rendered luminous, like that [434] of oil, by adding a small quantity of oil of turpentine to the usual mixture for generating this gas; and that the addition of $^1/_{17}$ of the same fluid to alcohol, will give it the property of burning with a highly luminous flame; and there is a certain point in the proportions, at which the mixture burns without smoke, like a gas light. In the first instance, he observes, when the ingredients are at the proper temperature, the light is greater than that produced by carburetted hydrogen gas. Speaking of this application of spirits, the professor judiciously adds: "It might be serviceable to *morals*, if the value of this article could be enhanced by *a new* mode of consumption." We find, also, that the effect of vapour on flame has been noticed by Dr. Dana, in the same Journal, vol. 1, p. 40; by which it appears, that when a jet of steam is made to pass into a charcoal fire, the vividness of the combustion is increased, and also the low attenuated flame of the coal; that it prevents the smoke of a common oil lamp, and makes the flame brighter; that the flame of spirit of turpentine, which is usually dull and reddish, is rendered bright, and no smoke is formed; or when the vapour of both are made to issue together from the same orifice, and inflamed, no smoke appears; that a jet of steam, thrown into the flame of a spirit of wine lamp, or into flames which evolve no smoke or carbonaceous matter, produces the same effect as a current of air; but that, in all flames which evolve smoke, steam produces an increased brightness and a more perfect combustion. Dr. Dana further suggests, that steam might be introduced into the flames of street lamps, which might be so contrived as to keep water boiling, to produce the steam, and thereby cause a more perfect combustion, and a greater quantity of light from the same materials.

Count Rumford has shown, that the quantity of light, emitted by a given portion of inflammable matter in combustion, is proportional, in some high ratio, to the elevation of temperature; and that a lamp, having many wicks near each other, so as mutually to increase their heat, burns with infinitely more brilliancy than the Argand lamps in common use. To measure the proportional intensities of two or more lights; place them a few inches asunder, and at the distance of a few feet or yards from a screen of white paper, or a white wall. On holding a small card near the wall two shadows will be projected on it, the darker one by the interception of the brighter light, and the lighter shadow, by the interception of the duller light. Bring the fainter light [435] nearer to the card, or remove the brighter one further from it, till both shadows acquire the same intensity. Measure now the distances of the two lights, from the wall or screen, square them, and you have the ratio of illumination. Thus, if an Argand flame and a candle, stand at the distances of 10 feet and 4 feet, respectively, when their shadows are equally deep, we have 10^2 and 4^2, or 100 and 16, or $6^1/_4$ and 1, for their relative quantities of light.

The author of the *Dictionnaire de l'Industrie*, vol. iii, p. 365, in treating on the subject of illumination, mentions different modes of illuminating, both with and without transparencies. We know that various mixtures will produce different coloured flame. Thus, arsenic will burn with a beautiful white flame in oxygen gas; iron and steel will burn also, affording a brilliant light; phosphorus and charcoal with a white, and sulphur with a beautiful blue flame; zinc with a green colour, &c.

Again, we know that a mixture of nitrate of strontia and charcoal will burn with a rose coloured flame; one part of boracic acid, and three of charcoal, with a green flame; one of nitrate of barytes, and four of charcoal, with a yellow flame; and equal parts of nitrate of lime and charcoal powder, with an orange flame. We also know, that cotton dipt in oil of turpentine, or ardent spirit, rosin, camphor, &c. will burn extremely vivid and beautiful.

The author, whom we have just quoted, gives some remarks on the various coloured flames, that may interest the reader.

Felt (*Feutre*, Fr.) he remarks, if put in the fire, will give most beautiful colours, a golden yellow and a brilliant blue. And this, he adds, may be proved by throwing pieces of old hats into the fire; for these colours depend on the substances used in dying the hat. He further remarks, that green oak wood gives a yellow flame, and alcohol with sedative salt, (boracic acid), a blue, and that, by uniting the flame of both, the product, as to colour, will be a green.

The flame of alcohol is changed of various colours, according to the salt it holds in solution. Of this circumstance, Schatt was apprised, when he gave some formula many years ago, on the manner of forming coloured flame. Reaumur remarked also, the different colours which some metals assume, when submitted to the action of heat, which is known now to be the effect of oxidizement.

As respects the phenomena with felt, we are told, that, if we throw into the fire the cuttings of hats, we will perceive at first a [436] white flame, and then in succession a blue, green, and violet colour; all which, our author observes, proceeds from the verdigris and other substances, employed in the composition of the dye stuff. There is one fact, which he has asserted, which may probably be explained on the *materiality* of light, so far as regards the *formation* of colour, (not considering, however, the theory of Bancroft, given in his *Philosophy of Permanent Colours*, or the more philosophical one of Dr. Samuel Conover, of Philadelphia, in the Transactions of the *American Philosophical Society*), and this fact is, that the flame carries the colour to the object which it illuminates, and that the object itself actually partakes of the colour, in order to produce any particular appearance. That colours, as visible to the eye, are all formed in the solar light, and their appearance depends upon the *absorption* of some of the rays of light, and the *reflection* of others, is a doctrine which followed the discoveries of Sir Isaac Newton. We have not room to notice this subject, however interesting it may be in a philosophical point of view.

There can be no doubt, that the art of colouring flame was known for a long time. We are told, that the philosopher Anaxilaus even pretended, that, by putting ink with the oil of a lamp, or the liquor of the cuttle fish, the faces of the bystanders will appear *black* by the light of this lamp! Sulphur has the effect of rendering the visage pale and cadaverous. Other persons, as Simon Sethe, advanced an opinion, that, if we moisten the wick of a lamp with ink, or in a mixture of the rust of copper, and having lighted the wick, and placed other lights around it, the faces will appear, some black, and some of a brass colour. Others, such as Cardan, say, that, by making a mixture of wine and salt, and then reducing it two-thirds by evaporation, the flame, which the wine will then give, will make the *living* put on a cadaverous appearance, if they remain in one posture. Malina also observes, that, by burning a piece of woollen cloth well soaked in a solution of salt in vinegar, the visage will appear frightful by the light of the flame. But the process of J. B. Porta is not less worthy of note. If good old wine, he observes, be put into a bowl with a handful of salt, and set on live coals, but not in the flame, and as soon as it begins to boil, is set on fire, (the other lights in the room being extinguished), the figure of each person will appear so hideous, as to produce a mutual dread. The author of the *Dictionnaire de l'Industrie*, iii, p. 433, observes, that he has repeated this experiment, sometimes with brandy, and at other times with alcohol, with perfect success. [437]

A cadaverous appearance is said to be given, by mixing common salt with alcohol, in which some saffron had been infused. When set on fire, and the other lights extinguished, the effect, we are told, is very striking.

The so called *miraculous luminaries*, are nothing else than solar phosphori, which are very numerous. Their effect is to emit light in the dark, but not heat. Almost every thing in nature possesses this property in a greater or less degree, which depends on the absorption and subsequent transmission of light. The eyes of various animals have this property; cats and owls in particular. Snow possesses it in a considerable degree. Putrid animal matter, fish, for example, rotten wood, &c. partake also of this property.

It may not be improper to notice, in a general way, some of the substances, which are denominated solar phosphori. The *Bolognian phosphorus* is the calcined baroselenite, (sulphate of barytes), which, when exposed a few minutes to the light, shines when taken into the dark like burning coals. In water it emits the same light. This property, as is the case with all other solar phosphori, it loses gradually; but by heating it again, imbibes light. *Canton's phosphorus* is calcined oyster shells. It is used in the same manner. *Baldwin's phosphorus* is fused nitrate of lime. Various saline and other bodies, as diamonds and precious gems, possess the same property. Expressed oils and animal fats, when heated to 450°, become phosphorescent.

Hanzelet (*Traité des Feux d'Artifice*) remarks, that a *stone* may be made to give light by water, if prepared in the following manner. Take quicklime, tutty, and saltpetre, of each one part; reduce them to powder, and expose them to the action of heat. On the addition of water, light is said to be given out.

When quicklime is mixed with essential oil, and brought in contact with water, spontaneous combustion is said to take place.

Fluor or Derbyshire spar, (fluate of lime), when pulverized and heated to 212° Fahr., and then removed to the dark, is very luminous. If writing be made on a copper or iron plate, with thin mucilage or white of egg, and powdered fluor spar, sprinkled on it; when the plate is removed to a gentle coal fire, the delineated objects will become luminous, and opaque again when the plate becomes cold. The lapis lazuli has the same effect.

The phosphoric substances, which become luminous by attrition or percussion, are numerous. *Homberg's phosphorus*, which is [438] nothing more than calcined muriate of lime, is of this character. When struck it emits light. Without either light or fire, a number of bodies will give out light. Flints, and other siliceous stones, struck against one another, appear luminous in the dark. Various other minerals have the same property. Wedgwood (*Phil. Trans.* 179,) Coates (*Nich. Jour.* 1799,) Westrumb (*Crell's Chem. Annals*, 1784,) have written on this subject; to which enumeration we may add the interesting remarks of Dr. Hulme, (*Phil. Trans.* 1800,) and the observations of Cabarris, in his Memoir, read before the National Institute.

It may be sufficient to remark, that the shell-fish called *pholas*; the *meduca* phosphorea, and other *molluscsæ*; several insects of the species *fulgora*, or lantern-fly; the *lampyris*, or glowworm; the *scolopendra electrica*; the *cancer fulgens*; the medullary substance of the human brain, &c. are all phosphorescent.

M. Dessaignes (*Bulletin de la Société Philomatique, Octobre*, 1810) made a number of experiments on solid, liquid, and aeriform bodies, relative to the disengagement of light by compression. Among other conclusions, he adds, that water is the cause of the spontaneous phosphorescence of bodies, such as quicklime, Canton's phosphorus, dry muriate of lime, &c. all which, when brought in contact with water, emit light, which he attributes to the consolidation of that fluid. The absorption of moisture, and its subsequent consolidation, may, in some instances, give rise to luminous appearances.

The *lapis solaris*, Bolognian stone, or the present sulphate of barytes, was discovered in 1602, by Casciorolus, a shoemaker of Bologna. He came to Scipio Begatello, who at that time was particularly known by his attachment to the art of gold-making, and showed him this stone, under the mystical name of *lapis solaris*, on account of its attracting the *golden* light of the sun, and its boasted fitness for converting the *semi-metals* into gold, the *sol* of the alchemists!

Dr. Brewster (*Edinburgh Philosophical Journal*) made a number of experiments on the colour and intensity of light, evolved by different minerals, by which it appears, that the yellow sulphate of barytes gives a pale light, while fluate of lime, a blue and green light. Cellini (*Treatise on Jewelry*, published near the beginning of the 16th century) was the first who observed the phosphorescence of minerals; it does not appear that he knew of the Bolognian stone. Grimshire (*Nicholson's Journal*, 8vo. vols. [439] 15, 16, 19,) made a number of experiments on the emission of light by bodies, when subjected to the electrical influence; and, when thus treated, sulphate of barytes gave a brilliant green light.

The *cawk* of the miners, as it is also a sulphate of barytes, phosphoresces when previously exposed to heat.

There are two water fountains, both set in motion by the action of heat on confined air, which, as it expands, forces the water from an under vessel in jets. The first is called the *illuminated fountain*, and plays when the candles are lighted, stopping when they are extinguished. The other is a fountain, which acts on the same principle, but by the heat of the sun. The effect of the first is more or less considerable according to the pressure of the air upon the water, and consequently, to the degree of rarefaction which the air undergoes.

The *chemical illumination* of some writers, by using oil of vitriol, iron filings, and water, and inflaming the vapour as it proceeds from a bottle, is nothing else than the inflammation of hydrogen gas. The "white vapours," which they describe, is the gas in question.

Having noticed the use of candles and lamps for illumination, we purpose, in concluding this article, to give the result of some experiments on the relative intensities of light, and duration of different candles, made by Dr. Ure, which we extract from his *Dictionary of Chemistry*.

Number in a pound.	Duration of a candle.		Weight in grains.	Consump. per hour: grains.	Proportion of light.	Economy of light.	Candles equal one argand.
10 mould	5 h.	9 m.	682	132	12¼	68	5.7
10 dipped	4	36	672	150	13	65½	5.25
8 mould	6	31	856	132	10½	59½	6.6
6 do.	7	2½	1160	163	14⅔	66	5.0
4 do.	9	36	1787	186	20¼	80	3.5
Argand Oil Flame				512	69.4	100	

The doctor remarks, that $^1/_8$th of a gallon of good seal-oil, weighs 6010 gr. or 13 and $^1/_{10}$th oz. avoirdupois, and lasts, in a bright argand lamp, 11 hours 44 minutes. The weight of oil it consumes per hour, is equal to four times the weight of tallow in candles, 8 to the pound, and three and one-seventh times the weight of tallow in candles, 6 to the pound. But its light being equal to that of 5 [440] of the latter candles, it appears, from the above table, that 2 lbs. weight of oil, in an argand, are equivalent, in illuminating power, to three pounds of tallow candles. The larger the flames in the above candles the greater the economy of light.[28]

Sec. XXIX. Of Imitative Fire-Works.

Imitative fire-works are nearly of the same character as the transparencies and illuminations mentioned in the last section; but, as this subject may be interesting to some of our readers, we thought proper for that reason to appropriate a section to its consideration.

Imitative fire-works are formed in the following manner: Take a paper that is blacked on both sides, or instead of black, let it be coloured on each side with a deep blue, which will be still better for such as are to be seen through transparent papers. It must be of a proper size for the figure intended to be exhibited. In this paper, cut with a pen-knife several spaces, and with a piercer make a great number of holes, rather long than round, and at no regular distance from each other.

To represent revolving pyramids and globes, the paper must be cut through with a pen-knife, and the space cut out between each spiral should be three or four times as wide as the spirals themselves. They must be so cut, that the pyramid or globe may appear to turn on its axis. The columns that are represented in pieces of architecture, or in jets of fire, must be cut in the same manner as if they are to be represented as turning on their axis.

In like manner may be exhibited a great variety of ornaments, cyphers, and medallions, which, when properly coloured, cannot fail of producing a most pleasing effect. There should not be a very great diversity of colours, as that would not produce the most agreeable appearance.

When these pieces are drawn upon a large scale, the architecture or ornaments may be shaded; and to represent different shades, pieces of coloured paper must be pasted over each other, which will produce an effect that would not be expected from [441] transparent paintings. Five or six pieces of paper, pasted over each other, will be sufficient to represent the strongest shades. To give these pieces the different motions they require, we must first consider the nature of each piece: if, for example, we have cut out the figure of the sun, or of a star, we must construct a wire wheel of the same diameter with those pieces. Over this wheel a very thin paper is to be pasted, on which is drawn with black ink the spiral figure. The wheel thus prepared, is to be placed behind the sun or star, in such a manner that its axis may be exactly opposite the centre of either of those figures. This wheel may be turned by any contrivance.

Now, the wheel being placed directly behind the sun, for example, and very near to it, is to be turned regularly round and strongly illuminated by candles placed behind it. The lines that form the spiral will then appear through the spaces cut from the sun, to proceed from its centre to its circumference; and will resemble sparks of fire that incessantly succeed each other. The same effect will be produced by the star, or by any other figure, where the fire is not to appear as proceeding from the circumference to the centre.

These two pieces, as well as those that follow, may be of any size, provided we observe the proportion between the parts of the figure and the spiral, which must be wider in large figures than in small. If the sun, for example, have from six to twelve inches diameter, the width of the strokes that form the spiral need not be more than one-twentieth part of an inch, and the spaces between them that form the transparent parts, about two-tenths of an inch. If the sun be two feet in diameter, the strokes should be one-eighth of an inch, and the space between, one quarter of an inch; and if the figure be six feet in diameter, the strokes should be one-fourth of an inch, and the spaces, five-twelfths of an inch. These pieces have a pleasing effect, when represented of a small size; but the deception is more striking when they are of larger dimensions.

It will be proper to place these pieces, when of a small size, in a box quite close on every side, that none of the light may be diffused in the chamber; for which purpose it will be convenient to have a tin door behind the box, to which the candlesticks may be soldered, and the candles more easily lighted.

The several figures cut out should be placed in frames, that they may be put alternately in a groove in the forepart of the box, or [442] there may be two grooves, that the second piece may be put in before the first is taken out.

The wheel must be carefully concealed from the eye of the spectator. Where there is an opportunity of representing these artificial fires by a hole in the partition, they will doubtless have a much more striking effect, as the spectator cannot then conjecture by what means they are produced.

It is easy to conceive, that, by extending this method, wheels may be constructed with three or four spirals, to which may be given different directions. It is manifest, also, that, on the same principle, a great variety of transparent figures may be contrived, which may be all placed before the same spiral lines.

In representing cascades of fire, it is necessary to observe, that, in cutting out the cascades, care must be taken to preserve a natural inequality in the parts cut out; for if to save time, all the holes are made with the same pointed tool, the uniformity of the parts will produce a disagreeable effect.

To produce the apparent motion of these cascades, instead of drawing a spiral, a slip of strong paper is to be provided, in which there must be made a great number of holes near each other, and made with pointed tools of different dimensions.

At each end of the paper, a part, of the same size with the cascade, must be left uncut; and towards those parts the holes must be made a greater distance from each other.

When the cascade that is cut out is placed before the scroll of paper just mentioned, and it is entirely wound upon the roller, the part of the paper that is then between, being quite opaque, no part of the cascade will be visible; but, as the wheel is turned gently and regularly round, the transparent part of the paper will give to the cascade the appearance of fire that descends in the same direction; and the illusion will be so strong, as to appear as a real cascade of fire.

CHAPTER XI.

OF AQUATIC FIRE-WORKS.

Fire-works, which are exhibited on water, have a very pleasing effect. Water rockets, in particular, are much admired.

Sec. I. Of Water Rockets. [443]

Water rockets are generally small, from four ounces to two pounds. When large, they are difficult to be kept above water without a cork float. When this is used, it is tied to the neck of the case. They will not dive as well with as without floats.

The cases for water rockets are made in the same proportion as for sky-rockets, but the paper is thicker. For those which are driven solid, put in at first a ladle full of slow-fire, and then two of the proper charge, and on that, one or two ladles of sinking charge; then the proper charge, then the sinking charge again; and so on till the case is filled within three diameters. Then drive on the composition one ladleful of clay, through which make a small hole to the charge. Fill the case within half a diameter with corn powder, on which turn down two or three rounds of the case in the inside; then pinch and tie the end very tight. Having thus filled the rockets, dip their ends in melted rosin or sealing wax, or secure them with grease. When they are fired, six or eight may be thrown in at once; but if they are all to swim or sink at the same time, they must all have an equal quantity of composition and be fired together.

In the rockets which burn in the water, there must be a considerable variation in the construction of the mould, and also in the materials of which they are composed. The composition should consist of three materials mixed together, *viz.* three ounces of meal-powder, one pound of saltpetre, and eight ounces of sulphur. If the rocket is to appear on the water with a beautiful tail, the composition must consist of eight ounces of gunpowder, one pound of saltpetre, eight ounces of sulphur, and two ounces of charcoal. When the composition has been prepared according to these proportions, and the rocket been filled, apply a saucisson to the end of it, and having covered the rocket with wax, pitch, &c. as before mentioned, attach it to a small rod of white willow, about two feet in length, that the rocket may conveniently float. Cork may be used, as we observed, for the same purpose. A certain quantity of meal-powder, without any mixture, put at certain distances, must be used, if it is required that these rockets should plunge down and again rise up.

Sec. II. Of Pipes of Communication.

The pipes of communication which are used under water, must be made of thick paper, and when dry covered with drying oil, [444] which must then be thoroughly dried. In oiling them leave about one and a half inches dry for joints; as the parts would not adhere where the oil was applied. The whole, however, is completely oiled after the leaders are joined, and the paste dry. These pipes will remain under water for some time without injury.

Sec. III. Of Horizontal Wheels for Water.

An octagon wheel is to be provided, made of flat boards eighteen inches in diameter, so that the length of each size will be near seven inches. In all the sides, cut a groove for the cases to lie in. Procure a wooden bowl without a handle, and on the top nail the wheel; then take four eight-ounce cases, filled with a proper charge, each about six inches in length. When the wheel is to be clothed with these cases, get some whitish-brown paper, and cut it into slips of four or five inches broad, and seven or eight long. These slips being pasted all over on one side, take one of the cases, and roll one of the slips of paper about one and a half inches on its end, so that there will remain about two and a half inches of the paper hollow from the end of the case. This case is to be tied on one of the sides of the wheel, near the corners of which holes must be bored, through which the pack thread is put to tie the cases. Having tied on the first case at the neck and end, put a little meal-powder in the hollow paper; then paste a slip of paper on the end of another case, the head of which put into the hollow paper of the first, allowing a sufficient distance from the tail of one to the head of the other for the pasted paper to bend without tearing. The second case is to be tied on in the same manner as the first, and so on with the rest except the last, which must be closed at the end; unless it is to communicate to any thing on the top of the wheel, such as fire-pumps, or brilliant fires, fixed in holes cut in the wheel, provided they be not too heavy for the bowl.

Before the cases are tied on, the upper part of all their ends except the last should be cut shelving, that the fire from one may play over the other, without being obstructed by the case. Wheel cases have no clay driven in their ends, nor are they pinched, but always left open; only the last, or those which are not to lead fire, which must be well secured.

Sec. IV. Of Water Mines.

A bowl and wheel, as above described, are necessary for this exhibition; but with this difference that in the wheel there must be [445] a hole large enough to receive the mine. These mines are tin pots, with strong bottoms, and a little more than two diameters in length. The mine must be fixed in the hole in the wheel, with its bottom resting on the bowl; then loaded with serpents, crackers, stars, small water rockets, &c. in the same manner as pots of aigrettes; but in the centre fix a case of Chinese fire, or a small gerbe, which must be lighted at the beginning of the last case on the wheel. These wheels are to be clothed as usual.

Sec. V. Of Fire Globes for the Water.

Bowls for water globes must be very large, and the wheels on them of a decagon form. On each side of the wheels, nail a piece of wood four inches long; and on the outside of each, cut a groove, wide enough to receive about one-fourth of the thickness of a four-ounce case. These pieces of wood must be nailed in the middle of each face of the wheel, and fixed in an oblique direction; so that the fire from the cases may incline upwards. The wheel being thus prepared, tie in each groove a four-ounce case, filled with a gray charge. Then carry a leader from the tail of one case to the mouth of another.

Globes for these cases are made of two tin hoops, with thin edges outwards, fixed one within the other, at right angles. The diameter of these hoops must be somewhat less than that of the wheel. Having made a globe, drive in the centre of the wheel, an iron spindle, which must stand perpendicular, and be in length four or six inches more than the diameter of the globe.

The spindle serves as an axis, on which the globe is fixed, which, when done, must stand four or six inches from the wheel. Round, on one side of each hoop, must be soldered small bits of tin, two and a half inches distant from each other. These pieces must be two inches in length each, and only fastened at one end, the other ends being left loose, on which to turn round the small port-fires, to hold them on: These port-fires must be made of such a length, as will last out the cases on the wheel. There need not be any port-fires at the bottom of the globe, within four inches of the spindle; for, if there were, they would have no effect, but only burn the wheel. All the port-fire must be placed perpendicular from the centre of the globe, with their mouths outwards; and must all be clothed with leaders, so as all to take fire with the second case of the wheel; which cases must burn two at a time opposite to [446] each other. When two cases of a wheel begin together, two will end together; therefore the two opposite end cases must have their ends pinched, and secured from fire. The method of firing such wheels is, by carrying a leader from the mouth of one of the first cases to that of the other; which leader, being burnt through the middle, will give fire to both at the same time.

Sec. VI. Of Odoriferous Water Balloons.

Odoriferous works are generally fixed in rooms, and, when speaking of scented fire, we noticed such compositions as would communicate an agreeable odour to the air. Water balloons are made in the same manner as air balloons, but very thin of paper, and in diameter 1¾ inches, with a vent, ½ an inch in diameter. The shells being made, and quite dry, are filled with odoriferous composition, which must be rammed in tight. These balloons are fired at the vent, and put into a bowl of water.

Water rockets may also be made of any of the following compositions, with a little alteration to make them weaker or stronger.

1.	Saltpetre,	2	oz.
	Sulphur,		—
	Camphor,	½	—
	Yellow Amber,	½	—
	Charcoal dust,	¾	—
	Flowers of benzoin,	¼	—
2.	Saltpetre,	2	oz.
	Sulphur,	½	—
	Antimony,	½	—
	Amber,	½	—

	Cedar-raspings,	¼	—
	Oil of roses,	10	drops.
	Oil of bergamot,	40	drops.
3.	Saltpetre,	12	oz.
	Meal-powder,	3	—
	Frankincense,	1	—
	Myrrh,	½	—
	Camphor,	½	—
	Charcoal,	3	—
	Oil of Spike,	a small quantity.	
4.	Saltpetre,	4	oz. [447]
	Sulphur,	1	—
	Sawdust of Juniper,	½	—
	Sawdust of Cypress,	1	—
	Camphor,	¼	—
	Myrrh,	¼	—
	Dried rosemary,	¼	—
	Cortex elaterii,	½	—

Sec. VII. Of Water Balloons.

Having made some thin paper shells, fill some with the composition for water balloons, and some after this manner: Having made the vent of the shells pretty large, fill them almost full with water-rockets, marrons, squibs, &c. Then put in some blowing powder, sufficient to burst the shells, and afterwards fix in the vent a water-rocket, long enough to reach the bottom of the shell, and its neck to project a little out of the vent. This rocket must be opened at the end, to fire the powder in the shell, which will burst the shell, and disperse the small rockets, &c. in the water. When the large rocket is well secured in the vent of the shell, take a cork float with a hole in its middle, which fits over the head of the rocket, and fasten it to the shell. This float must be large enough to keep the balloon above water.

Composition for Water-Balloons.

1.	Saltpetre,	4	lbs.
	Sulphur,	2	—
	Meal-powder,	2	—
	Antimony,	4	oz.
	Sawdust,	4	—
	Glass-dust,	1¼	—
2.	Saltpetre,	9	lbs.
	Sulphur,	3	—
	Meal-powder,	6	—
	Rosin,	12	oz.
	Antimony,	8	—

The following composition is given for Water-Globes.

Grain, or Corn-powder,	1	lb.
Saltpetre,	32	—
Sulphur,	8	—
Scraped ivory,	1	oz.
Sawdust (previously soaked in saltpetre and dried)	8	lbs.

Sec. VIII. Of Water Squibs. [448]

These are generally made of one-ounce serpent cases, seven or eight inches long filled two-thirds with charge, and the remainder bounced. The common method of firing them is this: Take a water-wheel, with a tin mortar in its centre, which load with squibs after the usual method; but the powder in the mortar must be no more than will throw the squibs out easily into the water. The cases may be placed on the wheel, either obliquely or horizontally, and on the top of the wheel, round the mortar, fix two cases of brilliant fire perpendicularly to the wheel. These cases must be fired at the beginning of the last case of the wheel, and the mortar at the conclusion of the same.

Sec. IX. Of the Water Fire-Fountain.

A float made of wood, three feet in diameter is to be provided. In the middle, a perpendicular post, four feet high and two inches wide must be inserted. Three circular wheels, made of thin wood, but without spokes, are fixed round this post. The largest of these wheels must be placed within two or three inches of the float, and must be nearly of the same diameter. The second must be 2 feet 2 inches in diameter, and fixed at the distance of two feet from the first. The third wheel must be 1 foot 4 inches in diameter, and fixed within six inches of the top of the post.

The wheels being arranged, take 18 four or eight-ounce cases of brilliant fire, and place them round the first wheel, with their mouths outwards, and inclining downwards. On the second wheel, place thirteen cases of the same, and in the same manner as those on the first. On the third, place eight more of these cases, in the same manner as before, and on the top of the post, fix a gerbe. Then clothe all the cases with leaders, so that they and the gerbe may take fire at the same time. The float should be tried first in the water, to see if the fountain stands upright.

Sec. X. Of Swans and Ducks, to discharge Rockets in Water.

This experiment may be made, by forming swans, or ducks of paper, leaving a cavity within. They are to be filled with small water-rockets, with some blowing powder to throw them out. Having made and painted some swans, fix them on floats. Then in the [449] place where their eyes should be, bore holes two inches deep, inclining downwards, and wide enough to receive a small port-fire. The port-fire case for this purpose must be made of brass, two inches long, and filled with a slow bright charge. In the middle of one of these cases, make a little hole. Then put the port-fire in the eye-hole of the swan, leaving about half an inch to project out, and in the other eye, put another port-fire, with a hole made in it. Then, in the neck of the swan, within two inches of one of its eyes, bore a hole slantwise, to meet that in the port-fire. In this hole, put a leader, and carry it to a water-rocket, that must be fixed upon its tail, with its mouth upwards. On the top of the head, place 2 one-ounce cases, four inches long each, driven with brilliant fire. One of these cases must incline forwards, and the other backwards. They must be lighted at the same time as the water-rocket; to do which, bore a hole between them in the top of the swan's head, down to the hole in the port fire, to which carry a leader. If the swan is filled with rockets, they must be fired by a pipe from the end of the water-rocket, under the tail. When the swan is put in the water, the two eyes are to be lighted.

Sec. XI. Of Discharging Rockets under Water.

Stands must be made as usual, only the rails must be placed flat instead of edgewise, and have holes in them for the rocket sticks to go through; for if they were hung upon hooks, the motion of the water would throw them off. The stands being made, if the pond is deep enough, sink them at the sides so deep, that, when the rockets are in, their heads may just appear above the surface of the water. To the mouth of each rocket fix a leader, which must be put through the hole with the stick. Then a little above the water must be a board, supported by the stand, and placed along one side of the rockets; and the ends of the leaders are to be turned up through holes made in this board, exactly opposite the rockets. By this means, they may be fired singly, or at once. Rockets may be fired by this method in the middle of a pond, by a Neptune, a swan, or a water-wheel.

A rocket, which is fired in the water, and, after burning there half the time of its duration, mounts into the air with great velocity, may be thus constructed. Take a sky-rocket, furnished with a rod, and, by means of a little glue, attach it to a water- [450] rocket, but only at the middle, in such a manner, that the latter will have its neck uppermost. Adjust to their extremity, a small tube, to communicate fire from the one to the other, and cover both with a coating of wax, pitch, &c. that they may not be damaged by the water. Then attach to the sky-rocket, after it has been thus cemented to the aquatic rocket, a rod, and, by means of a string, support a musket bullet, made fast to the rod by means of a needle or piece of iron. When these arrangements have been made, set fire to the match after the rocket is in the water, and, when the composition is in part consumed, the fire will be communicated through the small tube to the other rocket. The latter will then rise and leave the other, which will not be able to follow it, on account of the weight adhering to it.

Sec. XII. Of the Representation of Neptune in his Chariot.

This representation is performed by procuring a figure made of wood, or wicker wood, of the proper size, and supporting it on a float, on which must be two horses' heads and necks, so as to appear swimming. For the wheels of the chariot, there must be two vertical wheels of black fire, and, on Neptune's head, a horizontal wheel of brilliant fire, with all its cases to play upwards. When this wheel is made, cover it with paper, or pasteboard, cut and painted like Neptune's coronet; then let the trident be made without prongs; but, instead of them, fix three cases of a very weak gray charge, and on each horse's head, put an eight ounce case of brilliant fire, and on the mouth of each, fix a short case of the same diameter, filled with the white flame composition, sufficient to last out all the cases on the wheels. These short cases must be open at bottom, that they may light the brilliant fires. For the horses' eyes, put small port-fires, and, in each nostril, put a small case, filled half with gray charge, and the rest with port-fire composition.

If Neptune is to give fire to any building on the water; at his first setting out, the wheels of the chariot and that on his head, with the white flames on the horses' heads, and the port-fires in their eyes and nostrils, must be all lighted at once. Then, from the bottom of the white flames, carry a leader to the trident. As the figure is to advance by the help of a block and cord, it must be so managed as to prevent its turning about, till the brilliant fires on the horses and the trident begin. For it is by the fire from the horses (which plays almost upright,) that the building, or work is lighted, which must be thus prepared. From the mouth of the [451]
case, which is to be first fired, hang some loose quick-match, to receive the fire from the horses. When Neptune is only to be shown by himself, without setting fire to any other of the works; let the white flames on the horses be very short, and not to last longer than one case of each wheel; and let two cases of each wheel burn at a time.

Sec. XIII. Of the Representation of a Sea-Fight with Small Ships, and the Preparation of a Fire-Ship.

Having procured a number of small ships of two or three feet in length, prepare a number of small reports, which are to serve for guns. Of these, range as many as you please on each side of the upper decks. Then, at the head and stern of each ship, fix a two-ounce case, eight inches long, filled with slow port-fire composition; but take care to place it in such a manner, that the fire may fall in the water, and not burn the rigging. In these cases, bore holes, at unequal distances from one another; but make as many in each case as half the number of reports; so that one case may fire the guns on one side, and the other, those on the opposite. The method of firing the guns is by carrying a leader from the holes in the cases to the reports on the decks. These leaders must be made small, and care must also be taken in calculating the burning of the slow-fire in the regulating cases, that more than two guns be fired at a time. To give a broadside, let the leader be carried to a cracker, placed on the outside of the ship; which cracker must be tied loose, or the reports will be too slow. In all the ships, put artificial guns at the port-holes.

Having filled, and bored holes in, two port-fires for regulating the guns in one ship, make all the rest exactly the same. Then, when the engagement has commenced, light one ship first, and set it a sailing; and so on with the rest, sending them out singly, which will make them fire regularly, at different times, without confusion; for the time between the firing of each gun will be equal to that of lighting the slow-fires.

The fire-ship may be of any size. To prepare a ship for this purpose, make a port-fire, equal in size to those in the other ships, and place it at the stern. In any port, place a large port-fire, filled with very strong composition, and painted in imitation of a gun, and let them all be fired at once by a leader from the slow fire, within two or three diameters of its bottom. All along both sides, on [452]
the top of the upper deck, lay star-composition, about half an inch thick and one broad, which must be wetted with thin size, then primed with meal-powder, and secured from fire by pasting paper over it. In the place, where this composition is laid, some little tacks, with flat heads, are to be driven, to secure it fast to the deck. This must be fired just after the *sham* guns, and, when burning, will show a flame all round the ship. At the head, take up the decks, and put in a tin mortar, loaded with crackers, which mortar must be fired by a pipe from the end of the slow fire. The firing of the mortar will sink the ship, and make a pretty conclusion.

Having prepared all the ships for fighting, we shall next proceed with the management of them when on the water.

At one end of the pond, under the surface of the water, fix two running blocks, at the distance the ships are to fight apart, and at the other end of the pond, opposite to each of these blocks, under water, fix a double block. On the land, by each of the double blocks, place two small windlasses. Round one of them, turn one end of a small cord, the other end of which is to be put through one of the blocks. Then carry it through the single one at the opposite end of the pond, and bring it back through the double block again, and round the other windlass. To this cord, near the double block, tie as many small strings, as half the number of ships, at the distance required. These strings, however, should not be more than two feet each. Make fast the loose end of each to a ship, just under the bowsprit, but if tied to the keel, or too near the water, it will overset the ship. Half the ships being thus prepared, near the other double block, fix two more windlasses, to which fasten a cord, and to it, tie the other half of the ships as above. When the ships are fired, turn that windlass which draws them out, and so on with the rest, till they are all out in the middle of the pond. Then by turning the other windlass, they will be drawn back again; by which method, they may be made to change sides, and tack about backwards and forwards at pleasure.

For the fire-ship, fix the blocks and windlass between the others; so that, when she sails out, she will be between the other ships. She must not advance, however, till the guns at her ports take fire.

In the exhibition of water fire-works, it is obvious, from the observations we have made, and the different pieces prepared for that purpose, that such exhibitions may be varied, and even new pieces got up.

CHAPTER XII. [453]

OF THE ARRANGEMENT OF FIRE-WORKS FOR EXHIBITION.

Jones (*Fire-works*, 8vo. 1776) observes, among other remarks, that nothing adds more to the appearance of fire-works, than placing them properly; though the management of them chiefly depends on the judgment of the maker. When water-works are to be exhibited, divide them into several sets, and fire one set after every fifth or sixth change of land and air works. Observe this rule in firing a double set of works; always to begin with sky-rockets; then two moveable pieces; then two fixed pieces, and so on; ending with a large flight of rockets, or a marron battery. If a single collection, fire a fixed piece after every wheel or two, and occasionally some air and water works.

The rules, adopted in the arrangement of fire-works for exhibition, are the following: If they are a double set, place one wheel of a sort on each side of the building; and, next to each of them, towards the centre, place a fixed piece; then wheels and so on, leaving a sufficient distance between them, for the fire to play from one, without burning the other. Having fixed some of the works in front, place the rest behind them, in the centre of the intervals. The largest piece, which is generally a regulated or transparent piece, must be placed in the centre of the building; and behind it a sun, which must always stand above all the other works. A little before the building, or stands, place the large gerbes; and, at the back of the works, fix your marron batteries, pots des aigrettes, pots des bins, pots des saucissons, air balloons, and flights of rockets. The rocket-stands may be fixed behind, or any where else, so as not to be in the way of the works.

Single collections are fired on stands, which stands are made in the same manner as theodolite stands; only the top part must be long or short, according to circumstances. These stands may be fixed up without much trouble. The following is the order of firing works, *viz*:

1.	Two signal	Rockets.	
2.	Sky		
3.	Two honorary		
4.	Four caduceus		
5.	Two	Vertical	Wheels, illuminated. [454]
6.		Spiral	
7.		Transparent stars.	
8.	A line of rockets of five changes.		
9.	Four tourbillons.		
10.	Two	Horizontal wheels.	
11.		Air-balloons, illuminated.	
12.		Chinese fountains.	
13.		Regulating pieces, of four mutations each.	
14.		Pots des aigrettes.	
15.	Three large gerbes.		
16.	A flight of rockets.		
17.	Two	Balloon wheels.	
18.		Cascades of brilliant fire.	
19.	Twelve sky-rockets.		
20.	Two	Illuminated yew trees.	
21.		Air balloons of serpents, and two compound.	
22.	Four tourbillons.		
23.	Two	Fruiloni wheels.	
24.		Illuminated globes with horizontal wheels.	
25.	One pot des saucissons.		
26.	Two plural wheels.		
27.	Marron battery.		
28.	Two chandeliers, illuminated.		
29.	Range of Pots des brins.		
30.	Twelve sky-rockets.		
31.	Two yew-trees of fire.		
32.	Nests of serpents.		
33.	Two double cones, illuminated.		
34.	Regulating piece of seven mutations, viz.		
	1. Vertical wheel, illuminated.		
	2. Golden glory.		
	3. Octagon vertical wheel.		
	4. Porcupine's quills.		
	5. Cross fires.		
	6. Star piece with brilliant rays.		
	7. Six vertical wheels.		
35.	Brilliant sun.		
36.	Large flight of rockets.		

According to the arrangement, and execution of fire-works for exhibition, as given by Morel (*Traité Practique des Feux d'Artifice*, p. 131,) the following order is observed:

1. A salvo of artillery.
2. Six dozen rockets of honour, discharged two at a time from each side of the decoration.
3. Twelve Bengal lights, distributed in such a manner, as to light all parts of the decoration. [455]
4. Two batteries of ordnance, (fire-pots.)
5. Four regulated cases, each consisting of two dozen rockets of an inch caliber, forming the *mosaique* at the elevation of five hundred feet.
6. Eight turning suns, with the caliber of five-sixths of an inch.
7. Four caprices (detonating.)
8. Two balloons of golden rain, and two in stars.
9. The pyric piece, complete.
10. Twelve tourbillons, or table rockets.
11. Four girandoles; two mosaic, and two of Roman candles.
12. A large sphere.
13. Six balloons; three in golden rain, and three in stars.
14. Twenty-four honorary rockets, fired four at a time.
15. A large illuminating cut-work, with a device, accompanied with two Chinese parasols, and two wheels of coloured fire.
16. Four falling caprices.
17. Twelve balloons of stars, preceded by six dozen honorary rockets, fired twelve at a time.
18. The undulating fire, accompanied with eight *wings*, four on each side.
19. A battery of two hundred mosaics, and as many Roman candles, with marrons and fire-pots.
20. Illumination of the decoration, with four mosaic tourbillons, followed by two cases, containing two hundred rockets each; and a salvo of artillery, which announces the departure of the *girande*, composed of a thousand rockets, in golden rain.

PART IV. [456]

MILITARY PYROTECHNY.

CHAPTER I.

OBSERVATIONS IN GENERAL.

Laboratory-works comprehend all the operations of the *workshop*, connected with this branch of pyrotechny. The tools and instruments required for the laboratory, as well as the substances employed in the different preparations, we have already described.

Having noticed the origin of gunpowder, in the first part of our work, the following remarks in relation to that subject, namely, the history, of cannon, may be interesting.

For some time after the invention of artillery, gunpowder was of a weaker composition than that at present used, or than that described by Marcus Græcus. The first pieces of artillery were rough and very inconvenient, being usually framed of several pieces of iron bars, fitted together lengthwise, and hooped with rings. These guns were first employed in throwing stone shot of a prodigious weight, in imitation of the ancient machines, to which they succeeded, and were of an enormous bore. When Constantinople was besieged by Mahomet II. in the year 1453, the walls were battered with stone bullets, and some of the pieces were of 1200 lbs. caliber; but they could not be fired more than four times in twenty-four hours, and sometimes were burst by the first charge.

As mathematical knowledge increased in Europe, that of mechanics gradually advanced, and enabled artists, by making brass cannon of a much smaller bore for iron bullets, and capable of bearing a much greater charge of strong powder in proportion to their calibers, to produce a very material and important change in the construction and fabric of those original pieces. Guicciardin (*History*, &c. *1st book*) informs us, that, about 114 years after the first use made of those unwieldy pieces by the Venetians, in [457] their war against the Genoese in 1380, the French were able to procure, for the invasion of Italy, a great number of brass cannon, mounted on carriages, drawn by horses. He then enumerates the advantages which these pieces possessed, and particularly that they could be pointed with incredible quickness and expedition, in comparison with those formerly made use of in Italy. But, as our limits will not permit us to notice all the circumstances in connection with these pieces, it is sufficient to remark, that this change in the formation of artillery has as yet undergone no material alteration; if we except the introduction of carronades, first suggested by general Melville, and of Columbiads, by the late Mr. Barlow.

Glenie (*History of Gunnery*, 1776) appears to have been the first, who gave the theory of projectiles in vacuo by plain geometry, or by means of the square and rhombus, with a method of reducing projections on inclined planes, whether elevated or depressed below the horizontal plane, to those which are made on the horizon. The experiments, and observations, of Mr. Robins, on the subject of gunpowder, &c. may be seen in the article on gunpowder.

Besides the formation of cannon, by uniting iron bars together, and strengthening them by hoops, (one or two of which were made in Philadelphia in 1776, by a Mr. Wheeler, of a superior kind,) others were made of thin sheets of iron, rolled up together and hooped; and on emergencies, they were made of leather, with plates of iron or copper. Stone balls were used, and a small quantity of powder. In the 13th century, cannon were used in a sea fight, between the king of Tunis and the Moorish king of Seville. The Venetians used cannon at the siege of Claudia Jessa, now called Chioggia, in 1366, which were brought thither by two Germans, with some powder and leaden balls; as likewise in their wars with the Genoese in 1379. At the battle of Cressy, in 1346, Edward III made use of cannon. They were also employed in the seige of Calais, in 1347. Pieces of ordnance were made use of by the Turks, at the siege of Constantinople, then in possession of the Christians, in 1394, or in that of 1452, that threw a weight of 1006 lbs. Louis XII had one cast at Tours, of the same size. One of those cannon was taken at the seige of Dieu, in 1546, by Don John de Castra, and is in the castle of St. Juliao de Barra, 10 miles from Lisbon. Its length is 20 feet 7 inches, diameter at the centre, 6 feet 3 inches, and it discharges a ball of 1000 lbs. It has neither dolphins, rings, nor buttons, is of a curious kind of metal, [458] and has a large Indostan inscription upon it, by which it appears it was cast in 1400. The mortars at the Dardanelles are represented to throw shells, or ball of an immense size and weight.

Some do not consider cannon an European invention; because it is asserted, that authentic documents exist of their use in China, many centuries before they were thought of in Europe. If they say, the testimony of the Chinese themselves is not sufficient on this point, the fact of their great wall being furnished with embrasures, fitted in such a manner for cannon, leaves no doubt of their having been in use at the time of its erection. To this, an additional argument may be added, from their very ancient game of chess, in which pieces have been used from remote antiquity, designating engines of war, whose power was derived from gunpowder. Mr. Irvin, (*Trans. Royal Irish Academy*,) in his paper on the Chinese Game of Chess, proves, that gunpowder was in common use in China, 371 years after Confucius, or 161 years before Christ; and Du Halde has long since given documents to show, that the Chinese wall was in existence 200 years before the commencement of the Christian era; and consequently, for the reason before stated, the use of cannon must have been of at least equal antiquity. The Asiatic Researches contain some remarks to the same point. There is a strong probability then, that the invention of guns was of a much more remote date. It is not impossible, however, that the same thing may have been invented by different persons, in various parts of the world.

We mentioned, that it is much more probable, that the use of gunpowder in war was derived ultimately from the Chinese, notwithstanding the generally received opinion, that the Greek fire was the progenitor of its discovery; or that Bacon, or Schwartz, an obscure monk, has claims to the invention. The mode in which the use of gunpowder in war might have passed from China to Europe, is the most probable and simple imaginable. Zingis Khan is known to have conquered the five northern provinces of China, about the year 1234. He must have known the common use of gunpowder at that period, as it had been known in China 1400 years before. In the *Chinese annals* of the Moguls, by Yuen, as translated by Pére Gaubil, it is particularly stated, that the use of cannon and mortars was familiar in the wars and sieges of Zingis against the Chinese, both by them and him, in attack and defence. It is most probable, that he used gunpowder in his wars against Mahomet, Sultan of Carisme, whose dominions extended from the [459] Persian Gulf, to the borders of India and of Turkistan. It is known, that he had a body of Chinese engineers in his army, who, of course, must have been acquainted with the use of gunpowder.

The conquests of Zingis would thus have spread the knowledge of gunpowder, &c. over the western part of Asia; and the Europeans, in their crusades, may have had frequent opportunities of becoming acquainted with it. It was just after this time, that it became known, and was used in the European wars.

Sir Francis Bacon (*Moral and Political Essays*,) observes, that "ordnance was known in the city of Oxydraces, in India, and was that which the Macedonians called 'thunder, lightning, and magic;' and it is well known, that the use of ordnance had been common in China above two thousand years."

Beckman, (*History of Inventions*, iii, p. 434,) in his essay on the origin of guns and gun-locks, has given, at some length, the history of guns. All we can add here, is, that the first portable fire-arms were discharged by means of a match, which, in the course of time, was fastened to a cock, and afterwards a fire stone and steel plate were used. This fire stone was not a flint, but a compact pyrites, or marcasite, (sulphuret of iron), which was distinguished by that name. On each new improvement, the piece received a new name; as, *büchse*, *haken büchse*, *arquebuse*, &c. After explaining the origin of these names, he adds, that the large pieces were conveyed on carriages, called *karrenbüchse*, but soon after also *canna*, cannon. Pistols are mentioned by Beilay, in 1544, in the time of Francis I; and under Henry II, the German horsemen were called *pistoliers*. The name is derived from Pistoia, in Tuscany; because they were there first made. Muskets received their name from the Latin *muschetus*, which signifies a male sparrow-hawk. They were first used at the seige of Rhege, in the year 1521. They were known in France in the time of Francis I. Brantome, however, asserts, that they were first introduced by the Duke of Alva, in 1567, and used in the Netherlands. He also says, that they were made general in France by M. de Strozzi, under Charles XI. The lock was invented in Germany, in the city of Nuremberg, in 1517; it is uncertain whether it is the present lock. In the arsenal at Hanover, there are many ancient pieces. The oldest had on the barrel, the figure of a hen with a musket in its mouth; because it is said they were made at Henneberg. [460]

There are three species of cannon, the *gun*, the *howitzer*, and the *mortar*. The gun is the longest piece of artillery, employed at the present day: the *culverins*, *dragons*, &c. as they were formerly called, had calibers twice, and even three times as long as those now used. Guns were originally called *bombards*, and were eight calibers in length. The term *pieriers*, from *pierre*, a stone, were given to some guns, because they were employed in throwing rough stones. The carronades, derived from the river Carron, in Scotland, where they were originally made, is a short gun, with a bore about eight diameters of the shot in length. The howitzer is a species of mortar, but longer, and used to throw a hollow projectile, called a howitz, which acts at first as a *ricochet* ball. The mortar is the shortest species of cannon, and is used to throw bombs or shells. A stone mortar is used in sieges, to throw stones upon an enemy. Besides these descriptions of guns, there is another division, to which General Lallemand (*Treatise on Artillery*, vol. 1, p. 20,) has given the name of *demi-guns*, under which he ranks the *harquebus* on a swivel, the *rampart gun*, and the *repeating gun*, or *musket*, of the Americans.

He observes, that the harquebus nearly resembles the *amusette* of Marshal Saxe, has a barrel like that of a musket, and carries a ball weighing half a pound or more; that the rampart gun, or wall piece, is a large musket, that was anciently much used in the defence of fortresses, having a barrel of $5\frac{1}{2}$ or 6 feet long, and a ball from 10 to 14 to the pound; and that the repeating musket is a gun, consisting of 7 barrels, all of which discharges 32 rounds in succession, making 224 in all. With respect to this gun, the effect of which we have witnessed, not only in the discharge of thirty-two rounds from a single gun, but the combined effect of seven or more barrels, the General observes, that the diameter of the bore is three-fourths of an inch, and the weight seventy pounds. It is placed, like the rampart guns, upon a wooden frame, and has a handle at the breech to point by. As to its use, he adds:—it may be advantageously employed in the defence of places at the moment of assault; it may be useful in the field, to defend parts of a line of battle, or entrenchments, with few troops, and yet astonish the enemy by a warm fire, when he ventures to approach. Its discharge does not last a minute. It may be of great service in the tops of ships of war.

The inventor is a Mr. Chambers, of Pennsylvania. We witnessed its effect, when the President of the United States visited the [461]
navy yard in Philadelphia, where the inventor manufactured them; and also at Bush-hill, in the neighbourhood of that city. Having examined their construction, and also the shot it may be sufficient to remark, that the lead is cylindrical, one end being flat, and the other conical, and of such a size as to fit the caliber of the musket; that these rounds are pierced with a hole in the centre, which is charged with fuse composition; and, after a charge of powder, one of these cylinders is put in; then a charge, then a cylinder, &c. up to 32. The lock is placed opposite the last charge, so that when the first load is discharged, the fire communicates successively *through the cylinders*.

A repeating gun has been invented by a gentleman of New York. I have seen no description of it. The Marquis of Worcester, in his Century of Inventions, in the 58th to the 64th invention, hints at a similar contrivance; as for instance, (Inven. 58th,) "How to make a pistol to discharge a dozen times with one loading, and without so much as one new priming requisite, or to change it out of one hand into the other, or stop one's horse."

We may add, that, in 1764, M. Bouillet and Sons presented, to the Academy of Sciences, at Paris, a musket of their invention, which was lighter than the common kind, and had the property of firing twenty-four times in succession, charging and priming itself by a single circular movement of the musket upon an axis, fixed for that purpose. In the file of the *French Gazette*, for 1786, article Linberg, there is an account of an invention of the baron De Walskohl. It is the same, it would appear from the description, as the repeating musket. Being once charged, it will fire thirty-six times in succession. The experiments made with it were satisfactory.

Many patents have been secured in this country, and in England and France, for improvements on the musket and rifle; but, in order to accommodate short-sighted persons, M. Regnier's invention appears to be the first which consists in an *optic* glass fixed in the butt, enabling persons of that description to shoot with accuracy. This invention is given in the *Journal de la Blancherie* for 1779, p. 194.

In 1771, Moret, an armourer, announced a new constructed pistol, which would charge itself, &c. and in 1793, M. Gass
presented to the military committee of France, a pistol of a new construction, calculated to fire several *ball* in succession. The [462]
Journal des Inventions et Découv. i, p. 121, speaking of this invention, adds, that the means employed depended entirely on the construction of the ball, which, instead of round, was a cylinder, pierced in its length. This small canal is filled with meal-powder, and serves as the match of communication to the charges. This contrivance is much the same as the one we have described.[29]

Mr. Misson (*Travels through Germany and Italy*,) says, that in the arsenal at Venice, there is an engine which will light five hundred matches at once, and some very curious arms of ancient make, among which is a small trunk, with six little guns, which Carrara, the last lord of Padua, who was famous for his inhumanity, sent as a present to a lady; and was so contrived, that, upon opening of the trunk, the guns all fired at once, and killed her!

With respect to the invention of the various incendiary machines, we may observe generally, (as we purpose to notice them in their respective places), that Greek fire was employed in different ways, and was considered a destructive composition; that rain-fire, bombs, lances, matches, fire-balls and carcasses, torches, powder sacks, petards, &c. were all employed in more modern times for the same purpose; and, lastly, that the *fougette* of the Asiatics, called Indian rockets, the Congreve rocket, the incendiary bomb of the French, and the floating rocket carcass, are embraced under the same head, and are all used for similar purposes in war. These, and other subjects, belonging to military fire-works, we purpose to mention in this, and the following chapters.

Sec. I. Of Cartridges.

Cartridges are cases of paper, parchment, or flannel, fitted to the caliber of the piece, and holding exactly its proper charge. [463]
Strong paper is always used for musket and pistol cartridges, and the French musket-ball-cartridges are capped with flannel or coarse cotton. For heavy guns, they are made of thick, and as the English call it, of *cured* paper, with flannel bottoms. Those for field ordnance are all made of flannel, and their size suited to the bore, or chamber of pieces, for which they are intended. The ball cartridges, for wall pieces, muskets, carbines, and pistols, are made of whitish-brown paper, on formers of wood. A sheet of paper will make six for wall pieces, twelve for muskets, sixteen for carbines, and twenty-four for pistols. The quantity of powder they contain respectively is, for wall pieces ten drachms, musket six, carbine four, and pistol three drachms.

Blank cartridges, for pistols, carbines, and muskets, are made of blue paper, to preserve a distinction between ball and blank, and to prevent the possibility of accidents, from the ball cartridges being mixed with the blank.

The charge for muskets is commonly half the weight of the ball. The balls for musketry are eighteen to the pound; and one pound
of powder is sufficient for thirty-six cartridges.[30] Forty cartridges may be used to the pound, but forty-five would be too weak. [464]
The paper, necessary to form cartridges, should be well sized and not too thick. It is made for the purpose, under the name of cartridge paper, and should be of such a size as to cut to advantage. It is usually fourteen inches in length, and sixteen in breadth. A sheet will form twelve cartridges, but on account of wastage, it makes only ten. Half a sheet is employed as a wrapper for every ten cartridges, and one and a half sheets are used for ten and their wrapper. Six quires will make 1000 cartridges, and 31 reams, 100,000. Five ounces of packthread are necessary for binding 1000 cartridges, and 31 lbs. for 100,000.

Musket cartridges are made in the following manner. Long tables are provided, and, at certain distances, excavations, or holes are made, larger than the diameter of the ball, and one-third of its diameter in depth. These holes are designed for rounding the folds upon the ball. It is necessary first to be provided with formers to roll the cartridges upon, and measures to fill them with. These formers are made of hard and dry wood, seven inches, or seven and a half inches in length, and six-tenths of an inch in diameter, one-twelfth of an inch less than the diameter of the caliber. One end is rounded so as not to hurt the hand; the other is hollow, to receive one-third of the ball. The measures are in the form of the frustrum of a cone, open above. They are made of sheet-tin, and should contain one-fortieth part of a pound of powder, (one-forty-ninth according to the Strasburgh directions), or, when heaped, one thirty-sixth part of a pound. The height of these measures is one inch and a quarter; their diameter at the large end one inch and one-twelfth, and at the smaller end, three-quarters of an inch. In every squad of ten men, six are employed to roll the cartridges, two to fill them, and two to pack them. Each squad may make 10,000, but commonly 8,000, in a day.

To cut the paper for musket cartridges, we begin by folding the sheet in three parts widthwise; then each third part into two, again into three, and again into two, by a diagonal line which takes from 2.2 inches of a superior angle on the left, to 2.2 of the opposite inferior angle at the right; so that every sheet of paper will cut, without loss, into twelve parts, and every part will be 5.68
inches in height, 4.53 in width at one end, and 2.2 at the other end. According to Bigot, however, each trapezoid thus formed is $5\frac{1}{3}$ [465]
inches in length, $4\frac{1}{4}$ in width at one end, and $2\frac{1}{4}$ at the other end. The paper is cut by a person detailed for the purpose.

The person who rolls the cartridges, having spread the cut paper upon a table, takes the form with one hand, and the ball in the other, which he puts into the hollow of the form; after which, he rolls the paper round the ball and the form, so that there remains sufficient beyond the ball, to fold over in small folds; then he rolls the form surrounded with the paper, and having rounded the folds upon the ball, in a small hole made for that purpose in the table, he withdraws the form, and passes the cartridge to the man who is to fill it. He puts in the charge with a small tin measure, folds the paper over upon the powder as close as possible, and passes it on to him who is to make the packages. The packer takes ten in his hand, and arranges them on a sheet of paper folded in two, the balls half on one side and half on the other; and having wrapped them in the paper, he folds over the two ends, and ties the packets crosswise over the middle, and lengthwise.

Musket cartridges cannot be too tightly rolled upon the form; and to ascertain their accuracy, they must be calibered before they are loaded; that is, they must be put into the end of a musket. He who fills them, should make a charge complete in every cartridge, and not load one more than another, but always pour a full measure into every one. The packer should tie the cartridges, and round them as much as possible, without tearing the paper. He should take care that all the packets are of the same length; so that they may be placed in the partitions of the ammunition chest, which are all of one determined length, and will not therefore contain them, if made too long.

Cannon cartouches should be well arranged in the ammunition chests, and well stowed with tow, that they may be carried without danger of injury from the road. The tow is pressed down in small quantities, by a little wooden spatula, and cannot be pressed too hard; for the more the chests are stuffed with tow, the better the ammunition will be preserved.

Musket cartridges are placed in the ammunition chests in different arrangements, the height of which is proportioned to that of the cartridge. There are three stories in height in each chest, for musket cartridges; and between each a small separation, to prevent them from injuring each other. The number of cartridges contained in an ammunition wagon is proportioned to the kind of [466] wagon in use, and to the quantity necessary for the service. The common load of ammunition wagons does not exceed thirteen hundred weight, if it is meant to take the benefit of forced marches. In every ammunition wagon for cannon cartouches, there are cartouches with ball, grape-shot, quick-match, and port-fires, staffs for port-fires, priming wires and match-rope—so that every wagon contains all kinds of ammunition relative to its caliber. In an ammunition wagon filled with musket cartridges, a certain number of flints are contained, to be distributed to the troops from the same chest whence they receive their ammunition.

We might here speak of the load of every ammunition wagon; but this subject more particularly belongs to artillery and its suite, than to fire-works.

Cartridges, used in sieges, &c. are made of paper bags, of the calibers of the different pieces, and of a sufficient length to contain the requisite quantity of powder. The paper should be large and strong.

The handle of each of the formers should have such a length and size, as to render them convenient to hold in the hand. Care must be taken to pierce a small hole in the middle, through the whole length of the form, by which the air might enter to the cartouches, and cause the form to be more easily drawn out, after the cartridge is made.

Pasted cartridges are formed in the usual manner upon a former; and when five-sixths of the paper are rolled, the remaining portion is pasted with a paste made of flour and glue, mixed together. The bottom is pasted over in the same manner. When the cartridge is drawn off the former, it is placed to dry in the sun, or near a stove.

With regard to the cost of cartridges in France, it appears, that a pound of packthread costs twelve sous, and workmen receive from fifteen to twenty sous per thousand for their labour. The whole expense of 100,000 would be, for paper, 105 livres; for packthread, 18 livres, 15 sous; for making 100 livres; total 223 livres, 15 sous. Bigot has furnished us with the following estimate:

For 31 reams of paper, at 4 fr. 50 c. the ream, is		140 fr.	60 c.
For 31¼ lbs. of packthread at 80 centimes,		24	
Labour, 1 fr. per thousand,		100	
Five days work, for the cutter,		5	
		——————	
	Total.	269 fr.	60 c.

[467]

One hundred thousand cartridges, for which the above is a calculation, require also

Bullets of lead,	5556 lbs.
Powder,	2500 lbs.

Sec. II. Of Cannon Cartridges.

The *gargousse* of the French, in artillery, is a sack or bag of paper, or parchment, destined to enclose the load of a cannon. When it is made of serge, it is then called a pouch, (*sachet*); and, when united with the ball, it receives the name of ball-cartridge.

Bigot remarks, that these cartridges have been substituted for the dangerous and unsafe use of the spoon, or ladle, (*lanternes*, Fr.[31]), by means of which the load was carried to the bottom of the piece. They are paper bags or sacks, of the caliber of the gun. The loading is much more expeditious, and less danger is to be apprehended. It requires only, that the piece should be well sponged, and the priming to communicate with the load.

For the construction of these cases, coarse gray paper, and sufficiently strong, is used; and they should be well pasted. The paper, which is used with advantage, and commonly employed, is 23 inches in length, and 28 inches in breadth. It serves for all calibers, and even proof charges, which are stronger than the ordinary loads. The paper is cut of such a size as to leave from $1\frac{1}{4}$ inches, to $1\frac{1}{2}$ inches, on the roller, and a sufficiency to cover the lower extremity. One of the sides, as well as the side which is cut, is pasted. The paper is rolled upon the former, or roller, and is straightened, so that the hand may be passed over the pasted part, and the paper tightened. The bottom of the bag is placed upon the roller, and, in folding it, the bag is tied above that part of the paper, which is pasted. The bag is then dried, by placing it on one end upon a table, and exposing it to the air.

The rollers should be bored in their axis, so that, in drawing them out, they may come out easy, and without injuring the bag. This hole admits the external air, and prevents the formation of a vacuum in a degree, when the roller is suddenly withdrawn. The [468] bottoms (*culots*,) are cut of the same diameter as the roller. The paste is made of flour and glue.

The table given by Bigot, p. 28, relative to the dimensions of sacks or cartridges, for cannon, embraces the following particulars: The diameter of the former, or roller for a 24 pr. is $5\frac{1}{6}$ inches: for a 16, $4\frac{1}{2}$; for a 12, 4; for an 8, $3\frac{1}{2}$; for a 6, $3\frac{1}{6}$; and for a four pounder $2\frac{3}{4}$ of an inch: the circumference of the cartridge for a 24 pr. is $17\frac{2}{3}$ inches; for a 16, $15\frac{3}{12}$ths; for a 12, $13\frac{1}{3}$; for an 8, $12\frac{11}{12}$; for a 6, $6\frac{1}{2}$; for a 4, $9\frac{2}{3}$ds inches. The height of the roller for a 24 pr. is 18 inches; for a 16, 15; for a 12, 14; for an 8, 13; for a 6, $12\frac{1}{2}$, and for a 4, 12. The height of the paper, including the circumference, for a 24 pr. is $17\frac{2}{3}$ inches; for a 16, 14; for a 12, 14; for an 8, 11; for a 6, $10\frac{1}{2}$; for a 4, 10. The height, which covers the cartridge, is for a 24 pr. $1\frac{5}{10}$ inches; for a 16, $1\frac{3}{12}$; for a 12, $1\frac{1}{12}$; for an 8, $\frac{11}{12}$; for a 6, $\frac{10}{12}$; and for a 4, $\frac{9}{12}$. The bottom (*culot*,) for a 24 pr. is $1\frac{2}{12}$th inches; for a 16, 1; for a 12, $\frac{10}{12}$; for an 8, $\frac{2}{3}$ds; for a 6, $\frac{7}{12}$; and for a 4, $\frac{1}{2}$ inch. The height of the charge for a 24 pr. is $11\frac{1}{6}$ for a 16, $8\frac{1}{2}$; for a 12, $8\frac{1}{6}$; for an 8, $7\frac{1}{3}$; for a 6, $6\frac{9}{11}$; and for a 4, $6\frac{2}{12}$ths inches. The height of the paper, for the charges of exercise, is for a 24 pr. 10 inches; for a 16, 9; for a 12, 8; for an 8, 7; for a 6, $6\frac{1}{2}$; and for a 4, 6 inches.

In the table of the proportions of the charge, for different calibers, given by Ruggieri, (*Pyrotechnie Militaire*, p. 197,) besides the weight of the ball, and the height of the sack, the weight of the charge is given in pounds, and ounces, which is thus stated by him: for a 4 pr. 1 lb. 8 oz; an 8 pr. 2 lbs. 8 oz; a 12 pr. 4 lbs. 8 oz; a 16 pr. 5 lbs; and a 24 pr. 8 lbs.

Cannon Cartouches are composed of a bag of serge, and a shoe or base, in which the ball was fixed by means of a tin cross, nailed to the shoe or base. The bag should be as large as the shoe, and long enough to contain the requisite quantity of powder. The shoe is a little less in diameter than the ball, so that the tin and the bag put upon it, do not increase its size beyond that of the ball. The shoe is flat on one side, and hollow on the other. The hollow part should be a spherical concavity, about one-third of the diameter of the ball. At a small distance from the bottom of the shoe, a groove is made sufficiently deep to contain the packthread, with which it is fastened to the bag.

In the construction of cannon cartouches, the ball must first be fixed to the base by means of two tin bands in the form of a cross, and nailed with two small nails at the bottom and sides of the base. These bands for sixteen and twelve pounders, are at [469] least .44 decimal parts of an inch in width, and 15 inches long. Those for eight and four pounders, are .355 decimal parts of an inch in width, and 11.72 inches in length.

The ball being fixed on this base, it is put into a bag filled with powder, and the bag tied above to the base. Then a bit of parchment soaked in water, of from two to four inches in width, and of sufficient length to go round the cartouch, is placed round the bag, half on the shoe and half on the powder. Then tie it with a string passing in the groove, at about .27 parts of an inch below the base; so that the cartouch is tied in three different places—the two first above in the groove of the shoe, serves to hold the bag and it strongly together; the third below, is to prevent the powder from rising and slipping between the bag and the shoe. The band is placed on the part where the greatest friction is, to preserve the bag from being torn.

The cartouch thus made, is to be calibered by trying it with the piece for which it is intended, into which it must enter with ease. This cannot be too strongly recommended. It is of all things the most essential, and the only way of ascertaining the goodness of ammunition.

A workshop of twelve workmen is divided into four classes. The first class consists of two men who put the ball into the shoe; the second of two others who fill the bag with powder; the third, two others who press the powder into the bag; and the remaining six are employed in tying the bags to the shoes, two to each.

These twelve workmen can, in one day of twelve hours, make two hundred and forty cartouches, of sixteen or twelve pounders, or 320 of eight or four pounders.

Table relative to the Cartouch, or Pouch.

For	12	8	6	4	Light Troops
Height, without the folds.	Inches. 11	Inches. 10	Inches. 9½	Inches. 9	Inches. 6
Circumference, without the folds.	$12\frac{7}{12}$	$10\frac{9}{12}$	9¾	8½	$5\frac{3}{12}$
Diameter of the base, without the folds.	4	$3\frac{5}{12}$	$3\frac{1}{12}$	$2\frac{9}{12}$	$1\frac{8}{12}$

To make *grape shot*, we must have a bag of ticking, in which the small balls are arranged; also a shoe, to which not only the bag which contains the ball is attached, but also the serge filled with powder. [470]

The shoe is made of the same wood with the ball cartridges, and of the following dimensions, viz. The sixteen pounder should have 4.97 inches diameter; the twelve pounders, 4.35; the eight pounders, 3.82; and the four pounders, 3.1 inches diameter. Those of the caliber of sixteen and twelve, should be 1.6 inches in thickness, with a groove in the middle of .44 parts of an inch in depth, and the same in width; the eight and four pounders have but 1.07 inch in thickness, with a groove in the middle of .36 parts of an inch in depth and width. Every shoe or base, has a pin in its centre, the size of which is in proportion to the vacancy left by the small balls of iron arranged about it. The height is in proportion to the different layers of ball.—In general thirty-six balls are put into one grape shot, of whatever caliber it be; that is to say, six heights of six each. The balls should be proportioned to the caliber, so that the six balls on the base should exactly fill the circumference of it. The pin in the middle of the base is exactly the size of the ball and seven times its diameter in height. At the top of the pin a groove is made to tie the threads, the width of which is one-third, and the depth, one-fourth of its diameter.

The bag in which the small balls are arranged, layer upon layer, should be of good strong ticking closely woven. It is of the size of the shot, and 2.13 inches in length above the top of the pin. It is strongly fastened at the bottom in the groove of the base with strong pack-thread. There must be $3\frac{1}{2}$ fathom of strong pack-thread trebled, to tie the grape of the caliber of sixteen and twelve pounders, and three fathom only for one of eight and four.

Grape shot may be corded in the same manner as the carcase is corded; with this difference, instead of eight turns, taking only six. The best and strongest method of tying the thread in grape-shot, is in the net-work form—one person holding, and another tying it.

In a work-shop where ten men are employed, eight are employed to wind the thread round, and two to attach the bag to the base or shoe, or to arrange the small balls on the shoe, round the pin. Such a work-shop, in a day of ten hours, can complete 120 grape-shot of the largest caliber, and as many as 140 of eight or four pounders might be made.

The grape shot composed of 36 iron balls, weigh, without their charge of powder, as follows: [471]

		lb.	oz.
For	a caliber of 16	21	10
For	do. of 12	16	$3\frac{1}{5}$
For	do. of 8	10	$12\frac{4}{5}$
For	do. of 4	6	3⅓

The diameters of the small balls for grape shot, of which six exactly fill the circumference, are as follows:

For 16 pounders,	1.66 inch.	For 8 pounders,	1.31 inch.
For 12 do.	1.5 do.	For 4 do.	0.16 do.

M. Bigot has given the following Table relative to Cartouches, and their Balls.

Calibers.	12	8	6	4	Light Troops
Charge of powder.	lbs. oz. 4 0	lbs. oz. 2 ½	lbs. oz. 2 0	lbs. oz. 1 ½	lbs. oz. 0 17
Weight of the cartouch and ball.	16 11	11 2	8 ½	5 12	2 1
Height of the charge of powder.	Inches. $8\frac{3}{12}$	Inches. $6\frac{9}{12}$	Inches. $6\frac{3}{12}$	Inches. $6\frac{1}{12}$	Inches. $5\frac{1}{12}$
Total height of the cartouch.	13½	11½	$10\frac{8}{12}$	$9\frac{11}{12}$	$7\frac{8}{12}$

CHAPTER II.

OF MATCHES.

Matches, in artillery, are a kind of rope made of flax, hemp, or cotton slightly twisted, and prepared to retain fire for the use of artillery, mines, fire-works, &c. Bigot, (*Traité d'Artifice de Guerre*, p. 64,) has considered this subject under three heads; namely, of match-rope, priming fuses or tubes, and quick-match. We purpose, therefore, in the following sections, to treat the subject in this order.

Sec. I. Of Slow Match.

Slow-match may be prepared by different processes. When hemp or tow is spun on the wheel like cord, but very slack, and made [472] into three twists and then covered with tow, so that the twists do not appear, and then boiled in the lees of old wine, a slow-match will be formed which burns very gradually; but slow-match is commonly made after the following method: The rope for this match is made of flax, or of soft well-beaten hemp, thoroughly cleansed from the harder fibres, and the strands are loosely spun. Three strands are sufficient, which should not, when formed into rope, exceed one inch and two-thirds in thickness. It should not be shortened in twisting more than one-fifth, or one-fourth at most, in order to be firm without being hard.

The ley or lixivium in which the rope is soaked, is composed of wood ashes and quick lime; and every hundred pounds of match require fifty pounds of the former, and twenty-five pounds of the latter. They are boiled for fifteen hours and are taken out of the tub, piled in heaps and covered with tow, in which situation they are left to ferment. Some recommend, in order to improve them, immersing them two or three times in a nitrous solution, composed of four pounds of saltpetre in a sufficient quantity of water, to every one hundred pounds of match.

The match is afterwards polished by rubbing it along a hair rope, which removes all extraneous fibres that would spread fire too rapidly. Twisting the rope strongly before it is polished, is said to be a good plan.

Matches are finally dried in the sun, and rolled into pieces of twenty yards each, (weighing about two and a half pounds); then made up into barrels or boxes, each of which contains about twenty of these pieces. Match of a good quality burns uniformly at the rate of five inches per hour, and its coal terminates in a point that resists pressure. Match rope may be formed by boiling the rope in water, containing three pounds of wood ashes, one pound of quicklime, two pounds of the liquor of horse-dung, and one pound of saltpetre.

In the small work, called *The Bombardier and Pocket Gunner*, there are three formulæ given for slow-match: The first consists in soaking light twisted rope in strong ley for three days. It burns three feet in six hours. The second or No. 2, as made at Gibraltar, by immersing blue paper in a solution of eight ounces of nitre in a gallon of water. The No. 3, by soaking rope in a solution of three-fourths of an ounce of sugar of lead in a pint of rain-water, using a larger quantity in the same proportion, according to the rope.

The use of the acetate or sugar of lead for the formation of match-rope, was recommended by a French officer in 1782; and since [473] that time has been used in France both with and without saltpetre. The tinder-wood, if soaked alternately in solutions of saltpetre and sugar of lead, will form a very good match.

M. Rothelet (*Archives des Découvertes*, v, p. 239) has given some new observations on the use of acetate of lead for the preparation of combustible match-rope. He mentions the use of liquid acetate of lead, which may either be a solution of the oxide of lead in distilled vinegar, or a solution of sugar of lead in water. Rope, he adds, may be made very inflammable, by soaking it well in the liquid acetate, and drying it thoroughly. See also the *Bulletin de Pharmacie*, September, 1812.

Matches may be made very expeditiously by employing sugar of lead in the following manner: Put a quantity of rain or river water in a kettle over the fire, and when it boils, throw in sugar of lead in the proportion of three-fourths of an ounce to a pound of water. Remove the kettle when the sugar of lead is all dissolved, and immerse the cord or rope in the solution for ten minutes, and then take it out and dry it in the air. If cold water is used, the rope must remain longer in the solution. Rope of every description, old or new, or that made of the linden bark, and damaged match, may be submitted to the same process, previously boiling them in common water to remove their old coating. One pound of solution is required for each pound of cord.[32]

Ruggeri (*Pyrotechnie Militaire*, p. 185,) has a similar process. The *salt of saturn* there recommended, is the same as sugar of lead.

When matches have been made by contract, we may determine their quality by examining their interior, to see if they are not mixed with old matches, or pieces of dirty hemp. They should be sufficiently closed without being either too hard or too loose. The lixivium should penetrate to their centre; the difference of colour will indicate the contrary. They should be well dried and partake neither of mould nor rottenness, which are easily ascertained by the colour and smell. To be good, the match when lighted should preserve the fire, and burn uniformly without interruption in moist weather, so that a piece of five inches in length shall last at [474] least one hour.

In 1808, there appeared in our papers an article on the subject of *artillery rods*, of which the following is a copy. We re-published it in the Aurora, of Philadelphia, in the same year, with comments. Instead of the acetate, nitrate of lead is used.

M. Cadet, of Paris, has invented artillery rods to supersede the matches in common use. They may be made of birch, elm, poplar, or of the linden tree. They are saturated with nitrate of lead and undergo two ebullitions in spirit of turpentine. They then burn very well and are not extinguished by the air. A *metre* of each will last an hour and a half, while the common matches burn only seven minutes. General Gassendi has made a calculation, which proves, that matches, which now cost the French government twenty-thousand livres, will not cost more than fifteen hundred, if made on M. C's new principle.

One pound of rope-match, such as is used in the military academy of Segovia, lasts nearly thirty-five hours, and rather more provided it be damp. In that state it is generally surcharged with from six to seven per cent. of moisture. In short it would be better to dry the rods in an oven, before they are saturated with the nitrate as well as afterwards. The following table shows the difference of duration between the matches made of rope and the new invented rods; and the quantity of nitrate, each wood absorbs per quintal, is specified in the last column.

Woods.	*Durat. per 25 lbs.*	*lbs. French*
Cord-match	850	4
Linden,	2400	10
Pine,	2400	42
Cedar,	2400	42
Elm,	2430	19
Oak,	2200	18
Green oak,	1400	18
Walnut,	1400	7
Poplar,	1400	37
Willow,	2400	30

Hence we find that the poplar, pine, cedar and willow, exclude themselves when compared with the linden tree; since they absorb three or four times more nitrate than the latter, without burning longer.

The linden unites the advantages of economy and duration, since it absorbs only a tenth of its weight. The common oak, elm, [475] walnut and green oak, occupy but the second rank. We may remark also, that the hardest woods are not of the greatest duration; for a rod made of green oak, which is much harder than the common oak, supports combustion only eight hours, while the latter will burn for twelve hours. Half a *kilogramme* of nitrate of lead will saturate forty-five *metres* of elm, seventeen of birch; twenty-one of poplar, and twelve of the linden tree. The woods were cut in parallelepipeds and boiled in a fish-pan.

MM. Carnot, Guyton Morveau, and Deyeux, were appointed to examine this invention, who reported favorably. An extract of their report may be seen in the *Archives des Découvertes*, v, p. 240.

Born also recommends for the same purpose, nitrate of lead, and used in the same manner. Proust, it appears, repeated the experiments of Born, and came to the same conclusion;—that it was an expeditious, and, on a large scale, an economical process for making matches. Proust, however, used hazle wood. He observes that the solution must be strong; that when cold it requires three days immersion in the fluid, and when boiling, only one and a half hours. He also found that nitrate of copper may be substituted for either the acetate or nitrate of lead.

Sec. II. Of Priming Tubes.

Priming tubes, (*fusées d'amorce*) serve to communicate fire to the powder in a cannon. They were formerly made of tin, but in consequence of the inconvenience of rusting they were laid aside. James (*Military Dictionary*, p. 416) remarks, that, owing to this defect in the tin, a colonel Harding had invented a pewter tube in lieu of tin tubes. Tubes are used in quick firing. When made of tin their diameter is two-tenths of an inch, being just sufficient to enter into the vent of the piece. They are about six inches long. Through this tube is drawn a quick-match, the cap being primed with meal powder moistened with spirits of wine. To prevent the mealed powder from falling out by carriage, a cap of paper or flannel, steeped in spirits of wine, is tied over it.

They are composed of two distinct parts, the *cravat* which contains the priming, and the tube that enters into the touch hole. Small pieces of well dried reeds or of quills, a little less than the size of the vent of the piece, are preferred. They are made thus. [476] The reeds are cut into pieces three inches in length, square at one end and diagonally at the other, and are passed through a caliber two and one-third lines in diameter, (the diameter of the vent being two and one-fourth lines;) they are then rubbed clean in the inside by passing a small file several times through them, that removes the inner skin. Having prepared the reeds, they are filled, and also quills, or other cases, with the composition hereafter mentioned, made sufficiently thin to enter them. This may be done with the most facility by placing the cases side by side, with the square end up, in a tin or wooden box five inches deep; the composition is put into this, and made to descend into the cases, by knocking the box on the table. When they are full, they are taken out of the box, wiped clean, and laid to dry in the sun or in a warm room; before the composition is entirely dry, a knitting needle is passed from one end to the other, in order that the fire may reach the bore of the piece more rapidly. The match of communication (*etoupille*) is then fixed. This is done by cutting a notch on each side of the reed, near the end that is cut square, to which two strands of a match, two and a half inches long, are tied with a fibre of hemp.

The tubes are tied up in packets of ten each, to facilitate their distribution in service.

The reeds, or other cases, may also be filled in the following way, *viz*: Take twine made of the strands of cotton thread, and cut into pieces ten inches long; fold each of these into two lengths, and pass them through the reed from one end to the other by means of a loop of very fine thread. The two inches are covered with some of the composition made thick.

Composition of Priming Tubes.

Parts of,		*Meal-powder,*	*Saltpetre,*	*Sulphur,*	*Charcoal.*
Usual composition,		12	8	2	3
Very quick,		4	1	0	0
Particular	}	0	13	3½	4½
composition,	}	0	4	½	½

The composition is to be moistened with a solution of camphor, &c. in brandy. To every pint add one ounce of gum arabic, and half an ounce of camphor. Gum water retards the combustion of the match.

Fifteen pounds of this composition will make ten thousand tubes. [477]

M. Cadet, (*Archives des Découvertes*, i, p. 412) has connected with the match a preparation of chlorate of potassa, which is inflamed by sulphuric acid.

We have already spoken of the use of chlorate, formerly called hyper-oxymuriate, of potassa, in this way. See *chlorate of potassa.*

M. Cadet's invention is as follows: In a glass tube or tube of elder, is enclosed a match covered with a mixture of chlorate of potassa and sulphur; above which is fixed a small glass bulb containing sulphuric acid. This bulb has a small stem of glass similar to that of the candle cracker, to stick it by into the composition. This match is placed above the vent or touch hole, and retained there by a socket of lead. A spring, to which a small hammer is attached, is fixed to the gun, and is extended and kept in that position by a hook or bolt. When this is pushed, the spring is unhooked, and by recovering itself gives a blow with the hammer which breaks the glass ball, and the acid falls directly on the composition. This is then inflamed and the fire is communicated to the match, and from the match to the gunpowder.

A small portion of sugar mixed with the chlorate of potassa and sulphur, will ensure the composition to inflame with more certainty; although M. Cadet mentions only the hyper-oxymuriate and sulphur. If some of this composition, after the priming fuse is charged, be put in the cup of the fuse, a drop of sulphuric acid will inflame the fuse.

Sec. III. Of Quick Matches.

The *etoupille* of the French is the same as quick match, which is used to communicate fire in particular in military works, to priming tubes and other fuses. We have noticed in a former article the preparation of the matches of communication used in Fire-works, and the mode of forming leaders for the purpose of conveying fire to the different parts of a fixed or moveable piece. It will be sufficient, therefore, to notice the preparation of what is usually called quick match. These matches are made, according to Bigot, of five strands of fine cotton thread, soaked twenty-four hours in strong vinegar, and sometimes in brandy. They are then put, for twelve hours at least, in a liquid paste, made of meal gunpowder, and spirits, in which gum arabic and camphor are [478] dissolved, in proportions to be given hereafter. To make them imbibe this completely, they are pressed with a pallet knife. They are then taken out and drawn gently between the fingers to discharge the excess, spread upon a table, and when half dry, dusted with meal-powder. The match is rolled by hand to make it round, hung upon a frame, furnished with pins, to dry, and afterwards cut into lengths of two and a half feet and tied up in bundles.

Materials necessary to make ten thousand Priming Tubes.

Cotton thread,	5	lbs.
Meal-powder,	3	—
Vinegar,	5	quarts.
Brandy, or other spirits,	3	——
Gum arabic,	3	ounces.
Camphor,	1½	——

When matches are required to communicate fire slowly, sulphur and beeswax, or rosin are added to meal-powder, in proportion to the degree of slowness required. The cotton, in this case, must have been soaked in water instead of spirits.

Cotton,	1	lb.	12	ounces.
Saltpetre,	1	—	8	——
Spirits of wine,	2	quarts.		
Water,	2	——		
Isinglass,	3	gills.		
Meal-powder,	10	lbs.		

The cotton is then taken out and laid in a trough, where some meal-powder, moistened with alcohol, is thoroughly wrought into it. This done, the cotton, being in strands, is taken out separately, and drawn through meal-powder and hung upon a line to dry.

If worsted in the place of cotton is employed, the proportions then are,

Worsted,	10	ounces.
Meal-powder,	10	pounds.
Alcohol, (spirits of wine,)	3	pints.
Vinegar, (white wine,)	3	——

In the preparation of quick match, the following method is sometimes pursued; *viz.* soak the cotton well in a hot solution of saltpetre; then remove it and lay it in a trough with some mealed powder, moistened with spirits of wine, which is to be worked in by the hand. It is afterwards drawn through meal-powder, and dried upon a line or reel.

CHAPTER III.

OF PORT FIRES.

Port fires (*lances à feu*) are a species of fuse of a slow composition, designed for different purposes, and particularly for guns, when they are to fire rapidly. The paper, is first rolled in cases. The rod or mandril should be of hard wood, 16 or 18 inches long, and 5½ lines in diameter. Two brass rods to load them, one of 17 inches in length, the other of only 8, are required. A wooden rammer, with a heavy head, may be used. A small funnel with a spout 5½ lines in diameter, and a ladle to lift the composition, are also required. The instructions of M. Bigot for the formation of *Port-fire* are that the paper must be cut in bands, 3½ to four inches wide, and 15 inches long, and six strips of this paper are to be arranged on a level table, one above the other in such a way, that each strip extends about half an inch beyond the next below it, and pasting the projecting parts of it; that the wooden rod is then placed upon the upper strip, near the side, and the paper is rolled several times round it; pressing it at the same time, and shutting the case, thus formed, at one end, by bending the paper up 3 or 4 lines on the rod, and striking it on the table to flatten it; that the rod is then removed, and the case is dried, which is afterwards filled by introducing the composition through the funnel, and ramming it as fast as it falls down; which is done by alternately raising and lowering the copper rod, without drawing it entirely out; that in charging, care must be taken to beat it uniformly, with such a force, that the paper may not be torn, and the composition equally solid throughout; that when the composition is within an inch of the end of the paper case, a tow match is put over it, of 1½ inches in circumference, the two ends of which project from the paper case, and are covered with priming paste; and finally, that the port-fire is finished, by pasting upon its end a small bit of paper, which is torn off, when the match is to be used.

Port-fires are tied up in a sheet of paper, in parcels of ten.

Composition of Port-fires.

KINDS OF PORT-FIRE.	Meal powder.	Saltpetre.	Sulphur.	Charcoal.	Rosin.
To last 12 min. moistened with linseed oil.	10	12	6		
—— 10 do—do		19½	7¼	½	
—— 7 do—commonly used.		19½	8	½	½

The articles are pulverized, and mixed by passing them through fine sieves at least twice. After the addition of linseed oil, the composition is again mixed with the hand. If too much oil be added, the port-fire will not keep. Fourteen pounds of composition, and 2½ reams of paper, are required for 100 port-fires.

Port-fires are usually 16½ inches, and seldom more than 21 inches in length. The paper cases must be rolled, wet with paste. The distinction, made between what is called the wet, and dry port-fire, is, that, in the former, linseed oil is used, and, in the latter, the composition is mixed dry. Dry port-fire, according to the British formula, is composed of saltpetre 4 parts, sulphur 1, meal-powder 2, and antimony 1.

The following formulæ for port fire are given in the Pyrotechny of the Encyclopedia Britannica.

1.	Saltpetre			12	oz.
	Sulphur			4	—
	Meal-powder			2	—
2.	Saltpetre			8	oz.
	Sulphur			4	—
	Meal-powder			2	—
3.	Saltpetre	1	lb.	2	oz.
	Meal-powder	1½	lbs.		
	Sulphur			10	oz.
4.	Meal-powder			6	oz.
	Saltpetre	2	lbs.	2	—
	Sulphur			10	—
5.	Saltpetre	1	lb.	4	oz.
	Meal-powder			4	—
	Sulphur			5	—
	Sawdust			8	—
6.	Saltpetre			8	oz.
	Sulphur			2	—
	Meal-powder			2	—

Illuminating port-fires, used in fire-works for exhibition, &c. have been noticed heretofore.

The composition of the charge for fire-lances (port-fire,) is thus given by Ruggeri;

Substances.	*Proportions.*	
Saltpetre	16	parts.
Sulphur	8	——
Powdered antimony or powdered pitcoal	4	——

Mixed, and passed three times through a sieve.

CHAPTER IV. [481]

OF FUSES FOR SHELLS, HOWITZES, AND GRENADES.

The fusée of the French, is applied to various purposes, and is differently made by different artificers. Fuses are intended to communicate fire to the powder with which shells, &c. are filled, so as to make them burst in the places to which they are thrown. They are composed, according to some, of one pound of gunpowder, and two or three ounces of charcoal, well mixed together; or of four pounds of gunpowder, two of saltpetre, and one of sulphur. It is to be remarked that the time a bomb, or grenade, will take to burn, after it has been thrown out of the mortar, or a howitz out of a howitzer, depends entirely upon the length and quality of the fuse. Fuses are made of wood turned in the form of a truncated cone, in order to enter fairly into the *eye* of the shell. They are perforated through the middle, in the direction of the axis, so as to receive the composition. This channel is called the *light* of the fuse. The wood that is employed, should be strong, dry, sound, and without knots. The best kinds are the oak, the elm, and the linden. They are filled with a slow combustible composition. The materials are increased or diminished according to the nature of their application. Fuses are sometimes made of copper.

The fuses for 10 and 12 inch shells are $8\frac{1}{2}$ inches long; for 8 inch shells, $7\frac{1}{2}$, for howitzes, $5\frac{1}{2}$; and for hand grenades, $2\frac{1}{2}$. The diameter of the light, in the first is 5 lines, in the second and third, 4 lines, and 2 lines for grenades. At the larger end of the fuse for shells, and howitzes, a cup is made from 10 to 14 lines in diameter, and 3 deep. In turning them, a solid bit, $2\frac{1}{2}$ inches thick, is left at the small end, to prevent them from splitting, when the composition is pressed into the canal. When the fuse is to be driven into the eye of the projectile, this piece is sawn off, cutting the fuse diagonally. The turner marks its termination by a circle upon the fuse. Fuses decrease nearly one inch in length, and two lines in diameter, according to the caliber of the bomb. The diameter of the lights, or apertures, only diminish half a line.

In what is called the Shrapnel shell, invented by colonel Shrapnel, the seasonable use of the fuse constitutes one of its principal advantages. With regard to the American elongated shell, invented by a gentleman in the Ordnance, we have heard nothing. See [482]
Shrapnel shell, &c.

Sec. I. Of the Method of Charging the Fuses of Bombs or Shells.

Two rammers of copper are required for each of the several calibers of 12, 10, and 8 inches; the first an inch longer than the fuse, the second half as long. These rammers are of the same size with the lights of their respective fuses, and have a head to receive the blows of a mallet. Only one rod is wanted for the fuses of smaller calibers.

The first operation is to examine the fuses, to see that they have no knots or flaws, and are not wormeaten. The artificers place themselves astride, and facing each other, upon benches of strong plank, having, between them, a small vessel filled with the composition, and each one, a small measure. Each artificer takes a fuse, inserts the small end into a hole, made in the bench, for the purpose of maintaining it erect, and preventing it from splitting in the act of charging. He then passes a measure of the composition into the light, and introduces the first rod, on which he strikes 15 strokes, of equal force, with the mallet. Between every three strokes, he raises the rod, to make the composition fall. The ramming of this measure is therefore executed in 5 *vollies* or blows. He then withdraws the rod, and introduces a new charge of the composition, which he beats as before, and so on until the fuse is half full; after which he makes use of the second rod, and goes on loading, until the charge reaches within three lines of the cup. He then takes two strands of quick match, which (after placing them in the form of a cross, on the top of the fuse) he presses with his rod, pours some of the composition upon them, and, beating it carefully so as not to cut the match, he fills the fuse to the top of the cup.

The fuses of howitzes and grenades are charged in the same way; but the blows are not so heavy as in larger ones, for fear of splitting the wood.

The fuses being thus charged, the quick match is folded into the cup, and the opening closed with a bit of cloth or parchment, or very strong paper, which is tied an inch below the top. This operation is called *capping* the fuse. All the fuses for bombs or grenades are at present furnished with matches. Care must be taken, therefore, to leave a vacancy of about .27 parts of an inch, in
order to fix in the match. Fuses of grenades are charged with the same precision as those for bombs, only the blows, as we [483]
remarked, should be weaker for fear of splitting the fuse. Before the little end is driven into the bomb or shell, care is to be taken to have the end cut slopingly, without which the communication of the fire with the powder would be uncertain.

When fuses have been well loaded, and the materials previously well mixed, they will naturally burn with an equal steady fire, preserving in general an even length of flame, without splitting, or irregularly shaking. They may be proved by throwing them into water, tied to a stone, or by driving them with heavy blows into the earth. They should not go out in either of these cases. Fuses made with the composition we shall describe, and for 10 and 12 inch shells, last seventy seconds. According to the Strasbourg directions, it appears, that fuses for shells of 12.78 inches should last until you can count 80 or 85, or 70 seconds. Those for bombs 8.52 inches, 65 counts, or 60 seconds, and those for grenades 25 or 30 counts.

Before the fuse is driven into the bomb, the thin or small end must be cut off, in order that the fire may be easily communicated to the mass of gunpowder, which is lodged in the bomb. To fire bombs at a small distance, the fuse must be cut on a longer slant, so that the bomb may take effect sooner, and may not remain a long time in the place where it falls, without bursting.

The fuse must be of such a length, as to continue burning all the time the shell is in its range, and to set fire to the powder as soon as it touches the ground, which occasions the shell instantly to burst into many pieces. When the distance from the object is known, the time of the shell's flight may be computed to a second or two; which being ascertained, the fuse may be cut accordingly. By burning two or three, and making use of a watch, or of a string, by way of a pendulum, to vibrate seconds, we may determine the length of time a fuse, or any length of a fuse, will take to burn.

In order to preserve fuses for a length of time, and protect them from moisture, the cap is coated with a composition, or cement, made of 16 parts of bees' wax, and 4 of mutton tallow; melting the wax first, and then adding the suet. Some make use of two-thirds wax, and one-third rosin. The cap of the fuse is dipped in, when the mixture is half cold, and immediately withdrawn.

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Composition for the Fuses of Shells, Howitzes and Grenades.		PARTS OF			
		Meal powder.	Salt-petre.	Sul-phur.	Char-coal.
Composition usually employed,		5	3	2	
Quicker composition,		7	4	2	
Another (from Ruggeri)		14	6	8	
Do.	Do.	16	7	10	
Do.	(English)	7	3	4	
Do.	(Strasbourg) for 8.52 bombs,	4	2	3	
Do.	(from the Pocket Gunner) lbs.	2¾	1	3¼	
Do.	particular (from Bigot)	}	2⅝	6¾	⅝
		}	3⅞	9¼	⅞

The following is the quantity of composition required for fuses, viz:

1000	fuses,	for 10 and 12 inch shells,	92	lbs.
Do.	do.	for 8 inch shells,	53	—
Do.	do.	for 6 inch howitzes,	33½	—
Do.	do.	for hand grenades	16	—

Sec. II. Of Loading Shells, Howitzes and Grenades.

The shells, before they are loaded, are cleansed from any foreign substances that may be in them; and those which are split, or have flaws in the eye are rejected; so are also those that are not well bored, or are eccentric. They are then charged with powder, introduced into them by means of a funnel. Five or six pounds of gunpowder are usually put into twelve-inch shells; from three to five, in ten-inch shells; from one to one and a quarter, into eight-inch shells; from three-quarters to one pound, into howitzes; and grenades of all sorts are half filled. The charge of shells is increased, when they are to burst into a great number of pieces; for instance, when they are to fall among troops. Incendiary fire-works are added, when buildings are to be set on fire. Among these are fire-stone, and incendiary matches.

The charge having been put into these hollow projectiles, a fuse is introduced into the eye, after it has been cut diagonally at the smaller end, and the smaller part taken off. It is forced in by repeated blows of a mallet on the fuse driver, which is laid upon the [485]
cap of the fuse. It ought not to project more than eight or ten lines in shells, and six or seven in howitzes.

The fuses of loaded shells, howitzes, and grenades are preserved from wet and fire in the field, by dipping that part of the fuse, which projects from the surface of the sphere, for the same purpose as before mentioned, into the following composition. The immersion must be made, when the composition, after being melted, is half cold. Either this, or the formula before given, may be used.

Composition.

Pitch,	31	parts.
Turpentine,	16	——
Mutton tallow,	1	——
Linseed oil,	6	——

Agreeably to the Strasbourg Memoir on Military Fire-works, it appears, that, fuses being driven into the shell, four threads of match must be neatly arranged in the cap. Then cap the fuse with a piece of parchment dipped in brandy; after which, apply round the fuse, at the eye of the shell, some capping wax when lukewarm. Then dip all the extreme part of the fuse, down to the shell, in melted pitch, which you will leave to cool in the shade, in such a manner, that the shell may neither be exposed to moisture, nor to the accident of fire.

Composition of the Pitch.

Black pitch,	4	lbs.
Rosin,	4	—

This pitch serves not only to pitch the fuses of bombs and grenades, but also to cover the outside of fire-balls and other fire-works, intended to be preserved.

Another Composition of pitch for the same Purposes.

Black pitch,	6	lbs.
Linseed oil,	12	oz.

See the preceding section.

Sec. III. Of Fuses with Dead Light.

The *feu mort*, or dead fire fuse, is a peculiar species of fuse. The difference, between these fuses and the ordinary kind, consists in this, that the eye, instead of being pierced and hollow, is full, and of a hemispherical shape. In both cases, however, the [486]
composition is introduced through the small end.

Composition for dead light.

Meal-gunpowder,	16	parts.
Ashes of wood,	9½	——

The ashes must be dried, and run through a sieve. Potters' earth, or clay, will produce the same effect as the ashes.

In proceeding to charge a bomb-fuse that is made of ordinary wood, the eye, or aperture, is first closed with pipe clay, which is well beaten and pressed against the fuse in a small platter; the thin end of the fuse being held upwards. Three lines ($^{3}/_{12}$ths of an inch) of this earth will be sufficient to stop the communication of any fire. A tube, or trundle, filled with meal-powder, for the purpose of setting fire to the composition called *feu mort*, is thrust into the fuse, by which it is finally charged. If this charge of meal-gunpowder were to be omitted, the fuse might not be susceptible of ignition; but the quantity never ought to exceed three lines, as the fuse would split by the explosion. When the grains of gunpowder have been well pounded, a trundle or tube, filled with the aforementioned composition, must be applied, and it is finally loaded like the rest.

It must be recollected, that two inches of this composition will last as long as one of the quality, with which common fuses are charged. Before the fuse is driven into the bomb, it must be pierced through with a gimblet of one line in diameter; taking care, that the hole is made precisely through the charge of meal-powder. One end of a priming match must be forced in, and three others be tied to it, which three are to fall upon the bomb, when it lies in the mortar. The particular object to be obtained by this kind of fuse, is to prevent the least trace of fire or light being visible in its projection; so that the enemy may remain ignorant of the range, or direction of the bomb, and not be able, of course, to get out of the way when it falls, or to avoid the effects of its explosion.

These fuses were made use of at the siege of Ham in 1761. The experiments, which were made, in 1792, with this composition, by an artificer belonging to the ordnance board, at Douay, have proved, that it answers every purpose, for which it was invented.

The author of the *Manuel de l'Artilleur* observes, however, that the advantages to be derived from this invention, are not so great as they first appear. He remarks, that, with respect to the real utility of the fuse *à feu mort*, if it be considered as tending [487]
materially to the defence of any beseiged place, the argument cannot be very forcible, when we reflect, that to gain time constitutes one of the principal means of defence, and that the only way to obtain it, is by retarding the beseigers' operations. These ends are gained by various expedients. Among others, the common lighted fuse conduces not a little: since, during the whole direction of the bomb against the works of the assailants, the attention of the workmen is diverted from their immediate labour; and as long as it continues in its range, much uneasiness is created, because its ultimate explosion and concomitant destruction are unknown. Add to this, that, independent of the confusion that is occasioned among the assailants by repeated projectiles, the bombardier, by means of lighted fuses, is enabled to correct his aim during the darkest night. This kind of fuse has

been known for many years, and, it is presumed from these objections to its use, the common fuse has been hitherto adopted.

Sec. IV. Of the Dimensions of Fuses, and the Dimensions and Charge of Bombs, Howitzes and Grenades.

Shells, in gunnery, are hollow iron balls, to be thrown out of mortars or howitzers, with a fuse hole of about an inch in diameter, to load them with powder, and to receive the fuse. The bottom, or part opposite the fuse, is made heavier than the rest, that the fuse may fall uppermost. In small elevations, this is not always the case, nor is it necessary.

Shells are called hollow projectiles, and, besides powder, various incendiary matters are introduced; but in addition to shells, properly so called, hollow projectiles comprehend howitzes and grenades. As a principle, it is observed, that their sides ought to be proportionably thick to the shock they receive in the piece, and to the quantity of powder introduced for bursting them; and their weight, according to the objects they are to destroy. We remarked, that a shell should be thicker opposite the fuse. This thickness is called by the French a *culot*, or reinforcement of metal; the object of which is to prevent the breaking of the shell on rocks or stone, as well as to prevent its falling on the fuse. Four times as much powder may be put in the cavity as is sufficient to burst them. This admits the introduction of incendiary matter. Howitzes are hollow balls with a *culot*, or reinforcement of metal, upon the inside, opposite the eye, and are calculated for ricochet, that is, for passing, bounding, over the ground, and, by striking and [488] penetrating solid objects, and finally bursting, produce considerable havoc and devastation. For ricochet, the howitz, in fact, should be of the same thickness throughout.

Grenades are also a hollow ball, and are of two kinds; namely, the rampart or ditch grenades, of the caliber of 36, 24, 18, and 12 pounders, designed for rolling along a trough from the top of the rampart, and falling into the ditch, to annoy an enemy, in attempting to cross it; and the hand-grenade, that are thrown by hand into the interior of works, that are attacked, into covered ways and trenches, &c. They are of six and three pounder calibers, and their splinters will fly 35 yards. Grenades were invented about the time that shells were, and first used in 1594. Grenades have sunk into disuse; but they may be advantageously employed. During the seige of Cassel, under the count de la Lippe, in the campaign of 1762, a young engineer undertook to carry one of the outworks, with a small detachment of men by using grenades, and in consequence succeeded.

Message shells are nothing more than howitzer shells, and are so called, because they are used to carry letters or papers. During the bombardment of Flushing, and while the communication with Cadsand was cut off, means were found to convey a letter from the garrison into the latter place. It was inclosed in a shell without inflammable matter, and discharged from a mortar, planted on one of the sea batteries.

Shrapnel shells were invented by colonel Shrapnel of the British service. They were used, we are told, with peculiar effect against the French, in 1808, and at the battle of Waterloo in 1815. The fuses for these shells, after being turned so as to fit the fuse-holes, are bored, and a deep thread grooved inside, to hold the composition firm; and, instead of being turned with cups, they are hollowed conical, and roughed with a tool that cuts under, the better to receive the priming. After they are driven, with fuse composition, one and a half inches, they are sawed across the top about one-fifth of an inch down, so as not to touch the composition, and divided into five equal parts, of two-tenths of an inch each; after which, a bit of quickmatch is placed across, and drawn tight in the same grooves. They are then primed with meal-powder and spirits of wine, capped, and packed for service.

We here insert three tables, which we have extracted from the work of M. Bigot.

The first table is relative to the dimensions of fuses for shells, howitzes, and grenades; the second, respecting the dimensions of [489] bombs, howitzes, and grenades; and the third, of the charge of bombs and howitzes.

These tables, taken together, will exhibit all the particulars on this subject; and as this kind of data is necessary, in the practical operations of the laboratory, their introduction in this place, we consider important.

Table relative to the Dimensions of Fuses for Shells, Howitzes, and Grenades.

CALIBERS.	12 and 10-inch	8-inch.	howitzes, 6-inch.	Grenades. Rampart.	Grenades. Hand.
	inch.	inch.	inch.	inch.	inch.
Length,	9	8	5½	4	2½
Diameter.					
At the large end,	1⅔	1⅓	1¼	11/12	⅔
At 3 inches from the large end,	1⅓	1	11/12	0	0
At the small end,	1 1/6	11/12	10/12	¾	½
Of the light,	5/12	⅓	⅓	¼	1/6
Of the interior of the cup,	1 1/6	11/12	5/6	7/12	5/12
Depth of the cup,	3/12	3/12	3/12	3/12	3/12
Height of the massive,	5/12	5/12	¼	¼	0

Table of Dimensions of Bombs, Howitzes, and Grenades.

CALIBER.	12-inch.	10-inch.	8-inch, & howitz 8-inch.	howitzes 6-inch.	Hand grenades
	inch. lines. pts.	inch. lines. pts.	inch. lines. pts.	inch. lines. pts.	inch. lines. pts.
Diameter { of bombs,	11 10 6	10 0 0	8 1 6	6 0 0	3 6 0
{ of the light { exterior,	1 4 0	1 4 0	1 0 0	0 11 0	0 8 6
{ interior,	1 3 0	1 3 0	0 11 0	0 10 9	0 8 0
Thickness { of the sides,	1 6 0	1 6 0	0 11 0	0 11 0	0 4 0
{ of the culot,	2 2 0	1 4 0	1 3 0	0 0 0	0 5 0
	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.
Weight of the bombs,	145 to 150	97 to 100	43 to 45	20 to 25	3¼ 0

The rampart grenades are variable in their dimensions, and weigh from eight to twelve pounds.

Table of the Charge of Bombs and Howitzes.

	Bombs of 12-inches	Bombs of 10-inches	Bombs of 8-inches.	Howitzes. 8-inches.	Howitzes. 6-inches.	
Charge of full bombs,	17 lbs.	10 lbs.	4 lb. 1 oz.	4 lb. 1 oz.	1 lb.	6 oz.
sufficient to burst them.	5	3	1	1	0	12

CHAPTER V. [490]

OF INCENDIARY FIRE-WORKS.

Under this head are included all artificial preparations, designed, as the name expresses, to communicate fire to buildings, shipping, &c. and for other purposes, connected with the operations of war.

At different periods, even from the remotest antiquity, incendiary works have been used. Of these preparations, we may enumerate the following: shells, howitzes, and grenades; fire-stone to put into shells and howitzes, intended to produce conflagration; incendiary matches, used in the same manner; carcasses and fire balls, to be thrown from a mortar, designed to light up the works in front of a besieged fortress, and to burn buildings; incendiary, or fire-balls, to be thrown from cannon or by hand, used in besieged fortresses to light up the enemy's works; pitched tourteaux and fascines, to illuminate the passage of rivers and defiles; powder bags, to throw upon troops mounting to the assault; powder barrels, to roll from the top of a breach, or from the head of a sap from the glacis; thundering barrel, employed for the same purpose; burning or illuminating barrel; petard, to break down the gates and barriers of small towns, and even thin walls; torches or flambeaux, to give light during night marches, and other purposes; rockets, fougettes, and murdering and the Congreve war rocket, for various uses; rocket carcass of Congreve, as an incendiary; rocket light ball, to illuminate the horizon near the enemy; murdering marrons; Roman incendiary candles, and incendiary stars; tarred and pitched ropes; fire rain; marine fuses, &c. to which we may add the ancient Greek fire, and red-hot balls.

In this chapter, under the different heads, we purpose to describe these, and other fire-works, used in war. We may remark, also, that animals are sometimes used as incendiary agents. *Rats*, for instance, have been employed in certain enterprizes, as for the purpose of setting fire to magazines of gunpowder. On these occasions, a lighted match is tied to the tail of the animal. The *courier pigeon* of the French, or carrier pigeon, is not used in this way; but only as a carrier of letters, to which it is trained and used in Persia and Turkey.

Sec. I. Of Fire Stone. [491]

The fire stone (*Roche à feu*) is a compact, or solid composition. It is calculated to burn slowly, and when put into shells and howitzes, and thrown into cities, produces conflagration.

This stone is composed of sulphur, saltpetre, meal-powder, and sometimes grain-powder, &c. The sulphur is melted in a kettle, or glazed earthen vessel, over a clean charcoal fire; the saltpetre being pulverized, is then thrown into it, and the spirits of turpentine, if any is used. These articles are stirred with a spatula, and the fire must be so regulated, as to prevent the composition from boiling over, or taking fire. When these are well melted and mixed, they are taken off the fire, and permitted to cool a little; the gunpowder is then thrown in, and the composition poured upon a cold surface, where it consolidates. It is then broken into small lumps, to be made use of when required.

We may here remark, that, as the goodness of this composition depends upon the accuracy with which the mixture is made, too much care cannot be paid to this circumstance.

For the purpose of rendering this incendiary more inflammable, it is recommended to roll the pieces in meal-powder, before they become fully hard. If the same composition be mixed with suet and spirits of turpentine, it is used for the same purpose, but not in the same manner.

The invention of the fire stone is said to have originated from the fire-rain of Casimir Siemienowicz, an ingenious Polander, and Chevalier of Lithuania, &c.; and in fact, according to Ruggieri, the composition was taken from his treatise.

Incendiaries to be put into bombs or shells, are sometimes in rolls in the form of a *sausage*, which continue to burn after the shell has burst. They infallibly set fire to whatever combustible substance they touch. When thus made they are from .88 parts of an inch, to an inch in diameter, and from 3 to 4 inches long. Carcass composition is generally used. It is run into cylinders, which are pierced in the middle, and the hole is filled with the composition of bomb fuse. They are also furnished with cotton matches.

Composition of Fire Stone. [492]

			PARTS OF				
			Sulphur.	Salt-petre.	Meal Powder.	Powder in grain	Char-coal.
Composition	frequently	made use of,	16	4	4	3	0
Do	do	do	28	5	4	4	0
Do for	particular	purposes,	$9\frac{1}{4}$	$16\frac{7}{8}$	0	0	$\frac{7}{8}$
Do	do	do	11	29	0	0	1
Do	do	(spirits of	}				
turpentine,	12 oz.)	and	} 6	1	4		

Fire stone may be considered the *wild-fire*; but this term is applicable to any composition, as the Greek fire, which, when inflamed, burns with rapidity, and communicates its fire to surrounding objects with quickness. In such cases, the combustion is so rapid, that buildings, &c. are immediately wrapt in flames, which seem almost to defy all human power to extinguish. Such was the nature of the Greek fire, of which we shall speak hereafter.

Sec. II. Of Incendiary Matches.

These are better for the purpose of putting into shells and howitzes, than fire-stone alone, which does not burn as well. Their preparation consists in boiling common slow match in a solution of 20 parts of saltpetre, in six parts of water; then drying and cutting it into pieces of two or three inches long, and immersing it into fire-stone, in a state of fusion. Before the match has become solid, let it be rolled in meal-powder, or in grain powder. Fifty pounds of fire-stone will be sufficient for 1500 matches.

Sec. III. Of Carcasses and Fire-Balls.

Carcasses and fire-balls are made of a composition of combustible substances, and are used to produce light, as well as to fire buildings. The difference between them is, that the carcass has bands or hoops of iron, that form its shell. These hoops are made at right angles with each other, in an oval form, and fastened together with a base of iron. The fire-ball is made of a sack of strong [493] tow cloth, or of a bag of basket work, in an oval form, and covered with strong cord, to give it a body. Both, however, are well wrapped with cord, to make them more solid.

The Rev. J. P. Coste, in 1794, invented a carcass composition, which he submitted to the French national convention. It appears that its fire was very violent, which nothing could extinguish, and could be thrown 800 paces from a caliber of 24 in. and to a greater distance, if required. An account of this carcass is given in the *Moniteur*, No. 342.

Oblong carcasses were formerly in use. The round carcass is more applicable for mortars and howitzers. The 13-inch round carcass weighs about 212 lbs., 10-inch 96 lbs., 8-inch 48 lbs., and $5\frac{1}{2}$-inch 16 lbs. Carcasses are seldom or ever fired from guns or carronades, in the land or sea service. In bomb vessels, they are only fired from mortars. After the first invention of bombs, that of carcasses and grenades naturally followed. They are said to have been first used in 1594, and afterwards by the bishop of Munster, at the siege of Groll, in 1672, where the Duke of Luxemburg commanded.

The carcass for 12 and 10-inch mortars has six bands of iron; that for an 8-inch mortar, no more than four. These bands are of an oval shape, and fixed with nails, either clenched or rivetted to a bottom, of the shape of a segment of a sphere; then to a hoop, placed horizontally at one-third of their height; and at top, to another that closes the opening.

The sacks, that contain carcasses and fire-balls, are of a cylindrical form, and their diameter and height are equal, being the same as that of the carcass at one-third its height. They are sewed upon a circular bottom, like the woollen bags of gun-cartridges. When the ball is wound with thread, the folds will disappear. The sacks of fire balls are an inch less than the caliber of the mortar, and those of carcasses four inches more.

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Table relative to the Dimensions of Carcasses, to fire from the Mortar.

CALIBERS OF	12-inch.	10-inch.	8-inch.
	Inch.	Inch.	Inch.
The spherical segment.			
radius,	5 5/12	4⅔	1
height,	2	1⅔	1
Diam. of the circle,			
at ⅓ of the height	10	8½	7
at the opening	6	5	4 1/6
Height			
Of the iron mounting	12	10	8
Of the charged carcass, the ear not included	16	14	12
Of the enveloping sacks	16	14	12
	Pounds.	Pounds.	Pounds.
The weight of the iron, for the mounting of the carcass, about	20	18	7

Composition of Carcasses and Light Balls.

	Pitch.	White Pitch. (Turpentine.)	Mutton Tallow.	Rosin.	Sulphur.	Saltpetre.	Grain-powder.	Meal-powder.	Camphor.	Charcoal.	Carabé.
Moist composition.	24	12	4	0	0	0	36	0	½	0	0
Idem.	18	0	1	0	0	0	30	0	0	0	0
Dry composition.	0	0	0	12	1	2	0	2	0	0	0
Idem.	0	0	0	12	2½	11	0	0	0	1½	0
Another.	12	6	2	0	0	0	30	0	½	0	0
Ditto.	0	0	1	12	0	2	20	0	2	0	1
Ditto.	12	0	3	0	0	6	30	0	0	0	0
Ditto.	15	0	3	0	0	6	30	0	0	0	0
Ditto.	0	2½	0	1	1	1½	0	2	0	0	0
Ditto, particular, for setting fire to magazines, buildings, &c.	0	0	0	1	4	2	0	10	0	0	0
Ditto, same purpose.	0	0	0	4	16	32	0	48	0	1	0*
Ditto. do.	7	0	1	6	6	0	0	8	0	0	0
											Antim.
Ditto. do.	5	0	0	8	25	50	0	0	0	0	5

* Also, iron or steel filings, 2; and fir-tree sawdust boiled in a solution of saltpetre, 2.

We may remark, that the four first formulæ are given by Bigot, and are used in the French service. Therefore, although the others have been employed, we may consider the proportions in these, as best adopted for the carcass and light-ball composition. About 49 lbs. of composition and two lbs. of fine tow, are required for a carcass of 12 inches. [495]

Luminous or light balls are sometimes made of the following compositions.

Composition for Luminous Balls.

1.	Sulphur	6 oz.
	Antimony	2 —
	Saltpetre	4 —
	Rosin	4 —
	Charcoal	4 —
2.	Saltpetre	2 oz.
	Rosin	2 —
	Charcoal	2 —
	Antimony	1 —
	Sulphur	1 —
	Pitch	1 —

In the formation of luminous, or light balls, whatever may be the composition, we may remark, that the only ingredients which appear to be essentially necessary are nitrate of potassa and inflammable substances. In some preparations, antimony is used, for the same reason as in the Bengal lights. Rosin, pitch, and charcoal are all inflammable; and sulphur, although it takes fire more instantaneously than these, enters into the composition of such fires more on account of its flame than any other.

As a general rule for the preparation of carcass composition, the following particulars must be attended to. After melting the pitch, turpentine, rosin, and sulphur, add the tallow and camphor, and then the nitre and charcoal, in powder. They are then to be stirred, and mixed intimately. Care must be taken to regulate the fire, and prevent the composition taking fire. After the kettle is withdrawn from the fire, the gunpowder is then gently added, and stirred with a stick or spatula. The kettle is then again put over the fire, and afterwards withdrawn. Tow is now added in small quantities at a time, stirring the mixture well that it may be thoroughly incorporated.

The preparation of the carcass, or fire-ball, is as follows; observing, that, if it is a carcass, the iron-frame must be first placed in the sack. Four cords are taken, each four lines in diameter, four feet long for the calibers of 10 and 12 inches, but only 3 feet for the calibers of 8 inches. [496]

The middle of these four cords are laid one upon the other in the form of an eight-pointed star. Each end of the ropes is then fixed to a nail, and a bottom is formed, similar to basket-work, by interlacing a cord, two lines in diameter, three or four times round the central point. The small cord is then tied with a knot, and the bottom of the basket completed, by tying the four large cords together with four half knots. The bottom of the sack, containing the iron carcass, or of an empty sack, if a fire-ball is to be made, is placed upon the middle of this, and the filling performed in the following manner, namely: A sufficient quantity of the composition is taken from the kettle to fill the empty carcass, or sack, three or four inches high; a few loaded grenades, with the fuse down, or a howitz placed in the same way, are laid upon this first layer. The filling is continued to the top, putting the composition and grenades, in alternate layers. When it is done, the sack is tied with twine. In order to tie up the fire-ball in its cord net, the cords are raised from their nails, over the sack, and tied in such a way as to suspend it about the height of a man's head, and to permit it to be easily turned round. An artificer fixes the end of a small cord to one of the larger ones, at the distance of $1\frac{1}{2}$ inches from the bottom; he makes a half knot upon this, and carries the small cord round to the others, to which he ties it in the same way, forming a spiral round the ball. The large cords are kept regularly stretched in such a way, that each turn of the spiral may be $1\frac{1}{2}$ inches from that beneath it. When the spiral has reached the top of the ball, he unites the small cord, called the traverse, with the ends of the four others, called uprights. He divides the latter into two parcels, and forms a loop of them, through which a lever may be passed for the convenience of carrying it. At two or three inches from the upper end, and upon two sides, diametrically opposite to each other, two pins of hard dry wood, well greased, are driven in. These pins are 6 inches in length, one in diameter at the head, and half an inch at the point. They must be inclined in such a way, as to meet in the axis of the fire ball, at about half its height.

The carcass or fire-ball, when finished, is dipped into the following composition:

Composition of Pitch for Fire-Balls. [497]

Pitch,	32 parts.
Turpentine,	16 ——
Rosin,	8 ——
Linseed oil,	6 ——
Mutton Tallow,	1 ——

Grenades answer the purpose of dispersing the fire of the carcass in different places; and the shell will not burst, till the carcass has burnt for a sufficient length of time. Sometimes the ends of gun barrels, or pistols, loaded with ball, are put in.

Carcasses and fire-balls are primed before they are used, by drawing out the pins, and filling the holes with the composition for the fuses of shells; taking care to use for ramming, only wooden or copper rammers. Four cotton matches are placed in each hole, 6.4 inches long, in order to convey the fire.

Carcasses and fire-balls are discharged from mortars, in the same manner as a bomb. When the carcass is intended to give light to discover the enemy's works, then the small charges are to be put into the chamber of the mortar, and but little elevation given, for fear it should bury itself in the ground. If, on the contrary, the intention is to set fire to houses or magazines, a greater elevation is given to the mortars, in order that it may reach and destroy the buildings, upon which it is intended to fall.

The composition used by the Austrians at the siege of Valenciennes, which is called after it, has the same effect as carcass. It is composed of saltpetre 50 parts, sulphur 28, antimony 18, and rosin 6.

An English writer observes, that the best way of making light balls, is to take thick brown paper, and make a shell the size of the mortar, and fill it with a composition of equal parts of sulphur, pitch, rosin and meal-powder.

Before closing this article, we may add, that carcasses are sometimes made to weigh two hundred and thirty pounds, and those for the naval service differ from a shell only in the composition, and in the four holes, from which it burns when fired.

Sec. IV. Of Incendiary Balls, or Fire Balls, to be thrown from Cannon or by Hand.

Balls of this kind are employed chiefly in beseiged fortresses to light up the enemy's works. In order to burn ships, hollow balls filled with incendiary matter and red-hot shot are preferable. [498]

Composition of Incendiary Balls.

	Meal-powder.	*Saltpetre.*	*Sulphur.*	*Rosin.*	*Tallow.*	*Alum.*	*Antimony.*	*Char-coal*
Ordinary composition, moistened with spirits and linseed oil, meal,	4	4	3½	¾	0	0	0	0
Another,	8	8	24	0	4	2	1	0
Do.	0	7	4	3	0	0	0	½

The first composition is reduced to a paste with good brandy or other spirits, in which gum arabic and camphor have been dissolved; and after leaving it a few hours to dry, moisten it with linseed oil, and make it into balls a little less than the calibers of the guns, from which they are to be fired or weighing about four pounds, if they are to be thrown by hand. They are tied up in a cloth and steeped in a bath of pitch in the same way as carcasses. They are usually covered a second time with cloth and dipped in the same way. If they are to be fired from guns, they are enveloped in a netting of wire, to prevent them from being broke by the action of the charge. These balls when fired are put down over a small charge without ramming. Two holes are made in them in the same way as in carcasses and fire balls and they are primed in the same manner.

In employing the second and other compositions, the materials must first be melted, such as rosin, tallow, and sulphur, and the powder, alum, and antimony, added; when the melted matter is removed from the fire. After they are all mixed, the mixture is then poured into wooden moulds of two pieces, that are greased on the inside; the ball is taken from the mould when cool, and wrapped up in cloth or in tow. It is dipped in melted pitch. When it is to be used, holes are made in it with a gimblet, and it is primed like the others.

We may remark here, that the Congreve incendiary rocket is armed with carcass composition, which produces all the effects of the usual carcass. The rocket carcass will be considered under the head of war-rocket.

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Sec. V. Of Smoke Balls.

Smoke balls are composed of the same substances as carcasses and light balls, with this difference, that they contain five to one of pitch, rosin, and sawdust. This composition is put into shells made for the purpose, having four holes to let out the smoke. Smoke balls are thrown out of mortars, and continue to smoke from twenty-five to thirty minutes.

Sec. VI. Of Stink Balls.

Stink Balls are prepared with a composition of mealed powder, rosin, saltpetre, pitch, sulphur, rasped horses' and asses' hoofs, burnt in the hoof, assafœtida, seraphim-gum, stinking herbs, &c. made up into balls in the same manner as light-balls, according to the size of the mortar, out of which they are to be thrown.

Sec. VII. Of Poisoned Balls.

With respect to poisoned balls, we are informed, that, although they have not been used by European nations, the Africans and the Indians have always been very ingenious at poisoning several kinds of fire compositions. At the commencement of the French revolution, poisoned balls were exhibited to the people, pretended to have been fired by the Austrians, particularly at the seige of Lisle. They contained glass, small pieces of iron, &c. and were said to be mixed with a greasy composition, which was impregnated with poisonous matter. In 1792, they were deposited in the archives of Paris.

Poisoned balls, according to authors, are composed of meal powder four parts, pitch six, rosin three, sulphur five, assafœtida eight, extract of toads' poison twelve, other poisonous substances twelve, made into balls in the manner we have mentioned. See *Poisoned Arrow.*

Sec. VIII. Of Red-hot Balls.

It will be sufficient to observe, that red-hot shot, as an incendiary, are considered fully adequate to perform the effect which they are designed to produce. The balls are ignited in a coal fire on an iron grate, in a furnace constructed for the purpose; and, when thus heated, are thrown from guns, the space between the powder and ball being filled up with a piece of wood of the exact [500] diameter of the gun, or with wet hay or grass, to prevent the ball from setting fire to the powder.

With respect to chain balls, composed of two balls linked together by a chain from twelve inches to four feet in length, and designed to destroy palisadoes, wooden bridges, and chevaux-de-frize of a fortification; stang-balls, or bar-shot, called by some, balls of two heads, made by uniting, by means of a bar, half shot; and anchor balls, filled with the same composition as light-balls, with some trifling variation in the ball itself, &c.—they are all used as destructive weapons, which belong more particularly to the service of artillery.

Sec. IX. Of Pitched Tourteaux and Fascines.

Tourteaux are employed to illuminate the passages of rivers and defiles. They are placed in portable *lanterns* or in fire-grates. They are used chiefly to light up the works of the beseiger, when he approaches the covert way, and to burn the gabions and fascines, with which he constructs his passage to the ditch. Tarred links are nothing more than old junk or matches, dipped into a composition of pitch, suet, linseed oil and turpentine; the junk being cut into lengths of about five feet, which is called a link. The *Tourteaux goudronnés* of the French are the same, and formed of old rope, which is untwisted, immersed in pitch or tar, and afterwards left to dry. The French make the *Tourteaux goudronnés* in the following manner: Take twelve pounds of tar or pitch, six pounds of tallow, and three pints of linseed oil; melt them together and dip twisted pieces of rope of any length into the boiling mixture. If they are required to burn slow, six pounds of rosin and two pounds of turpentine are added. Sometimes to the composition of pitch, tallow, and linseed oil, are added two parts of saltpetre, one part of sulphur, and half a part of antimony. Tourteaux, according to Bigot, are made in the following manner: Old cords or pieces of match are beaten with mallets to take out the dirt, and prepare them to receive the composition. They are untwisted a little for the same purpose. They are then cut into pieces about five feet in length, and each is intertwined to form a circle of five or six inches of external diameter, making a hole at the same time in the middle for the passage of the point of the lantern.

The rope, being thus prepared, is next boiled in the composition given below, for the space of ten or fifteen minutes, and then [501] laid upon a wet plank. They are a second time dipped into the composition, and thrown into cold water, to give them again, by hand, the circular figure they may have lost. Flower of sulphur is now put over them, and they are dried in the shade.

Composition for Tourteaux.

Pitch,	24 parts.
Turpentine,	12 ——
Rosin,	6 ——
Mutton tallow,	4 ——
Linseed oil,	1 ——
Venice turpentine,	1 ——

Another, for Tarred Links and Fascines, according to the Strasbourg formula.

Pitch,	18 parts.
Turpentine,	9 ——
Suet, or tallow,	4 ——
Linseed oil,	1 ——
Spirits of turpentine,	1 ——

When a great quantity of links are to be made, either for illumination or for lighting a city, the oil may be omitted. The links will cost less, and they will answer the purpose equally well.

Fascines are made of strips of wood, or dry twigs, or wine shoots, which are the best, of the length of fourteen or sixteen inches. They are tied in bundles of four or five inches in diameter, with a cord or iron wire, and then boiled in the composition for tourteaux, and thrown into water to cool. They are principally used to give light to the works of an enemy, and to set fire to the passage of the ditch.

Fascines are of different kinds. In fortification, they are a kind of fagot, made of small branches of trees or brush wood, tied in three, four, five, or six places, and are of various dimensions, according to the purposes intended. Those that are to be pitched over for burning lodgements, galleries, or any other work of the enemy, should be one and a half or two feet long.

Sec. X. Of Torches or Flambeaux.

We have already spoken of torches, but in connection with military pyrotechny, we may add, that they are used to give light [502]
during night marches, and for other purposes. They are made in the following manner.

Boil, in a mixture of equal parts of water and saltpetre, old cords or old match, well cleaned and untwisted. Take them out and dry them; then cut them in pieces of four and a half feet in length, and tie four of these pieces with twine to a cylindrical piece of wood, of the same length, and an inch in diameter; so that the whole together may be from two to two and a half inches thick. Dip this torch into a liquid made of equal parts of meal-powder and sulphur, mixed together with brandy, in which some gum has been dissolved. Fill the intervals of the pieces of cordage, with a paste, composed of three parts of sulphur, and one of quicklime. Dry the torch, and when dry, turn it gently round, and finish it by pouring on it the following composition.

Composition for Flambeaux.

Turpentine,	32 parts.
Venice turpentine,	4 ——
Beeswax,	32 ——
Sulphur,	12 ——
Camphor,	6 ——

Another.

Pitch,	6 parts.
Turpentine,	6 ——
Venice turpentine,	1 ——

Torches or flambeaux may also be made without the central piece of wood.

Torches ought to have the quality of burning, let the weather be what it may. The following method of making them is also recommended.

Take four large cotton matches, three or four feet long, boil them in saltpetre, and arrange them round a pine stick; after which cover them with priming powder and sulphur, made into a thin paste with brandy. When dry, cover the matches with the following composition; viz. 2 lbs. of yellow wax, as much white pitch, 12 oz. sulphur, 6 oz. camphor, and 4 oz. of turpentine: melt the whole together.

Sec. XI. Of Powder Bags. [503]

Powder bags are little sacks, that contain four pounds of powder.

They are of great use in besieged places. They are cast by the hand, set fire wherever they fall, and very much intimidate troops making an assault. They are made with good coarse cloth. Their width and size are not determined. It is sufficient that they can be easily thrown. The sides only are sewed up. In charging them, we begin by tying one end with strong packthread. Then turn it inside out, so that the ligature may be within, and fill it with powder, ramming it down with a cartridge form, proportioned to the bag, until it is full. Then put in the fuse, the large end inwards, and tie the bag tight. Afterwards the outside is covered with tar, or pitch.

Sec. XII. Of the Powder Barrel.

A powder barrel is a common barrel, filled with powder, to roll from the top of a breach, or upon the head of a sap from the glacis. The barrel contains from 100 to 200 pounds of powder, and is covered with a cloth. A hole is made at each end, in which a fuse may be fixed, of such a size, that the fire may be communicated to the powder, at the moment when the barrel, rolled from the top of the breach, is met by the troops mounting to the assault.

English writers state the diameter of powder barrels at 16 inches, and 30 or 32 inches in length, and capable of holding 100 pounds of powder. The quantity of powder put into them is 90 lbs; into a half-barrel, 45 lbs; and into a quarter-barrel, used for rifle powder, only 22½ lbs. This proportion leaves a space for the powder to separate when rolled, or otherwise it would always be in lumps, and liable thereby to damage.

Sec. XIII. Of the Burning or Illuminating Barrel.

This barrel differs from the thundering barrel, which we shall describe in the following section, only in having no grenades; and when it is placed upon a glacis, it lights up or discovers the works of the besieger. It has a fuse in only one of its ends.

When shavings are boiled in the composition for links and fascines, or of tourteaux, and arranged layer by layer, scattering, over [504]
each stratum, some priming-powder, the combustion must be rapid, when the barrel is set on fire.

Fire barrels, we may observe, are of different kinds. Some are mounted on wheels, filled with composition, and intermixed with loaded grenades, and their outsides full of sharp spikes. Some are placed under ground, and have the effect of small mines; and others, as the kind we have mentioned, are used to roll down a breach to prevent the entrance of the enemy. The following composition has been used for the same purpose.

Composition for Fire-Barrels.

Grained powder,	30 lbs.
Pitch,	12 —-
Saltpetre,	6 —-
Tallow,	3 —-

Sec. XIV. Of the Thundering Barrel.

This is employed for the same purpose as the preceding, or to light up the works of the besieger at the foot of the glacis. It has the same dimensions with the other, but has no cover. It is filled with chips, (dipped into the composition of the tourteaux), which are arranged in layers, putting, between each layer, meal-powder, and grenades, furnished with their fuses, or with pieces of musket barrels. The first and last layers are made with tow, boiled in the carcass composition. The barrel being filled, it is then closed and primed in the same way as the powder barrel, with a bomb fuse at each end. Holes are made along the barrel to assist the combustion. Grenades are employed in particular to prevent the approach of persons to extinguish the flame.

The invention of bombs is said to be owing to Scotland, and to the siege of St. Andrews. In the *Art of War* (says the *Anthologia Hibernica*, vol. iii, p. 174) printed at Venice, we are shown the representation of a hogshead, coated with conical headed nails, in which there is enclosed a barrel of gunpowder, suspended in the centre by an iron tube, which communicates at both ends with the open air. This engine, we are told by the author, killed 558 persons by its explosion in the fosse.

Sec. XV. Of the Petard. [505]

The petard is used to break down the gates and barriers of small towns, and even their walls, by hanging it against them, and setting fire to the fuse. Its invention is ascribed to the French Huguenots in 1579, who, by means of petards, took Cahors, in the same year. It was invented, as others inform us, by the celebrated Coehorn.

The petard is a hollow piece of iron, either cast or wrought, of the figure of a truncated cone, and usually eight inches high, and nine and a half inches diameter at the base, the metal being five-sixths of an inch thick at top, and half an inch at bottom. It is open at the large end; and the small end, which is rounded, is pierced with a hole, in which is placed a brass fuse, filled with composition, in lieu of which, however, an ordinary bomb-fuse, or a quick-match may be used. It is furnished with four trunnions, (one and a half inches by one), to receive the iron staples, that are attached to an oaken plank, eighteen inches square, and two and a half inches thick, and reinforced below by two iron bands, in the form of a cross, nailed and dove-tailed in. It has two iron handles to carry it by, and to hook it to a screw, fixed in the gate intended to be broken. It is filled with gunpowder.

When the petard is to be loaded, it is filled with powder to within three inches of the bottom. Some folds of cartridge paper are then put in, and a bed of tow well rammed. It is finished with a hot cement made of one part of rosin, and two parts of ground brick, or Spanish brown. A plate of iron four or five lines thick is set into this, that fits the inside of the petard at that part. It is furnished with three iron points, to be driven into the plank. A petard, ready for use, weighs eighty-five pounds, and contains nine pounds of powder.

Dimensions of the Petard.

		Inches.
Exterior diameter of the opening.		9½
Exterior height.		8
Thickness of the metal,	At the height,	5/6
	In the middle,	¾
	At the bottom,	½
Trunnions,	Length,	1½
	Height,	1
Fuses,	Length,	4 5/12
	Diam. under the screw,	11/12
	Diam. of the screw,	1⅓
Plank,	Length and width,	18 [506]
	Thickness,	2½

According to Ruggeri, a petard is filled, after warming it, with three fingers of powder, which is moistened with brandy, and then compressed without crushing it. On this powder, a quick match is placed, which is also compressed; after which, it is filled with composition previously melted. The composition is as follows:

Composition for Petards.

Pitch	4	parts.
Sulphur,	3	——
Saltpetre,	1	——
Antimony,	1	——

After introducing one-half of this mixture, when melted, we put in the iron plate, which rests on the composition, and then add the rest of it, which finishes the operation.

Sec. XVI. Of the Stink-Fire Lance.

This lance (*Lance à feu puant* of the French) is prepared in the same manner as stink-pots, and is principally used by miners. When a miner or sapper has so far penetrated towards the enemy, as to hear the voices of persons in any place contiguous to his own excavation, he first of all bores a hole with his *probe*, then fires off several pistols through the aperture, and lastly forces in a *lance à feu puant*. He takes care to close up the hole on his side, to prevent the smoke from returning towards himself. The explosion and fetid gas and vapour, which issue from the lance, and remain on the side of the enemy, infect the air so much, that it is impossible to approach the quarter for three or four days. Sometimes, indeed, they have had such instantaneous effect, that, in order to save their lives, miners, who would persevere, have been dragged out in an apparent state of suffocation.

The composition of ordinary fire-lance has been given. They are sometimes used to set fire to fuses.

The fire-pot is a vessel made of clay, with two handles, in which a grenade with powder is confined, and which is thrown against an enemy, after the match has been lighted; but a stink-pot is a vessel, filled with combustible and other matter, used in boarding ships, &c.

The suffocating pot is another contrivance, as its name expresses, to produce suffocation; and, as the materials consist only of [507]
sulphur and nitre, the gas which principally produces this effect is the sulphurous acid.

Composition for Suffocating Pots.

Sulphur,	6	parts.
Nitre,	5	——

Connected with this subject, we may mention another composition, to produce *smoke*, which is used either in pots, or balls. Hence, the *smoke-pot*, and *smoke-balls*. The following is the composition.

Composition for Smoke-Balls.

Grained-powder,	10	lbs.
Nitre,	2	—–
Pitch,	4	—–
Sea-coal,	3	—–
Tallow,	1	—–

The coal and pitch produce the smoke, and the gunpowder and nitre promote the combustion, and, with the tallow render the product of combustion more offensive.

Sec. XVII. Of the Combustible Substances used in, and the Manner of preparing, a Fire-Ship.

A fire-ship is a vessel, filled with combustible substances, and fitted with grappling irons, to hook, and set fire to the enemy's ships in battle, &c.

With respect to the preparation required, some knowledge may be had by considering the following particulars. From the bulk-head at the fore-castle, to a bulk-head to be raised behind the main chains, on each side, and across the ship at the bulk-heads, is fixed, close to the ship's sides, a double row of troughs, two feet distance from each other, with cross troughs quite round, at about two and a half feet distance, which are mortised into the others. The cross troughs lead to the sides of the ship, to the barrels, and to the port-holes, to give fire both to the barrels and to the chambers, to blow open the ports; and the side troughs serve to communicate the fire all along the ship, and the cross troughs.

The timbers, of which the troughs are made, are about five inches square; the depth of the trough, half their thickness; and they [508]
are supported by cross-pieces at every two or three yards, nailed to the timbers of the ship, and to the wood-work, which encloses the fore and mainmasts. The decks and troughs are all well payed with melted rosin. On each side of the ship, six small port-holes are cut, from fifteen to eighteen inches large, (the ports opening downwards), and are close caulked up.

Against each port is fixed an iron chamber, which, at the time of firing the ship, blows open the ports and lets out the fire. At the main and fore chains, on each side, a wooden funnel is fixed over a fire-barrel, and comes through a scuttle in the deck, up to the shrouds to set them on fire. Both funnels and scuttles must be stopped with plugs, and have sail-cloth or canvass nailed close over them to prevent any accident happening that way by fire to the combustibles below.

The port-holes, funnels, and scuttles, not only serve to give the fire a free passage to the outside and upper parts of the ship and her rigging, but also to allow the inward air (otherwise confined) to expand itself, and push through those holes at the time of the combustibles being on fire, and prevent the blowing up of the decks, which otherwise must happen from the sudden and violent rarefaction of the air.

In the bulkhead behind on each side, is cut a small hole, large enough to receive a trough of the same size as the others, from which, to each side of the ship, lies a leading trough, one end coming through a sally port, cut through the ship's side, and the other fixing into a communicating trough, that lies along the bulk head, from one side of the ship to the other; and being laid with quick-match, at the time of firing either of the leading troughs, it communicates the fire, in an instant, to the contrary side of the ship, and both sides burn together.

Having thus described this preparatory arrangement, we shall consider, in the next place, the combustibles made use of in fitting up a fire-ship.

Fire-barrel. The fire-barrels for this purpose are cylindrical, on account of that shape answering better both for filling them with reeds, and for stowing them between the troughs. Their inside diameters are about 21 inches, and their length 33. The bottom parts are first filled with double-dipt reeds, set on end, and the remainder with fire-barrel composition, made of the following substances.

Composition for fire-barrels, for fire-ships. [509]

Grained Powder	30	lbs.
Pitch	12	—–
Saltpetre	6	—–
Tallow	3	—–

There are 5 holes of three-quarters of an inch in diameter, and 3 inches deep, made with a drift of that size, in the top of the composition, while it is warm; one in the centre, and the other four at equal distances, round the sides of the barrel.

When the composition is cold and hard, the barrel is primed by well driving these holes, full of fuse composition, to within an inch of the top; then fixing in each hole a strand of quick-match twice doubled, and in the centre hole, two strands the whole length; all which must be well driven with meal-powder. Then lay the quick-match all within the barrel, and cover the top of it with a dipped curtain, fastened on with a hoop to slip over the head, and nailed on.

Bavins. Bavins are made of birch, heath, or other sort of brush wood, that is both tough and quickly fired. Their length is 2½ to 3 feet. The bush ends are all laid one way, and the other ends, tied with two bands each. They are dipped, and sprinkled with sulphur, the same as reeds; with this difference, that the bush ends only are dipped, and should be a little closed together by the hand as soon as done, to keep them more compact, in order to produce a stronger fire, and to preserve the branches from breaking in shifting and handling them.

Composition for Bavins.

Rosin	120	lbs.
Sulphur, coarse, or roll	90	—–
Pitch	60	—–
Tallow	6	—–
Meal-powder	12	—–

Iron Chambers. These are ten inches long, and 3.5 in diameter; breeched against a piece of wood, fixed across the holes. When loaded, they are almost filled with grained powder, with a wooden tompion well driven into their muzzles. They are primed with a small piece of quick-match, thrust through their vents into the powder, with a part of it hanging out; and, when the ship is fired, they blow open the ports, which either fall downwards, or are carried away, and accordingly give vent to the fire out of the sides of [510] the ship.

Curtains. Curtains are made of barras, about three-quarters of a yard wide, and one yard in length. When they are dipped, two men, with each a fork, must run the prongs through the corner of the curtain at the same end. Then dip them into a large kettle of composition, (which is the same as the composition for bavins,) well melted; and, when well dipped and the curtain extended to its full breadth, whip it between two sticks of about 5.5 feet long, and 1.5 inches square, held close by two other men, to take off the superfluous composition hanging to it. Then immediately sprinkle sawdust on both sides, to prevent it from sticking, and the curtain is finished.

Reeds. They are made up in small bundles of about 12 inches in circumference, cut even at both ends, and tied with two bands each. The longest sort are 4 feet, and the shortest 2.5, the only lengths which are used. One part of them is single dipped, only at one end; the rest are double dipped, that is, at both ends. In dipping, they must be put about 7 or 8 inches deep into a copper kettle of melted composition, of the same kind as that for bavins; and, when they have drained a little over it, to carry off the superfluous composition, sprinkle them, over a tanned hide, with pulverized sulphur, at some distance from the copper. With respect to the stores, required for a fire ship of 150 tons, the following complement is given: *viz.*

		No.
Fire barrels		8
Iron chambers		12
Priming composition barrels		3½
Quick-match barrels		1
Curtains dipped		30
Long reeds, single dipped		150
Short reeds	{ double dipped	75
	{ single dipped	75
Bavins, single dipped		209

The quantity of composition, for preparing the stores of a fire ship is as follows:

For 8 barrels; grained powder 960 pounds, pitch 480 pounds, tallow 80 pounds.

For 3 barrels of priming composition, saltpetre 175 lbs. sulphur 140 lbs. grained powder 350 lbs. rosin 21 lbs. oil-pots 11.

For curtains, bavins, and reeds, and sulphur to *salt* them, as artificers call it; sulphur 240 lbs. pitch 350 lbs. rosin 175 lbs. tallow [511] 50 lbs. tar 25 lbs.

Total weight of the composition 3017 pounds, equal to 26 cwt. 3 qr. 21 lbs.

The composition, required for the rods and barrels, is one-fifth of the whole of the last article, which is equal to 160 lbs. making in the whole, 3177 lbs. or 28 cwt. 1 qr. 13 lbs.

Adye (*Bombardier and Pocket Gunner*) has given two general formulæ for the composition, used in fire-ships, which we will here insert.

Composition for dipping reeds, bavins, and curtains.

Rosin,	120	lbs
Coarse sulphur,	90	—
Pitch,	60	—
Tallow,	6	or 8
Mealed powder,	12	—

Composition for priming.

Pulverized saltpetre,	22	lbs.	8	oz.
Rosin,	2	—	11	—
Sulphur,	18	—		
Meal-powder,	45	—		
Linseed oil,	1	pint.		

The composition put in cases, to set fire to fascine batteries, is sometimes used in fire-ships, *viz.*

Composition for setting fire to Fascine Batteries.

Meal-powder,	1 lb.	4 oz.
Saltpetre,	6 —	

Sulphur,	1 — 8 oz.

There is also another composition, which might be used advantageously for the same purpose, and which is employed for hoops, fire-arrows, and lances, namely:

Composition for Hoops, Fire-Arrows, &c.

Meal-powder,	1 lb.
Saltpetre,	3 —
Sulphur,	8 oz.
Linseed oil,	8 —

The composition of kitt, used for the last covering of carcasses, may also be employed. It must be applied when very thin and hot. [512]

Composition of Kitt.

Rosin,	9 lbs.
Bees' wax,	6 —
Pitch,	6 —
Tallow,	1 —

Sec. XVIII. On Infernal Machines.

The *Machines Infernales* of the French, which have excited so much attention in Europe, we deem of sufficient importance to describe.

This invention is by no means new, although it has been attributed to the French. It appears that Fredric Jambelli, an Italian engineer, was the first that used them, when Alexander, of Parma, besieged Antwerp. The Prince of Orange likewise had recourse to the destructive effects of an infernal machine, in order to bombard Havre-de-Grace, and to set it on fire. The Dutch and English, in conjunction, attempted to destroy St. Malo by the same means. The first instance, however, upon record, in which the French made use of this machine, was when Louis XIV ordered a vessel, carrying an enormous shell, full of every kind of combustible matter, to be despatched to Algiers, for the purpose of demolishing its harbour. This, it is supposed, suggested the use of fire-ships, which have frequently been used against maritime places.

The author of the *Œuvres Militaires*, tom. xxii, p. 222, speaking of the infernal machine, observes, that, if he were to be in a situation, which required the use of so dreadful an explosion, especially to destroy a bridge, he would prefer having the machine made simply with different strong pieces of wood, joined together, so as to be in the shape of an egg, or of a cone reversed.

The whole must then be made compact with cords twisted round. This method, in his opinion, is not only the best, but can be executed in the most easy and expeditious manner. He further adds, that, in order to burn or blow up wooden bridges, and even to destroy such as are constructed upon arches, several sorts of barges or boats might be used, which should be filled with fire-works, bombs, petards, &c. It would, likewise, be easy to construct these machines upon floating rafters, carrying several thousand pounds weight of gunpowder, which might be confined within strong pieces of wood, put together in the manner already described.

These machines should be piled one above another, and long iron bars must be thrown across the floats, or be fixed like masts; [513] so that, when the whole of the combustible material is beneath the centre of the bridge, the rafters may be stopped. Great care must be taken to dispose the matches in such a manner, that no fire may be communicated to the gunpowder before the machine reaches the exact spot, which is to be destroyed.

In 1804, an infernal machine was used at Boulogne, which is described as follows:

This machine appears to be as simple in its construction, as it is calculated to be effectual in its operations. It is composed of 2 stout planks, 17 feet long, which form its sides, and are distant from each other about 7 feet.

These planks are connected by transverse timbers, screwed to the planks; so as to keep the whole firm and compact, and to prevent the danger of their being separated at sea. Of these transverse timbers, two are at the fore extremity, and three behind. This may be called, the frame or hull of the machine; the remainder of the work, being either for the stowage of the combustible matter, or for the accommodation of the seamen, who row the machine. Along the transverse timbers, at both extremities, are laid parallel to the sides, five longitudinal bars of nearly the same strength as the transverse timbers, which form a kind of grate, on which the coffers, containing the combustible matter, are placed. The grate behind is double the size of the one before, on the principle of giving facility to the motion of the whole, by making the machine lighter at the head. In the centre, between the planks forming the sides, from the inner extremity of the grate behind, to the outer extremity of the grate before, there is fixed a plank, somewhat broader than the side planks, which is well secured to them by three stout transverse timbers, which pass under the centre plank, to prevent its giving way to pressure.

In this plank, two triangular apertures are cut for men who row, to dispose of the lower extremities, whilst they ply the machine. Their seats, however, are so contrived, that each man's pressure is directly over that part of the plank, which is supported by the transverse timbers. The seats lie nearer to the head than to the hind part of the machine; perhaps to be some counterpoise for the greater weight of the combustible matter behind. Near each seat are fastened by rings to the sides, two oars, one on each side, and each man plies a pair. When the machine is worked to its destination, the men set the combustibles in a train for explosion, [514] and abandon their posts.

The whole is so regulated, as to weight of materials, that the machine floats, or, more probably, moves under the surface of the water; so that little more than the heads of the men are seen. This secures the men and the machine from the fire of the enemy; and as the oars must be constantly plied under water, there is less danger of their being discovered by their noise, as they approach.

Infernal machines have also been made, to be used on land. Such is the machine we are told, which was intended for the destruction of Bonaparte. They may be made to explode at a given time, by clock-work, or by a match, calculated to burn a certain time!

Sec. XIX. Of the Catamarin.

The catamarin, properly so called, is a floating raft, originally used in China, and among the Portuguese as a fishing-boat. The Indian catamarin consists of two logs of wood, upon which the natives float, and go through the heaviest surf.

The military or naval catamarin is a different thing. It is properly a case, filled with combustibles, and contrived to remain so low in the water as to be almost imperceptible. This, being towed to the building, or ship, against which the attack is to be directed, is left to explode, by means of machinery within itself, when its operation is sometimes very destructive.

English writers acknowledge, that the catamarin, submitted by the late Mr. Pitt to the English government, and which cost in its construction a considerable sum, was originally invented by our countryman, the late Mr. Fulton, of whose invention we will speak hereafter.

Some observations on a boat, named, by the French, *Chelingues*, and the Indian catamarin, may be seen in the *Dictionnaire de l'Industrie*, article *Bateau*.

Several diving machines have been invented in France and elsewhere. M. Castera (*Archives des Découvertes*, iii, p. 185) describes a *plunging boat*, which resembles in figure a cone. It is furnished with a reservoir, calculated to hold water, and may be filled or emptied by means of pumps. By means of glasses and copper handles, the navigator is enabled to see and to take hold of objects. It is also furnished with tubes for the transmission of the air necessary for respiration, that communicate from the interior of the vessel with the atmosphere; and a double bellows, designed as well for receiving, as expelling air. Besides oars or paddles, [515] necessary to move it under water, there is a contrivance for detaching the boat from the reservoir, either wholly or in part, according to circumstances.

M. Castera, in a memoir on *sub-marine navigation*, has noticed several applications of the plunging boat, which may be seen in the *Bulletin de la Société d'Encouragement*, No. 71. In No. 61, of the same work, is the first notice of Castera's invention, an extract of which may be seen in the *Archives des Découvertes*, ii. p. 121. A description of Lutgendorf's boat may be seen in the *Magazin der Erfindungen*, No. 46.

It is well known that the diving-bell, and similar contrivances, have been used for naval purposes, in connection with naval warfare.

Divers, or those who made it a business, by long habit and experience, to remain under water, and go to a great depth, were often employed in war to destroy the works and ships of the enemy. When Alexander was besieging Tyre, divers swam off from the city, under water, to a great distance, and, with long hooks, tore to pieces the mole, with which the besiegers were endeavouring to block up the harbour. The invention of the diving-bell, the *campana urinatoria* of some, is generally assigned to the sixteenth century; but it is evident, from the writings of Aristotle and others, that, in his time, divers used a kind of kettle to enable them to continue longer under water.

At the pearl fisheries, in the Bay of Condalzchy, in Ceylon, divers usually remain under water two minutes. There are some who can stay five minutes; and a diver from Anjano, engaged in this fishery in 1797, was able to remain six minutes under water. But their efforts are so great, that, when they come up, blood frequently issues from their mouths, ears, and nostrils. Notwithstanding this, they frequently dive from forty to fifty times a day, and bring up in a bag-net a hundred oysters each time.

It may be proper to observe, that the subject of sub-marine navigation was largely descanted upon by Mersennus, (*Tractatus de Magnetis Proprietatibus*), and by Bishop Wilkins (*Mathematical Magic*, 1648), who, by the way, is rather visionary. The conveniences and advantages he enumerates, are: 1. 'Privacy, as a man may thus go to any part of the world invisibly, without being discovered or prevented. 2. Safety, from the uncertainty of tides and tempests, &c. 3. It may be used to blow up, or [516] undermine a navy: 4. Or to relieve a blockaded place, &c. But, with regard to the use of sub-marine vessels in war, Mr. David Bushnel, of Saybrook, Connecticut, appears to be entitled to the credit of the invention. His account of it may be seen in the *Transactions of the American Philosophical Society*. The intended object of this vessel was to destroy shipping, by the explosion of a magazine of gunpowder.

In Silliman's *Journal of Science and Arts*, vol. II, p. 94, is a communication by Mr. Griswold, on the subject of Bushnel's machine, with an account of the first attempt with it, in August, 1776, by Ezra Lee, a sergeant in the American army, to destroy some of the British ships then lying at New York. Mr. Griswold remarks, that, considering the invention of Mr. Bushnel as the first of its kind, it will be pronounced to be remarkably complete throughout in its construction, and that such an invention furnishes evidence of those resources and creative powers, which must rank him as a mechanical genius of the first order.

He has given a description of it; but the outline which we give is taken from *Nicholson's Journal*, quarto, iv, p. 229.

It is a decked boat, to go underwater: and several persons have gone under water many leagues. The difficulty is, to provide the persons in the boat with fresh air for respiration; and this is contrived, by having a reservoir of air, of suitable dimensions to the size of the boat, and the number of persons in it. By means of a condensing pump, the air, in this reservoir, is condensed about 400 times; and by a spring, the air is let out at intervals, as circumstances require, the carbonic acid produced by respiration being absorbed by quicklime. Within this boat are flaps, like those of a rundle, to move the boat, two rudders, one vertical, the other horizontal, and a pump to empty the hold, or air reservoir. The person within, can, at pleasure, come to the top of the water. The different experiments made by Mr. Bushnel may be seen in the *Transactions* referred to, or in *Nicholson's Journal*, quarto, iv, 229.

During the late war, Mr. Fulton, Mr. Mix, and some others, made various experiments with submarine machines; and during the revolution, the incendiary kegs, well known by the name of the "*battle of the kegs*," excited no small attention, and, had it not been for some unforeseen circumstance, they would, in all probability, have produced the effect for which they were intended.

Of Bushnel's vessel, we may observe, that, in the fore part of the brim of the crown, as it is called, was a socket, and an iron tube [517] passing through the socket. The tube stood upright, and could slide up and down in the socket, six inches. At the top of the tube was a wood screw, fixed by means of a rod, which passed through the tube, and screwed the wood screw fast upon the top of the tube. By pushing the wood screw up against the bottom of a ship, and turning it at the same time, it would enter the planks. When the wood screw was firmly fixed, it could be cast off by unscrewing the rod, which fixed it upon the top of the tube.

Behind the submarine vessel, was a place, above the rudder, for carrying a large powder magazine. This was made of two pieces of oak timber, sufficiently large, when hollowed out, to contain 150 lbs. of powder, (130 lbs. according to Griswold,) with the apparatus used in firing it, and was secured in its place by a screw, turned by the operator. A strong piece of rope extended from the magazine to the wood screw above mentioned, and was fastened to both. When the wood screw was fixed, and to be cast off from its tube, the magazine was to be cast off likewise by unscrewing it, leaving it hanging to the wood screw; it was lighter than the water, that it might rise up against the object, and apply itself when fastened.

Mr. Griswold remarks, that the most difficult point of all to be gained, was to fasten this magazine to the bottom of a ship.

Within the magazine, was a machine, constructed to run any proposed length of time under twelve hours. When it had run out its time, it unpinioned a strong lock resembling a gun-lock, which gave fire to the powder. This apparatus was so pinioned, that it could not possibly move, till, by casting off the magazine from the vessel, it was set in motion.

This skilful operator could swim so low on the surface of the water, as to approach very near a ship in the night without fear of discovery, and might, if he chose, approach the stem or stern above water, with very little danger. He could sink very quickly, keep at any depth he pleased, and row a great distance in any direction he desired, without coming to the surface; and, when he rose to the surface, he could soon obtain a fresh supply of air; when, if necessary, he might descend again and pursue his course. The projector found some time and attention to be requisite for the gradual instruction of this operator, and, after various attempts, he [518] found one, on whom he thought he could depend. He sent this man from New York to a 50 gun ship, lying not far from Governor's island. He went under the ship, and attempted to fix the wood screw in her bottom, but struck, as he supposed, a bar of iron, which passes from the rudder's hinge, and is spiked under the ship's quarter. Had he removed a few inches, which he might have done without rowing, the projector has no doubt but he might have found wood, where he might have fixed the screw; or if the ship were sheathed with copper, he might easily have pierced it. But, not being well skilled in the management of the vessel, in attempting to row to another place, he lost the ship. After seeking her in vain some time, he rowed to some distance, and rose to the surface of the water, but found day light had advanced so far, that he durst not renew the attempt. He says, he could easily have fastened the magazine under the stern of the ship above the water, as he rowed up to the stern, and touched it before he descended. Had he fixed it there, the explosion of 150 lbs of gunpowder (the quantity contained in the magazine) must have been fatal to the ship. In his return from the ship to New York, he passed near Governor's island, and thought he was discovered by the enemy on the island. Being in haste to avoid the danger he feared, he cast off the magazine, as he imagined it retarded him in the swell, which was very considerable. After the magazine had been cast off an hour, the time the internal apparatus was set to run, it blew up with great violence.

Mr. Griswold gives an account of an attempt to destroy a ship of war; and having received his information from Mr. Lee, one of the adventurers, we have thought proper to introduce it from that source.

"It was in the month of August, 1776, when Admiral Howe lay with a formidable British fleet in New York bay, a little above the narrows, and a numerous British force upon Staten Island, commanded by General Howe, threatened annihilation to the troops under Washington, that Mr. Bushnel requested General Parsons, of the American army, to furnish him with two or three men to learn the navigation of his new machine, with the view of destroying some of the enemy's shipping.

"General Parsons immediately sent for Lee, then a sergeant, and two others, who had offered their services to go on board a fire ship; and on Bushnel's request being made known to them, they enlisted themselves under him for this novel piece of service. The [519] party went up into Long Island sound with the machine, and made various experiments with it in the different harbours along shore; and after having become pretty thoroughly acquainted with the mode of navigating it, they returned through the sound; but, during their absence, the enemy had got possession of Long Island and Governor's Island. They, therefore, had the machine conveyed by land across from New Rochelle to the Hudson river, and afterwards arrived with it at New York.

"The British fleet now lay to the north of Staten Island, with a large number of transports, and were the objects against which this new mode of warfare was destined to act. The first serene night was fixed upon for the execution of this perilous enterprize, and sergeant Lee was to be the engineer. After a lapse of a few days, a favourable night arrived, and, at 11 o'clock, a party embarked in two or three whale boats, with Bushnel's machine in tow. They rowed down as near the fleet as they dared, when sergeant Lee entered the machine, was cast off, and the boats returned.

"Lee now found the ebb tide rather too strong, and before he was aware, had drifted him down past the men of war. He, however, immediately *got the machine about*, and by hard labour at the crank for the space of five glasses by the ship's bells, two and a half hours, he arrived under the stern of one of the ships at about slack water. Day had now dawned, and by the light of the moon he could see the people on board, and hear their conversation. This was the moment for diving: he accordingly closed up over head, let in water, and descended under the ship's bottom. He now applied the screw, and did all in his power to make it enter; but owing probably in part to the ship's copper, and the want of an adequate pressure, to enable the screw to get a hold on the bottom, his attempts all failed. At each essay, the machine rebounded from the ship's bottom, not having sufficient power to resist the impulse thus given to it. He next paddled along to a different part of her bottom, but, in this manœuvre, he made a deviation, and instantly rose to the water's surface on the east side of the ship, exposed to the increasing light of the morning, and in imminent hazard of being discovered. He immediately made another descent, with a view of making one more trial; but the fast approach of day, which would expose him to the enemy's boats, and render his escape difficult, if not impossible, deterred him; and he concluded the best generalship would be, to commence an immediate retreat. He now had before him a distance of more [520] than four miles to traverse, but the tide was favourable. At Governor's island, great danger awaited him; for his compass having got out of order, he was under the necessity of looking out from the top of the machine very frequently, to ascertain its course, and at first made a very irregular zigzag track. The soldiers at Governor's island espied the machine, and curiosity drew several hundreds upon the parapet to watch its motions. At last a party came down to the beach, shoved off a barge, and rowed towards it. At that moment, sergeant Lee thought he saw his certain destruction, and as the last act of defence, let go the magazine, expecting they would seize that likewise, and thus all would be blown to atoms together. Providence, however, otherwise directed it: the enemy, after approaching within 50 or 60 yards of the machine, and seeing the magazine detached, began to suspect a *yankee trick*, took alarm, and returned to the island. Approaching the city, he soon made a signal; the boats came to him, and brought him safe and sound to the shore. The magazine, in the mean time, had drifted past Governor's island into the East river, where it exploded with tremendous violence, throwing large columns of water, and pieces of wood that composed it, high into the air. General Putnam, with many other officers, stood on the shore, spectators of this explosion.

"In a few days, the American army evacuated New York, and the machine was taken up the North river. Another attempt was afterwards made by Lee, upon a frigate that lay opposite Bloomingsdale. His object now was to fasten the magazine to the stern of the ship, close at the water's edge. But while attempting this, the watch discovered him, raised an alarm, and compelled him to abandon his enterprize. He then endeavoured to get under the frigate's bottom; but in this he failed, having descended too deep. This terminated his experiments."

With regard to diving bells, several machines, for the purpose of descending under water, &c. have been invented. Some experiments have been made by the French with similar contrivances, without any adequate result; and the difficulty of carrying them into execution, in real practice, will prevent their introduction.

Dr. *Caustic*, (*Terrible Tractoration*, p. 65), in a note, in reference to Bushnel's invention, observes, that if you consult the Transactions of the American Philosophical Society, "you will see what Mr. D. Bushnel, of Connecticut, has done, and had like to [521] have done, by virtue of submarine explosions. You will find, that several English ships have been put in jeopardy, and one schooner actually blown up and demolished by Mr. Bushnel's submarine explosions."[33]

Sec. XXI. Of the Torpedo.

The late Mr. Fulton applied himself to the improvement of the *Turtle* during the late war, and brought it to such perfection, that if it came in contact with a ship's bottom, it would inevitably blow up the vessel. From the account we have given of the turtle, we may readily imagine the construction of the torpedo. These were of several kinds; some (or rather the magazine attached to them,) were designed to be screwed under the bottom, and others to explode by coming in contact with the vessel, or any resisting body. The time of explosion was so determined, by clock-work machinery, in the manner of Bushnel's contrivance that it would invariably explode at the minute or second required.

Mr. Fulton wrote a number of essays on this torpedo, and other contrivances for annoying the enemy, such as the harpoon, &c. The torpedo, at which the British ships, stationed on our coast, were so much alarmed, is in fact a powerful weapon of destruction. It is to be observed, that the magazine, accompanying the *bell*, in some instances, was detached; so that the latter was removed out of danger, when the former was fixed to the ship's bottom. In order to prevent the torpedo from floating against the sides of a [522] vessel, the precaution of having netting spread at some considerable distance round the vessel, and of keeping up a constant guard of boats, which were rowed round the ship both day and night, was used. Not having the writings of Mr. Fulton before us, we can give no precise description of his improvements. They are described to be an apparatus, of which the principal piece is a copper box, and prepared with an interior spring, which sets fire to the powder; at the same time that the whole is enclosed in a covering of cork, or some other light wood, to make the torpedo float under the surface of the water.

It will be sufficient to remark, that *they* have produced the *effect* of causing a constant, and, in our opinion, painful anxiety to the British. Of this we have abundant proof. We may add, however, the result of some of the experiments, by which it will appear, that they are eminently calculated, like the infernal machine, to produce death and destruction.

In consequence of some essays, published by Mr. Fulton, on the practicability of destroying ships by torpedoes, several persons turned their attention to this subject; among whom was a Mr. Mix of the navy. Mr. Mix's intention was to destroy the ship of war Plantagenet, of 74 guns, lying in Lynnhaven bay. Having made a torpedo, Mr. Mix, accompanied by two gentlemen, one of whom was a midshipman, proceeded in a boat, on the night of the 24th of July, 1813, and, having reached within 100 yards of the ship, dropped the torpedo. It was swept along by the side, but exploded a few seconds before it would have come in contact with the vessel. It produced, however, great consternation and confusion on board the vessel, and induced several of the crew to take to their boats. The ship was greatly agitated, and some damage done by the violent motion of the water. The noise, occasioned by the explosion, was loud and tremendous; and the appearance of the water, thrown up in a column of thirty or forty feet high, awfully sublime. It has not been ascertained, that any lives were lost.

The case of a Mr. Penny, of Easthampton, Long Island, is connected with the subject of torpedoes. He was carried on board the Ramilies, and put in irons; because his name had been entered on the books of one of the frigates, as having been "*employed in a boat, contrived for the purpose, under the command of Thomas Welling, prepared with a torpedo, to destroy this* (Capt. Hardy's) *ship*."

The affair of Stonington, also, shows, that the British were determined to punish the inhabitants for having, as captain Hardy [523] expresses it, prepared torpedoes; and the captain stated, in his reply to the deputation from the town, that the bombardment should cease, in case the inhabitants would engage that no *torpedoes* should be fitted out by them. No torpedoes, however, were fitted out at Stonington.[34]

Mr. Fulton made a number of experiments with the torpedo, in the harbour of New York; and one vessel was completely cut in two. These experiments were very satisfactory to all who witnessed them.

The greatest difficulty he experienced was in giving them a proper direction, so as to hit the vessel intended to be destroyed. This he acknowledged to a friend, professor Eaton, of Troy, who informed us of the fact. He entertained no doubt whatever of the effect of the torpedo, when once brought in contact with a vessel.

At Havre, in France, Mr. Fulton constructed a sub-marine boat, sufficient to contain several men, and air for eight hours, and strong enough to bear submersion to the depth of one hundred feet, if necessary. In this boat, he remained an hour under water, made half a league of way in that time, with his boat horizontally situated, and at various depths, where he found that the compass traversed exactly, as on the surface. To the boat he attached a machine, by means of which he blew up a lighter in Brest Harbour.

While in France, in the time of the Republic, Mr. F. directed his attention to this subject. His *Bateau-poisson*, described in the *Dictionnaire de l'Industrie*, vol. i, p. 265, is of the same character. A number of experiments performed with it are given.

Sec. XXII. Of the Marine Incendiary Kegs, &c.

We purpose to notice, under this head, two contrivances, which have been used, the one in the revolution, and the other, during the late war with Great Britain.

The piece of poetry, called the *Battle of the Kegs*, written by the late Francis Hopkinson, Esq. of Philadelphia, narrating the incendiary kegs, is founded on this contrivance.

For the purpose of destroying the shipping at Philadelphia, which was then in possession of the British, some forty or more kegs were fitted up at Burlington, N. J. or in its neighbourhood, containing a quantity of gunpowder. These kegs were connected in such [524] a manner, that, while they formed one float, when one exploded, the whole would go off. This arrangement was also made with another, if our information is correct, which consisted in a trigger connected with a gun-lock, (one or more kegs having the same); so that, when the triggers went off, by the casks coming against any thing, in floating down the tide, the whole would explode at the same time. There is one of the original kegs in the magazine of Fort Mifflin. We apprehend, however, that the contrivance was more like that of clock-work, set to a given time, like the torpedo of Fulton; but of this we have no certain account. These kegs were towed down the river, within a mile or two of the city, and were seen about sunrise opposite to it. They did no execution; but, if they had been taken to a given spot, instead of being left to the direction of the running current, and then properly adjusted, no doubt the effect would have been as the contriver calculated. It excited, however, no small sensation at the time.

Of the other contrivance, we have the following account: A Mr. Scudder (*History of the late War, &c.* p. 187) formed a design of destroying the British ship Ramilies, of 74 guns, off New London. For this purpose, 10 kegs of powder were put into a strong cask, with a quantity of sulphur mixed into it. At the head of the cask were, fixed two gun-locks, with cords fastened to the triggers, and to the under side of the barrels in the hatchway; so that it was impossible to hoist the barrels, without springing the locks each side of the powder. On the top were placed a quantity of turpentine and spirits of turpentine, which in all probability were sufficient to destroy any vessel that ever floated. These kegs were put on board the smack Eagle, which sailed from New York on the 15th of June, for New London; but which the crew abandoned, on being pursued by the boats of the enemy. It was expected, that the vessel would be brought alongside the Ramilies, and, by exploding, destroy that ship. The wind dying away, and the tide being against them, she could not, very fortunately for the enemy, be brought alongside. When the Eagle exploded, there were four boats alongside, and a great many men on board of her. After the explosion, there was not a vestige of the boats to be seen. A body of fire rose to a vast height, and then burst like a rocket. Every man, near or about her, was probably lost, as the boats sent from the Ramilies were seen to return without picking up anything.

In relation to similar enterprizes, what could have been a more daring and hazardous enterprize, than that of lieutenants Wadsworth, Summers, &c. who, by a previous agreement, determined, if they were likely to be captured by the Turks, to blow themselves up in the fire-ship, which they had prepared to destroy the enemy's shipping, in the harbour of Tripoli? Their fate is too well known, lamentable as it is! [525]

The marquis of Worcester, in his *Century of Inventions*, inventions nine and ten, speaks of certain contrivances for the destruction of vessels, which seem to have been of the kind mentioned: *viz.* "An engine, portable in one's pocket, which may be carried and fastened on the inside of the greatest ship, *tanquam aliud agens*; and, at an appointed minute, though a week after, either of a day or night, it shall irrecoverably sink that ship;" and "a way from a mile off, to drive and fasten a like engine to any ship, so as it may punctually work the same effect, either for time or execution."

Sec. XXIII. Of Sea Lights.

The *fanaux de mer*, or sea lights, are so called, from the particular application of this fire.

It is sometimes required at sea to throw light upon the water, and around the vessel, in order to perceive the approach of an enemy. This is effected by the composition for sea lights.

A tube must be formed of not less than three inches in diameter, and eleven inches in length. A shield is then adapted, of four times the exterior diameter of the tube or case, which shield is to be made of wood, and attached at about the distance of one-fourth of the length of the tube, and near the end of the orifice.

The case or tube is then charged with the following composition:

Composition for Sea Lights.

Saltpetre,	16	parts.
Sulphur,	8	——
Meal-powder,	3	——
Antimony,	3	——

The tube, which may be made of iron, pasteboard, or wood, by boring it out, after being charged, is primed in the usual manner, inserting in the end, at the same time, a piece of quick-match. When dried, it is wrapped in paper for better preservation. [526]

Sec. XXIV. Of Signal and War-Rockets.

Rockets, we have said, are cylindrical cases, formed generally of pasteboard, and filled with a peculiar composition, made of meal-powder, saltpetre, sulphur, and charcoal; or without powder, and sometimes with the addition of pulverized cast iron. In some, as the Congreve rocket, iron cases are substituted for those of paper. The outer diameter is usually from one and a half to two inches, the length of the charge five diameters, and the interior diameter two-thirds as much as the exterior. The tools necessary are, a rod or former of wood, to mould the case upon; an artificer's tool to roll the paper close; a conical spit or piercer, by means of which the rocket when loaded has a hollow through the middle, which piercer should be four and two-thirds times as long as the outer diameter of the rocket, one-third of this diameter at the base, and one-sixth at the small end; three rods for loading, having a conical aperture to receive the piercer, and one massive; and a ladle or measure, whose diameter is equal to that of the inside of the rocket, and its length three times as much. The construction of the cartouch case, or paper cylinder, consists in using pasteboard of three or more thicknesses, which is rolled on the former, until the case becomes sufficiently thick. The choaking of the cylinder is performed by means of a cord, of three lines in diameter, one end of which is firmly fixed into a wall, and the other tied to a stick, against which the artificer who bestrides the cord rests. The rocket is loaded or charged, by introducing at a time, a ladle full of composition, first fixing the case over the piercer, and using the appropriate rammer and mallet, in the manner stated, &c.[35]

Signal rockets are sometimes *trimmed* with serpents, stars, and petards. The serpents are made of cases in the manner already mentioned; *viz.* by rolling playing cards in the direction of their length, upon a former, three lines in diameter, and covered with three coats of paper, the last of which is pasted. The cases are choaked at one end, and in the niche is placed a strand of tow, and a priming of meal-powder, moistened with brandy. They are loaded, by means of a rod, three-fourths full of the composition, and again choaked at half their height. The remainder is filled up with powder, to make a report. If a serpent with stars is to be made, only half the case is filled with the serpent-composition, and the rest with that for stars. Serpents are placed upright in the pot, the priming down. [527]

Composition for Serpents, for trimming Signal Rockets.

Meal-powder,	16	parts.
Saltpetre,	3	——
Sulphur,	2	——
Charcoal,	½	——

The star composition is the same as before given.[36] It is mixed and made into balls or cubes, in the same manner. The petards or crackers are small cubes of paper, filled with grained gunpowder. They are wrapped with two layers of good thread, which is drawn tight in every direction. They are dipped in tar to give them more consistence, and pierced and primed with quick match. We have already given the theory of the flight of rockets in the first part of this work; and also the opinions of Mariotte and Dr. Desaguliers. On this head, therefore, further observation seems unnecessary We have said, however, that it is necessary, for giving the rocket a sufficient degree of motion, that the powder within the rocket be bored with a tapering cavity from the choke, and at the choke this cavity must be as wide as the choke itself, and at the further end, not more than half that width. The length of this bore must be but one inner diameter of the rocket, short of the whole height to which the rocket is rammed. The use of this bore, it is to be observed, is to increase the surface, that takes fire at once; that a greater body of fire may issue out of the mouth of the rocket. From the vehemence with which the fire issues out, the rocket receives its motion. We have seen, that rockets are used in all fire-works that have motion; for cases charged give motion to wheels of various kinds, and act on the same principle. Such works as are thrown into the air after the manner of bombs, are, however, an exception.

The rocket-stick is a necessary appendage. When very heavy, to prevent mischief by their fall, they now bore the sticks, and fill them with powder, that they may shiver in the air before they fall. [528]

That the stick keeps the rocket perpendicular is obvious. If the rocket should begin to tumble, moving round a point in the choke, as being the common centre of gravity of rocket and stick, there would be so much friction against the air, by the stick between the centre and the point, and the point would beat against the air with so much velocity, that the reaction of the medium would restore it to its perpendicularity. When the composition is burnt out, and the impulse upwards has ceased, the common centre of gravity is brought lower towards the middle of the stick. Hence the velocity of the point of the stick is decreased, and that of the point of the rocket increased; so that the whole will tumble down, with the rocket end foremost. During the combustion of the rocket, the common centre of gravity is shifting and getting downwards, and faster and lower as the stick is lighter.

In the *Philosophical Transactions*, (vol. xlvi, p. 578) and Robins's *Mathematical Tracts*, (vol. i, p. 317, &c.) are sundry experiments, and observations concerning the flight of rockets; and as these experiments appertain more to military purposes, the following extracts may, on that account, be useful.

Mr. Robins, considering the great use that may be made of rockets, in determining the position of distant places, and in giving signals for naval and military purposes, procured some, with a view of ascertaining the height to which they rise, and the distance at which they may be seen. The greatest part of them did not rise to above four hundred yards; one to about five hundred; and one to six hundred yards nearly. The greatest distance at which these were observed, was from thirty-five to thirty-eight miles. Others were fired at a different time, one of which rose to six hundred and ninety yards; and it was observed, that the largest, which were about two and a half inches in diameter, rose the highest. In some subsequent experiments, conducted by Mr. Da Costa, Mr. Banks, &c. it was found, that, of two rockets, of about three and a half inches in diameter, one rose to about eight hundred and thirty-three, and the other to 915 yards. In another trial, a rocket of four inches in diameter rose to one thousand one hundred and ninety yards. In other experiments, a rocket of one and a half inches rose to seven hundred and forty-three yards; one of two [529]
inches to six hundred and fifty nine; one of two and a half inches to eight hundred and eighty; another of the same size to one thousand and seventy-one; one of three inches to one thousand two hundred and fifty-four; one of three and a half inches to one thousand one hundred and nine; and one of four inches rose to seven hundred yards, and, turning, fell to the ground before it went out. Besides these, there was one of the rockets of "twenty-four inches in diameter,"[37] which rose to seven hundred and eighty four yards, and another of the same size, to eight hundred and thirty-three yards. From these experiments, it is inferred, that rockets from two and a half to three and a half inches in diameter, are sufficient to answer all the purposes for which they are intended; and they may be made to rise to a height, and to afford a light capable of being seen to considerably greater distances than those just mentioned.

Before we mention the war-rockets of Congreve, it may not be improper to speak of the Indian rockets, which are used by the native troops of India, and which were employed against the British, with great effect, during the seige of Seringapatam in 1799. These rockets are made of iron, and are lashed to a bamboo cane. The weight is seldom more than two pounds, or less than one. The *fougette*, or Indian rocket, resembles in shape a sky-rocket, *whose flight is gradually brought to run along a horizontal direction*. By throwing several fougettes into parks of artillery, and upon caissons, &c. considerable damage might be occasioned from the fire, which would inevitably be communicated to some part. A fougette forces itself immediately forward, cuts as it penetrates, by the formation of its sides, which are filled with small spikes, becomes combustible, and on fire at all its points, and possesses within itself a thousand different means, by which it can adhere to whatever object it is destined to set on fire or destroy. A French writer even asserts, that this weapon would be more effectual, because it might be more variously applied, to defend the mouth of a harbour against an enemy's shipping, than red-hot balls can ever prove; and we are also told, that, by means of their natural velocity, they would do more execution, in a less space of time, than the most active piece of ordnance could effect; and they would also require fewer hands, as the only necessary operation would be to light and dart them forward.

The fougette, called also in French the *Baguette à feu*, has received improvements in France, which we will notice hereafter. In [530]
favour of these improvements and their application, we are told, that, to do execution at a distance, especially in sea-fights, fougettes may be so made as that they may reach shipping at a great distance, and with a given velocity.

The Congreve rocket is a new species of war-rocket, invented by Sir William Congreve. This incendiary rocket drew the attention of the European nations, after the attack of the British on Copenhagen; where, we are informed, they did incredible execution. This rocket may be considered to be a carrier of fire. Their effect, however, in the Chesapeake, and elsewhere, during the late war, was very trifling. They seemed, in fact, little calculated to injure and more to intimidate.[38] They differ from the common rocket as well in their magnitude and construction, as in the powerful nature of their composition; which is such, that without the encumbrance of any ordnance, (the rocket containing the propelling power wholly within itself), balls, shells, case-shot and carcasses, may be projected to the distance of one thousand to three thousand yards. The principle of projectile force is so greatly increased, as not only to triple the flight of small rockets so formed, but also to allow of the construction of rockets of such dimensions, as, on the ordinary principles of combination, would not even rise from the ground, and of such powers of flight and burthen, as have hitherto been considered altogether impracticable.

On the basis of this increase of power, Congreve has succeeded in making this rocket. They are formed of various dimensions, as well in length as in caliber, and are differently armed, according as they are intended for the field, or for bombardment and conflagration; carrying in the first instance either shells or case shot, and in the second, for the purpose of destroying shipping, buildings, stores, &c. a peculiar species of composition, which never fails of destroying every combustible material with which it comes in contact. The latter are called *carcass-rockets*, and were first used at Boulogne in 1805, after many experiments, which [531]
were made by Congreve, at Woolwich. The attack in 1806 was merely desultory, in which not more than 200 rockets were fired. The town was set on fire by the first discharge, and continued burning for near two days. After the affair at Copenhagen, which established their reputation, it appears that a committee of officers, who had witnessed their effect in that bombardment, pronounced them to be "*a powerful auxiliary to the present system of artillery.*"

At the seige of Flushing, they appear to have been used with success, and general Monnet, the French commandant, made a formal remonstrance to lord Chatham respecting the use of them in that bombardment. The rocket system was also tried with success, and the crown prince of Sweden was the first general, who bore testimony to their effects in this service. At the memorable battle of Leipzig, they proved, we are informed, a powerful weapon, and also, when the British army under Wellington, crossed the Adour. In 1814, a rocket-corps was established in the British service.

General de Grave transmitted, to the Society of Encouragement of Paris, a Congreve rocket, or an English incendiary rocket, which was found on the French coast. M. Gay-Lussac examined it. The case was made with gray paper, and painted. The inflammable matter was of a yellowish-gray, and the sulphur was distinguishable with the naked eye. It burnt with a quick flame, and exhaled sulphurous acid gas.

According to his analysis, (*Archives des Découvertes*, ii, 303), the composition gave

Nitrate of potassa,	75.00
Charcoal,	1.6
Sulphur,	23.4
	———
	100
	———

Gay-Lussac, after determining the proportions of the constituent parts, made a composition of a similar kind, and charged a case, which exhibited the same properties as the English rocket.

The great general point of excellence of the rocket system, if we may judge from the account of English writers, is the facility with which all the natures of this weapon may be conveyed and applied. Its peculiar applicability to naval bombardment is said to rest on this property, that there is no reaction, no recoil in the firing of the largest rocket; so that by this means carcasses, equal to [532]
those projected by the largest mortars, may be thrown from the smallest boats. Its peculiar fitness for land service is, that it is a description of extremely powerful ammunition without ordnance, so that the burthen of mortars and guns is dispensed with, and all that is to be carried is actual available missile matter, capable of range, and of many of the most important effects of the heaviest artillery. The rocket system, as a system of ammunition without ordnance, is highly extolled by British writers.

We will now speak of their construction. All rockets designed for service are cylindrical, having strong metallic cases, and armed, as we before observed, either with carcass composition for bombardment and conflagration, or with shells and case shot for field service. They are, however, of various weights and dimensions, from the eight-inch carcass or explosion rocket, weighing nearly three hundred weight, to the six pound shell rocket, which is the smallest size, used in the field. The sticks, which are employed for regulating their flight, are also of different lengths, according to the size and service of the rocket; and which, for the convenience of carriage, are stowed apart from the rocket, and so contrived as to consist of two or more parts, which are connected to it, and to each other, when requisite, with the utmost expedition. The 32 pounder rocket carcass, which is the nature hitherto chiefly used for bombardment, will range 3000 yards with the same quantity of combustible matter as that contained in the 10 inch spherical carcass, and 2500 yards with the same quantity as that of the 13 inch spherical carcass. The 12 pounder rocket case shot, which is so portable that it may be used with the facility of musketry, has a range nearly double that of field artillery, carrying as many bullets as the 6 pounder spherical case. We may remark here, that the projectile force of the rocket is well calculated for the conveyance of case shot to great distances; because, as it proceeds, its velocity is accelerated instead of being retarded, as happens with any other projectile; while the average velocity of the shell is greater than that of the rocket only in the ratio of 9 to 8. Independent of this, the case shot conveyed by the rocket admits of any desired increase of velocity in its range by the bursting of powder, which cannot be obtained in any other description of case.

Rocket ammunition is divided into three classes, *heavy*, *medium*, and *light*; the former including all those above 42 lbs., which are denominated according to their caliber, as eight-inch, seven-inch, &c. rockets; the medium including all those from 42 lbs. to [533]
24 lbs.; and the light embracing from 18 pounder to 6 pounder inclusive.

The carcass-rockets are armed with strong iron conical heads, containing a composition as hard and solid as iron itself, and which, when once inflamed, cannot be extinguished. A 32 pounder carcass rocket will penetrate 9 feet in common ground. They have been known to pierce through several floors, and through the sides of houses. For field service, the 24, 18, 12, and 6 pounders are commonly used. The ranges of the eight-inch, seven-inch, and six-inch rockets, are from 2000 to 2500 yards, and the quantity of combustible matter, or bursting powder, from 25 lbs. to 50 lbs. These sized rockets are equally efficient for the destruction of bomb proofs, or the demolition of strong buildings. The largest rocket that has yet been constructed has not exceeded 300 weight. It is proposed, however, to make them from half a ton to a ton in weight.

The 42 and 32 pounders, which are used in bombardment, will convey from 7 lbs. to 10 lbs. of combustible matter each, and have a range of upwards of 3000 yards. The 24 pounder is equal to the propelling of the coehorn shell, or 12 pounder shot. It is, from the saving in weight, generally preferred to the 32 pounder. The eighteen-pounder, which is the first of the light nature of rockets, is armed with a nine pound shot or shell; the twelve-pounder, with a six do.; the nine-pounder, with a grenade; and the six-pounder, with a 3 lb. shot or shell.

The following table presents a general view of the ranges, elevations, and other particulars of several of the most useful descriptions of Congreve rockets.

Nature of ammunition.	Armed with	Extreme range.	Elevation for extreme range.
	Carcasses,	yards.	
42 Pounder carcass rockets.	large, 18lbs. of combustible matter; }		not less
	small, 12 lbs. do. }	3,500	than 60°
42 Pounder shell rockets.	Shells, 5½, 12 pr. spherical. }		
32 Pounder carcass rockets.	large, 18 lbs. of combustible matter;	2,000	60° [534]
	medium 12 lbs. = 13 inch carcass;	2,500	60° to 55°
	small, 8 lbs. = 10 inch carcass.	3,000	55°
32 Pounder shell rockets.	shells, 9 pr. spherical.	3,000	50°
32 Pounder case shot rockets.	Case { large, 200 carbine balls.	2,500	55°
	shot, { small, 100 do.	3,000	50°
32 Pounder explosion rockets.	Strong iron containing from 5 lbs. to 12 lbs. of powder, to burst by fusées.	from 2500 8000	55°
12 Pounder case shot rockets.	Case { large, 72 carbine balls.	2,000	45°
	shot, { small, 48 carbine balls.	2,500	45°

From the preceding table, it will be seen, that the 32 pounder carcass rocket will range 3000 yards, with the same quantity of combustible matter as that contained in a ten-inch spherical case, and 2500 yards, with the same quantity as that of the thirteen-inch spherical carcass. The twelve pounder case-shot rocket, which is so portable that it may be used with the facility of musquetry, has a range nearly double that of field artillery, carrying as many bullets as the six pounder spherical case: add to which, that, from the nature of the combination of the rocket, these bullets are projected from it in any part of its track, with an increase of velocity, by which its operation becomes frequently more destructive at that point, where any different species of ammunition ceases to be effective. Of this description of rocket-case-shot, one hundred soldiers will carry into action, in any situation where musquetry can act, 300 rounds, and 10 frames for discharging them; from each of which, four rounds may be fired in a minute. Of the same description of case-shot, four horses will carry 72 rounds, and four frames; from which may be fired 16 [535] rounds in a minute. The rockets used by cavalry are twelve pounders, armed with a 6 pounder shell or case shot; each horse carrying four of these rockets. To detail the arrangement of the rocket corps, the weight of ammunition carried by the troop horse, and other particulars, would require more space than we can conveniently appropriate to these subjects.

We may remark, however, that the heavier species of rockets, as the 32 pounder or 24 pounder, as also the 18 and 12 pounders, are sometimes carried in cars of a peculiar description; which not only convey the ammunition, but are contrived also to discharge each two rockets in a volley, from a double iron-plate trough. This trough is of the same length as the boxes for the sticks, and travels between them; but being moveable, may, when the car is unlimbered, be shifted into its fighting position, at any angle from the ground ranges, or point blank, up to 45°, without being detached from the carriage. The limbers are always in the rear. The rockets are fired with a port-fire and long stick.

When used by infantry, one man in ten, carries a frame of a very simple construction, standing on three legs like a theodolite, when spread. It is mounted at top with an open cradle, from which the rockets are discharged, either for ground ranges, or at any required elevation.

When they are used for bombardment, they are discharged from frames of a different, though simple, construction; and, in many cases, the frames are dispensed with, as they are thrown from a battery, erected for the purpose.

For the defence of a pass, or for covering the retreat of an army, the rockets are laid in batteries of 100 or 500 in a row, according to the extent of the ground to be protected. One man may fire the whole.

With regard to their use in the naval service, some additional remarks may be interesting.

We observed, that, in consequence of there being no reaction in these projectiles on the point of discharge, rockets may be used in the smallest boats of the navy. These rockets carry a quantity of combustible matter, and, according to the ordinary system, would require to be thrown from the largest mortars, and from ships of very heavy tonnage. The 12 and 18 pounder have been fired from a four-oared gig. They may be made to ricochet in the water at low angles. In boarding, they have been recommended, to be thrown into the port holes of the enemy. They have also been recommended for fire-ships, in order to produce an extensive [536] and devastating fire among the ships of the enemy.

Besides the advantages, which rockets possess, and of which we have spoken; namely, that it is a species of projectile, containing within itself the propelling power, by which heavy ordnance is dispensed with, and that an extensive fire may be kept up, by a few men, against any important point; there is another advantage said to be peculiar to them; *viz.* that they may be employed in a variety of cases, in which the usual artillery, from the nature of the ground, or other impediments, cannot be rendered effective; and that, in several bombardments, in consequence of their trifling reaction, they may be thrown from cutters and small boats, and, therefore, from points, which could never be approached by the vessels, usually employed in that service. With respect to the expense of the formation of war-rockets, calculations have been made, by which it appears, that their cost is less than the usual expense of carcasses.

We are informed on this head, that it is the cheapest of all ammunition, depending on the projectile force of gunpowder. For a 32 pounder carcass rocket costs only 1*l.* 1*s.* 11*d.* complete for service, and its equivalent, the 10 inch spherical carcass, with the charge of powder necessary to convey it 3000 yards, which power is contained in the rocket, costs 1*l.* 2*s.* 7*d.*, independent of any charge for the mortar, mortar bed, platform, difference of transport, &c. A vessel of 300 tons will carry 5000 of them at least. But the comparison, as to the expense, is still more in favour of the rocket, when compared with the larger nature of carcasses. The 15 inch spherical carcass costs 1*l.* 17*s.* 11½*d.* to throw 2500 yards; while its equivalent rocket costs but 1*l.* 5*s.* being a saving on the first cost, of 12*s.* 11½*d.*

Notwithstanding all the encomiums, bestowed on the Congreve rockets by the English, the French entertain a different opinion of them. For the following remarks, we are indebted to Ruggeri, (*Pyrotechnie Militaire*, p. 278), by which it appears, that Congreve was not the original inventor. He acknowledges, however, that they experienced the sad effects of them; and we do not offer this remark with any sort of prejudice, but as an acknowledgment, that the French experienced their "sad effects." Ruggeri says, that the Congreve rocket is nothing more than he described in his *Elements of Pyrotechny* five years before they were known to the English. It is, therefore, wrong, he adds, that we regard it as an English invention. It was invented, says he, by a naval officer at [537] Bordeaux, and ought not, he further remarks, to be regarded as a useful weapon in war. The reason he gives is, that its utility must depend upon places and circumstances. If it is required, he adds, to attack a fleet, we must employ two or three hundred before making any impression; because we cannot direct a firing rocket, as a cannon or ball. This is certainly a great inconvenience. He makes the cost also much greater than the English calculation; namely, for a single one of them ten times more than for a red-hot shot. Ruggeri, however, is candid enough to say, that, notwithstanding he differs in opinion, he is far from opposing any trials or experiments, made with the view of improving or perfecting it; but is decidedly of opinion, that it can never be employed at sea with the same advantage as bombs and cannon-ball.

Ruggeri published, in the *Journal of Paris*, in September, 1809, a letter, in reply to a writer, who had published some reflections on incendiary rockets, from which, as it throws some light on this subject, we shall here introduce a few extracts:

"Although Monsieur, the *cannonier* of Ostend, may not have given the precise construction of the rocket, which we name the sky-rocket, and of which the English have made so criminal a use, I will commence at first by assuring you, that I coincide perfectly with him, in the preference he gives to howitzes, bombs, and other projectiles, which are used by civilized nations. He has very satisfactorily demonstrated their advantages over the Congreve rocket. I will only add, that bombs and howitzes have also the advantage of being one-fifth cheaper, and projected with greater facility.

"The Congreve rocket cannot be of any particular advantage, because it only carries fire to the place where it falls; and if we wish to use them against any vessel whatever, it is impossible to assure ourselves of a direction on a given point, as many difficulties occur in projecting them.

"The merit of the invention of these rockets does not belong to the English.

"This invention was made by a Frenchman, a captain of a privateer, who made the first attempt to use them about seventeen years since, (1795).

"The English have perfected, or rather have modified this rocket.

"It is sometime since I offered a kind of bomb, which may be used with more facility than the common kind. This bomb has the advantage over the Congreve rocket: 1st, Because it is less troublesome to use; 2dly, It may be made of any diameter or size, and [538]
consequently suited to all calibers; 3dly, The place and time of its fall is readily determined; and fourth, and lastly, It bursts into pieces, and attaches itself to all combustible bodies, with which it meets.

"It remains for me to say, that it is not the powder which moves the rocket, but a composition almost as strong. The powder, which is used in the Congreve rocket, is intended to destroy the machine after it has produced its destructive effects." See *Pyrotechnie Militaire*, p. 278.

The difference between incendiary rockets, and common signal rockets, is in the interior. Instead of the furniture, or garnishing pot and head, a conical head of sheet iron is substituted, in which several holes are made to suffer the composition it contains to burn more readily. The composition is the same as that for fire-rockets; but is coarsely pulverized, and mixed with an equal quantity of the composition of fire-lances. These rockets are employed with advantage to burn a city, or vessels in a harbour. The cone, with which they are capped, enables them to penetrate the roofs of houses, and set them on fire.

Sec. XXV. Sky-Rockets (Meurtrières.)

The sanguinary or *murdering rocket* is made in the same manner as the preceding. They have neither head nor pot; but, in their place, they are furnished with a cone of beaten or solid iron. This cone is the appendage, or weapon, which produces such destructive effects. These rockets, when they fall upon the troops of an enemy, wound them very dangerously, without their being able to prevent it. The advantage, more particularly derived, is, that they may be projected from under cover, and to double the distance of ordinary musketry. To make use of these rockets, a box is constructed, whose interior is so arranged as to receive the rockets in regular order. They should be placed in it with their sticks; and, therefore, the case must be made sufficiently large to admit them. By this contrivance, the rockets are sheltered from the fire and water. To discharge them, the box is first inclined on the side next to the heads of the rockets, and in the direction of the place, to which they are to be thrown. A communication is made by leaders, in the manner already mentioned in the preceding part of this work; so that, when the match is fired, or a single rocket, they all are discharged at the same time. The mode of firing rockets either singly or in numbers, the manner of preparing the cases, the different compositions, and the operation of filling, and of furnishing them, &c. are given in the preceding part. [539]

Sec. XXVI. Of the Rocket Light-Ball.

Congreve also invented a species of light-ball, which, when thrown into the air by means of one of his rockets, and having reached the elevation of the rockets' ascent, is detached from it with an explosion, and remains suspended in the air by a small parachute, to which it is connected by a chain. Thus, in lieu of the transient momentary gleam, obtained by the common light ball, a permanent and brilliant light is obtained, and suspended in the air for five minutes at least, so as to afford time and light sufficient to observe the motions of an enemy, either on shore or at sea; where it is particularly useful in chasing, and for giving distant and more extensive night signals. It is to be observed, that nothing of this kind can be obtained by the projectile force of either guns or mortars; because the explosion infallibly destroys any construction, that could be made to produce the suspension in the air.

We have seen no account of any experiments, which have been made with it.

Sec. XXVII. Of the Floating Rocket Carcass.

Congreve also applied his rocket, and the parachute, for the purpose of conveying combustible matter to distances far beyond the range of any known projectile force, at the same time that it is cheap, simple, and portable. The floating carcass, like the light-ball, is thrown into the air, attached to a rocket, from which being liberated at its greatest altitude, and suspended to a small parachute, it is driven forward by the wind, and will, in a moderate breeze, afford ranges at least double those of the common carcass. It may, therefore, for naval purposes, be thrown from a blockading squadron, in great quantities, by a fair wind, against any fleet or arsenal, without the smallest risk, or without approaching within range of either guns or mortars. The rocket containing the carcass is no larger than the 32 pounder carcass rocket; and the whole expense, added to the rocket, does not exceed five shillings. Nor are the approaches of the carcass itself necessarily visible by night; as it may be so arranged, as not to inflame, till some time after it has settled. It is evidently, therefore, capable of becoming a harassing weapon, if the account of it be true; and, among large fleets and flotillas, it may do as much injury as any other carcass, by lodging unperceived in the rigging, [540]
or lighting on extensive arsenals, in such situations, where other means of annoyance could not be used.

Sec. XXVIII. Observations on Rockets.

The following remarks on the subject of rockets by M. Bigot, (*Traité d'Artifice de Guerre*, p. 131,) may be interesting to the reader.

Authors, who have written on rockets, are of opinion, that the height of the different kinds of rockets should not be increased on account of their diameter; because, as the diameter increases, the rocket also increases in weight and surface; and if augmented in height in the same ratio, its power of ascension would be feeble. It is from this reasoning, together with practice, that they have determined the height of empty cases. Some have given the proportion of six times their exterior diameter, and others again have made them a third longer than the piercer. There has resulted from this difference of opinion, such an irregularity in the formation of rockets, that artificers or fire-workers were left in uncertainty as to the best mode to be pursued. To avoid, however, this embarrassment, if we consider the diameter of the base of the piercer of any kind of rocket as one-third of the exterior diameter of the case, the small end must be the one-sixth part of it; and the piercer and the cone are of the same diameter, and the surface of the one is equal to the surface of the other. We might conclude, accordingly, that the increase of the height of the case, should be the same with all kinds of rockets. It appears by different authors, that the ancient and modern fire-workers have fixed the dimensions of rockets and their piercers, by various experiments. If we take for granted all the heights of the piercers, or the rockets themselves, we obtain a curve of double or treble reflection, which is very evidently in opposition to the above principles, and of the law which results from them.

Experiments prove, that to make a good rocket of half an inch in diameter, the piercer must be five times and a third of the same diameter; and for a rocket of three inches, the piercer, or broach, as it is sometimes called, is only four times the diameter in height. To determine, however, the height of the piercer in general, greater than the preceding, it is found necessary to have some satisfactory result, in order to employ, mathematically speaking, *less times* of the exterior diameter of the rocket. The half-inch [541]
and three-inch rocket are the extremes of an increasing arithmetical progression; and their equivalents, $5^1/_3$ and 4 diameters is the extreme of a similar, but decreasing progress; but if we insert the same number of arithmetical mean between the two extremes of each of these two progressions, and then continue them indifferently, the terms of the first will express the diameter of as many different cases; and those of the second, the height of the corresponding piercers. They will be, for instance, in the two following proportions:

÷	6	7	8	9	10	11	12	13	14,	&c. 36.
÷	$5^{14}/_{45}$	$5^{12}/_{45}$	$5^{11}/_{45}$	$5^9/_{45}$	$5^7/_{45}$	$5^7/_{45}$	$5^2/_{45}$	$5^1/_{45}$	$4^{44}/_{45}$	&c. 4.

The first of which has unity for its common difference. It has been found, that, by inserting in each, a mean of 29, the height of the piercers will correspond with the superior diameter, which is less, or regulated by their respective diameters. Besides, as the diameters go on augmenting, the rockets are proportionably increased in height, but only in an inverse order, until the 58th term included, and beyond which they decrease, until they become negative, which appears to indicate that the term appertains to the diameter of the rocket, and without any uncertainty.

It results from the intimate relation of these two progressions, that, in stopping at the 58th term, if we bring back on an axis as it were, the height of the piercers, we obtain a straight instead of a curved line.

Bigot has given two tables relative to the construction of rockets, and, as their use is seen by mere inspection, we here introduce them without remark.

They comprehend the dimensions of rockets of different calibers, compared with the exterior and respective diameter of each kind; and relative to the dimensions of the tools of sky-rockets of different calibers, and also compared with the exterior and respective diameter of each.

It will be seen, on an examination of these tables, that all the data are satisfactorily given; so that, in the construction of rockets, the artificer will find them extremely useful, if not absolutely necessary.

The principles on which these tables are founded, may be depended on, inasmuch as M. Bigot has taken considerable pains on that head; and, consequently, the calculations, which follow, and the proportions, established for the construction of rockets in general, are sufficiently conclusive.

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Name of the Rocket.	Diameter of the rocket.		Height of tools of wood.							Diameter of the tools of wood.						Dimension of mallets.	
			Rammers, &c.							Rammers.							
				For charging the head not comprised.													
	Exterior.	Interior.	Roller.	1	2	3	Solid 4	Pot.	Conical head.	To run.	To charge.	Of pots.	Sockets of the pot.	Base of conical head.	Ladle.	Diameter.	Length.
	inch.	Diam.	D.	D.	D.	D.	D.	D.	D.	D.	D.	D.	D.	D.	D.	inches.	inches.
Small Partement,	½	⅔	24	6⅓	$4\frac{5}{9}$	$2\frac{7}{9}$	1⅓	3	1⅔	⅔	$\frac{7}{12}$	1⅔	⅔	1⅔	⅔	2¾	3⅓
Partement,	¾	idem.	16	$6\frac{2}{9}$	$4\frac{13}{27}$	$2\frac{6}{27}$	idem.	2⅔	$1\frac{5}{9}$	idem.	$\frac{11}{18}$	$1\frac{5}{9}$	$\frac{7}{9}$	$1\frac{5}{9}$	idem.	2¾	3⅓
Marquise,	1	idem.	12	$6\frac{1}{12}$	$4\frac{7}{18}$	$2\frac{25}{36}$	idem.	2⅓	1½	idem.	idem.	1½	$\frac{5}{6}$	1½	idem.	3½	4¼
Double marquises	1¼	idem.	idem.	$5\frac{14}{15}$	$4\frac{13}{45}$	$2\frac{29}{45}$	idem.	$2\frac{1}{5}$	$1\frac{8}{15}$	idem.	$\frac{3}{5}$	$1\frac{8}{15}$	$\frac{13}{15}$	$1\frac{8}{15}$	idem.	3½	4¼
Ditto, for 4 doz.	1½	idem.	10	$5\frac{7}{9}$	$4\frac{5}{27}$	$2\frac{16}{27}$	idem.	2	1½	idem.	$\frac{11}{18}$	1½	$\frac{5}{6}$	1½	idem.	4	5
Rocket of	2	idem.	9	5⅜	$3\frac{31}{36}$	$2\frac{25}{72}$	$1\frac{1}{6}$	1¾	idem.	idem.	⅝	idem.	⅞	idem.	idem.}		
Ditto,	2½	idem.	$8\frac{2}{5}$	$5\frac{1}{15}$	$3\frac{29}{45}$	$2\frac{2}{9}$	$1\frac{2}{15}$	1½	idem.	idem.	$\frac{19}{30}$	idem.	$\frac{9}{10}$	idem.	idem.}		
Ditto,	3	idem.	8	$4\frac{7}{9}$	$3\frac{4}{9}$	$2\frac{1}{9}$	$1\frac{1}{9}$	1⅓	idem.	idem.	$\frac{23}{36}$	idem.	$\frac{11}{12}$	idem.	idem.}	5½	6⅔
Ditto,	4	idem.	$6\frac{5}{6}$	4¼	$3\frac{3}{32}$	$1\frac{15}{16}$	$1\frac{1}{8}$	$1\frac{1}{16}$	idem.	idem.	$\frac{31}{48}$	idem.	$\frac{15}{16}$	idem.	idem.}		
Ditto,	5	idem.	6	$3\frac{43}{60}$	$2\frac{133}{180}$	$1\frac{137}{180}$	$1\frac{7}{60}$	$\frac{9}{10}$	idem.	idem.	$\frac{13}{20}$	idem.	$\frac{14}{15}$	idem.	idem.}		

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Name of the Rockets.	Diameter of rockets.		HEIGHT OF								Diameter of the parts of the pierc				
									Total of the piercer, button						
	Exterior.	Interior.	Empty cases.	Charged rockets, button,&c. included.	Massive Rockets.	Piercers.	Button & their cylinder.	Culots.	and culot, comprised.	Screw.	Base.	Exterior of small end.	Button and cylinder.	Culot.	Screw the b
	inch.	Diam.	D.	D.	D.	D.	D.	D.	D.	D.	D.	D.	D.	D.	D
Small partement,	½	⅔	7⅓	$6\frac{5}{6}$	⅔	$5\frac{1}{3}$	⅔	1⅔	7⅔	¼	⅓	$\frac{1}{6}$	⅔	1	1
Partement,	¾	idem.	idem.	$6\frac{7}{9}$	idem.	$5\frac{2}{9}$	idem.	idem.	$7\frac{5}{9}$	2⅔	idem.	idem.	idem.	idem.	$\frac{7}{9}$
Marquise,	1	idem.	$7\frac{7}{12}$	$6\frac{7}{12}$	idem.	$5\frac{1}{12}$	idem.	idem.	$7\frac{1}{12}$	2½	idem.	idem.	idem.	idem.	⅔
Double marquise of 3 doz	1¼	idem.	7	$6\frac{7}{15}$	idem.	$4\frac{14}{15}$	idem.	$1\frac{1}{5}$	$6\frac{4}{5}$	2	idem.	idem.	idem.	idem.	$\frac{3}{5}$
Ditto, 4 doz.	1½	idem.	$6\frac{7}{9}$	$6\frac{5}{18}$	idem.	$4\frac{7}{9}$	idem.	$1\frac{1}{18}$	6½	$1\frac{5}{6}$	idem.	idem.	idem.	idem.	$\frac{5}{9}$
Rocket of	2	idem.	6⅜	5⅞	½	$4\frac{13}{24}$	idem.	⅞	$6\frac{1}{12}$	1½	idem.	idem.	idem.	idem.	½
Ditto,	2½	idem.	$6\frac{1}{15}$	$5\frac{17}{30}$	$\frac{7}{15}$	$4\frac{4}{15}$	idem.	$\frac{4}{5}$	$5\frac{11}{15}$	$1\frac{3}{10}$	idem.	idem.	idem.	idem.	idem.
Ditto,	3	idem.	$5\frac{7}{9}$	$5\frac{5}{18}$	$\frac{4}{9}$	4	idem.	⅔	5⅓	$1\frac{1}{6}$	idem.	idem.	idem.	idem.	idem.
Ditto,	4	idem.	5¼	$4\frac{73}{76}$	$\frac{11}{24}$	$3\frac{15}{32}$	idem.	½	$4\frac{61}{96}$	$\frac{15}{16}$	idem.	idem.	idem.	idem.	[illegible]
Ditto,	5	idem.	$4\frac{43}{60}$	$4\frac{13}{60}$	$\frac{9}{20}$	$2\frac{14}{15}$	idem.	$\frac{2}{5}$	4	$\frac{4}{5}$	idem.	idem.	idem.	idem.	$\frac{2}{5}$

Note. The rockets of two inches, and those between that and three inches, require to be beaten with four rammers, independently of that which is solid; and also those above three inches, require five. The rolling board should be sufficiently large for the cases we wish to form; *viz.* one of twenty-eight inches in length, and six inches in breadth for small rockets; one of thirty inches in length, and ten inches in breadth for middlesized rockets; and one of thirty-six inches by eighteen for the largest rockets.

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Sec. XXIX. Of the Succouring Rocket.

The succouring, or marine rocket, is a name given to a rocket, which is sufficiently large to convey a small cord or rope to some distance from a vessel, and by its means to save the lives of persons in danger of shipwreck. Rockets for this purpose should be at least two inches in interior diameter. The rod should be of the same length and thickness as a rocket of half this caliber. To this rod is tied the cord, which must be light, and yet strong, and when the rocket is fired, the string should be arranged loose, so that no impediment is experienced in the flight of the rocket.

The applications of the succouring rocket are two in particular: *viz.* In case a seaman should fall overboard, and in case of shipwreck; in the former, to throw a cord to some distance, and in the latter, to convey a cord from the ship to the shore, should a vessel be stranded on a beach. Several methods have been proposed for the same purpose, namely, that of conveying a line or rope to shore, when the surf is too high for a small boat to live in it.

The invention of lieut. Bell, described in the *Annales des Arts et Manufactures*, and in the *Archives des Découvertes*, ii, 120, is designed for a similar purpose as the succouring rocket. Mr. Bell's invention consists simply in throwing a rope from a vessel by means of a mortar, attaching it to a shell, in order to make a communication from a vessel in danger to the shore. For this contrivance, he received one hundred guineas.

Several experiments were made with it, which were satisfactory.

In the essays, published by Mr. Fulton, a contrivance of this kind is suggested, using, however, an instrument similar to a harpoon, to which a rope is attached. This harpoon is thrown by a long gun. It is calculated, also, as the harpoon for this purpose is furnished with several barbs, to pierce and secure an enemy's vessel.

Sec. XXX. Of the Greek Fire.

It is not known precisely what the composition of the Greek fire was. It was invented by Callinicus of Hellipolis, a town in Syria, who used it with so much skill and effect during a naval engagement, that he destroyed a whole fleet belonging to the enemy, in which were embarked thirty thousand men. It is defined to be a sort of artificial fire, which insinuates itself beyond the surface of the sea, and which burns with increased violence, when it mixes with water. Its directions are contrary to the course of natural fire; for the flames, we are told, will spread themselves downwards, to the right or left, agreeably to the moment that is given. [545]

It was used in the year 1679, and was known and used in 1291. It was certainly liquid, and employed in many different ways; but, chiefly, on board ships, being thrown from large engines on the ships of the enemy. This fire was sometimes kindled in particular vessels, which might be called fire-ships, and which were introduced among a hostile fleet. Sometimes it was put into jars and other vessels, which were thrown at the enemy by means of projectile machines; and sometimes it was squirted by soldiers from hand-engines, or, as it appears, blown through pipes. This fire was discharged from the fore part of ships, by a machine constructed of copper and iron, the extremity of which resembled the open mouth and jaws of a lion or other animal. They were painted, and even gilded, and, it appears, were capable of projecting the fire to a great distance.

Professor Beckman, who examined all the ancient authors respecting the Greek fire, expressly says, that the machines which the ancients employed to throw this fire were *spouting engines*. He also observes (*History of Invent.* iv, p. 85) that "John Cameniata, speaking of his native city, Thessalonica, which was taken by the Saracens in the year 901, says, that the enemy threw fire into the wooden works of the besieged, which was blown into them by means of tubes, and thrown from other vessels. This passage, which I do not find quoted in any of the works that treat on the Greek fire, proves, that the Greeks, in the beginning of the tenth century, were no longer the only people acquainted with the art of preparing this fire, the precurser of our gunpowder. The Emperor Leo, who about the same period wrote his art of war, recommends such engines, with a metal covering, to be constructed in the fore part of ships; and he twice afterwards mentions engines for throwing out Greek fire. In the east, one may easily have conceived the idea of loading some kind of pump with the Greek fire; as the use of a forcing pump for extinguishing fires was long known there before the invention of Callinicus."

Writers differ considerably as to the composition of Greek fire, properly so called, as there were many preparations, some hundred years after the discovery, which went under the name of Greek fire. Certain it is, that the Greeks had a knowledge of a [546] very highly combustible preparation, which water would not extinguish, and which, from its nature, must have had the property of decomposing water itself, or possessed so much oxygen, as to support the combustion of the inflammable substances, even in contact with water.

Mr. Parke, (*Chem. Catechism*, p. 465), speaking of some of the uses of nitre or saltpetre, says, that "for the same purposes it was used by the ancients in that destructive composition of antiquity, the Greek fire. Sulphur, rosin, camphor, and other combustibles, were melted with it, and in this melted mass, woollen cords were dipped, which were afterwards rolled up for use. These balls being set on fire were thrown into the tents, &c. of the enemy, and as the combustibles were furnished with a constant supply of *oxygen* from the nitre, nothing could extinguish them." He also observes: "For many centuries, the method of making this dreadful article of destruction was lost; but it has just been discovered by the librarian of the elector of Bavaria, who has found a very old latin manuscript, which contains directions for preparing it."

It appears, however, that it could only be extinguished by urine, sand, &c. James (*Mil. Dic.* p. 329) says, "it is composed, or made up of naphtha, sulphur, bitumen, gum, and pitch, and it can only be extinguished by vinegar, mixed with urine and sand, or with undressed leather and green hides."

The author of a French work, *Œuvres Militaires*, says, that a powerful composition, which is not extinguishable with water, may be made of the following substances: *viz.* pitch, rosin, tallow, camphor, turpentine, saltpetre, liquid varnish, oil of sulphur, linseed, rock oil, flax, and charcoal finely pulverized. The whole is melted together and boiled, and before it grows cold, quicklime in powder is added. It is said to be susceptible of the most subtile and destructive fire.

Bertrandon de la Brocquiere, who was in Palestine in 1432, as counsellor to the Duke of Burgundy, observes, that the Moors were then in possession of the Greek fire. He was present at Barrat, during one of the Moorish celebrations. "It began," says he, "in the evening at sun set. Numerous companies, scattered here and there, were singing and uttering loud cries. While this was passing, the cannon of the castle were fired, and the people of the town launched into the air, '*bien hault et bien loing, une maniére de feu plus gros fallot que je veisse oncques allume*.' They told me, they made use of such at sea, to set fire to the sails of [547] an enemy's vessel. It seems to me, that as it is a thing easy to be made, and at a little expense, it may be equally well employed to burn a camp or a thatched village, or in an engagement with cavalry, to frighten their horses.

"Curious to know its composition, I sent the servant of my host to the person who made this fire, and requested him to teach me this method. He returned for answer, that he dared not, for that he should run great danger, were it known; but as there is nothing a Moor will not do for money, I offered him a ducat, which quieted his fears, and he taught me all he knew, and even gave me the moulds in wood, with the other ingredients, which I have brought to France."

Although La Brocquiere may have brought the secret to Europe, yet it does not appear to have been used.

We may justly conclude, that the present gunpowder possesses superior advantages to the Greek fire, and some authors, as Ruggeri, are of opinion, that the account we have of it, that of its fire *descending*, and the like, are exaggerated.

Porta, (*Magie Naturelle*), in treating of this subject, observes, that the Greek fire was composed of the charcoal of willow, salt, burnt brandy, sulphur, pitch, frankincense, flax, and camphor, and that camphor alone has the effect of burning in water. He remarks also, that, when Constantinople was attacked, the emperor Leon burnt the vessels, or boats, to the number of 1800, by means of the Greek fire. The *Journal des Savants*, 1676, p. 148, speaks of the origin and use of the same fire.

In 1249, at the siege of Damietta, the French experienced the fatal effects of it. The *Journal des Savants* for 1666, mentions a machine, which, when applied against a vessel, communicates fire to it immediately, without injuring the person who uses it. In the *French papers* for 1797, M. Chevalier announced, that he had invented an inextinguishable incendiary fuse, which is thrown by fire arms, and calculated to set fire to the rigging of ships. In 1759, Dr. Dupré published in the *French Journals*, that he had invented a composition, which had the same properties and effects as the ancient Greek fire, and that he possessed the means of extinguishing it. An experiment was made at Versailles to the satisfaction of all, and the secret was purchased by Louis XV. The Rev. J. P. Coste, in 1794, laid before the French national convention, a new invention, for the purpose of war, consisting of a [548] carcass composition, which nothing could extinguish, and which resembled in that respect the Greek fire.

Thevenot (*Travels in the Levant*), says, that in the 52d year of the Hegira, (Anno Domini 672), Constantinople was besieged in the reign of Constantine Prognates, by Yesid, the son of Moavia, the first caliph of the family of the Ammiades; when the *Greek* emperor found himself so pressed, that he was almost reduced to despair. But the famous engineer, Callinicus, invented a kind of *wild fire*, which would burn under water, and by this means destroyed the whole fleet.

Gibbon (*History of the Decline and Fall of the Roman Empire*, vol. vii, p. 282), speaks also of the Greek fire, and observes, that the deliverance of Constantinople may be chiefly ascribed to it. It appears, that Callinicus, the inventor, deserted from the service of the Caliph to that of the Emperor; and Gibbon is of opinion, that this discovery or improvement of the military art, was fortunately reserved for the distressful period, when the degenerate Romans of the east were incapable of contending with the warlike enthusiasm and youthful vigour of the Saracens. He is of opinion, that little or no credit can be given to the Byzantine accounts, as to the composition of this fire; although, from their obscure and fallacious hints, it should seem that the principal ingredient was naphtha, a liquid bitumen which springs from the earth.[39] This was mixed with sulphur, and with the pitch, extracted from the evergreen firs, according to the testimony of Anna Commena, (*Alexid*, l. xiii, p. 383), and Leo, in the xixth chapter of his *Tactics*, speaks of the new invention.

Gibbon describes its effects much as we have stated, viz. that the fire was strong and obstinate, and was quickened by water; that sand, urine, and vinegar were the only agents that could damp its fury; that it was used for the annoyance of the enemy, both by sea and land, in battles or in sieges, and was either poured from the rampart in large boilers, or lanched into red-hot balls of stone and iron, or darted in arrows and javelins, twisted round with flax and tow, which had deeply imbibed the inflammable oil; [549] that, at other times, it was deposited in fire ships, or blown through long tubes of copper, fixed on a prow of a galley; that its composition was kept secret at Constantinople, pretending that the knowledge of it came from an angel to the first and greatest of the Constantines, with a sacred injunction not to divulge it under any pretext, &c. He also observes, that, after it was kept secret above four hundred years, and to the end of the 11th century, the method of preparing it was stolen by the Mahometans, who employed it against the crusaders. A knight, it appears, who despised the swords and lances of the Saracens, relates, with heartfelt sincerity, his own fears, at the sight and sound of the mischievous engine, that discharged a torrent of the Greek fire, the *feu Gregeois*, as it is styled by the more early of the French writers. "It came flying through the air," says Gibbon, quoting Joinville, (*Histoire de St. Louis*) "like a winged long tailed dragon, about the thickness of a hogshead, with a report of thunder and the velocity of lightning; and the darkness of the night was dispelled by this deadly illumination. The use of the Greek, or as it might now be called, Saracen fire, was continued to the middle of the 14th century, when the scientific or casual compound of nitre, sulphur, and charcoal, effected a new revolution in the art of war, and the history of mankind."

Ramsay, our learned historian, (*Universal History*, vol. ii, p. 150), gives the same account of the Greek fire. Morse, in his *Universal Geography*, page 588, observes, that naphtha forms springs in Persia, and, when scattered on the sea, it burns, and the flame is often wafted to a great distance.

For remarks respecting the naphtha of Persia, and the universal fire of the followers of Zoroaster, see the article on *Naphtha.* In naphtha districts, the quantity of inflammable air is so great, that it is used for fuel.

Since writing the above, we have examined Ruggeri, (*Pyrotechnie Militaire*, p. 289), and find nothing new. He states the composition of Greek fire, on the authority of others, to consist of naphtha, sulphur, bitumen, camphor, and petroleum; that it was invented by Callinicus, and employed against the Saracens as an incendiary; that Pliny, in his time, mentioned a combustible substance, which was thrown upon armed men, and burnt and destroyed them in the midst of the battle; that it was employed successfully by the successors of Constantine, and its composition was kept a state secret; that the Turks used it, or a composition [550] of a similar nature, at the siege of Damieta, in 1249, forty-five years after the death of Roger Bacon; and, finally, that, when the composition and effects of gunpowder became known, the Greek fire, although it laid the foundation of the invention of gunpowder, was no longer in use, and the secret of the original preparation became lost. See *Gunpowder.*

Sec. XXXI. Of Mines and Mining.

A mine is a subterraneous passage, dug under the wall or rampart of a fortification, for the purpose of blowing it up by gunpowder; and mining is the art of accomplishing this effect.

The art of mining, having become one of the most essential parts of the attack and defence of places, should be well understood; and requires a perfect knowledge of heights, depths, breadths, and thicknesses; to judge perfectly of slopes and perpendiculars, whether they be such as are parallel to the horizon, or such as are visual; together with the true levels of all kinds of earth. To this may be added, a knowledge of rocks, clays, soil, &c. and the effect of gunpowder.

Mines were made long before the invention of gunpowder. The ancients made galleries, or underground passages, much in the same manner as the moderns, from without, under the walls of places, which they cut off from the foundation, and supported with strong props. The intervals were filled with all manner of combustibles, which, being set on fire, burnt their props, and the wall, being no longer supported, fell, by which a breach was made.

The besieged also made underground passages, from the town, under the besiegers' machines, by which they battered the walls, to destroy them, proving that necessity has been the inventress of mines.

The first mines we read of, since the invention of gunpowder, were made in 1487, by the Genoese, at the attack of Serezanella, a town in Florence. These, however, failed, and they were neglected, till Peter Navarro, being then engineer to the Genoese, and afterwards to the Spaniards, in 1503, against the French, at the siege of the castle del Ovo, at Naples, made a mine under the wall, and blew it up; in consequence of which the castle was taken by storm. Valliers says, that the engineer was Francis George, an Italian.

The place where the powder is lodged, is called the chamber of the mine, or *fourneau*, and the passage leading to the powder, is [551] called the gallery. The line of the least resistance, is the line drawn from the centre of the chamber, perpendicular to the surface of the ground; and the excavation, called the crater, is the pit or hole, made by springing the mine.

Counter-mines are those made by the besieged, whereas mines are generally made by the besiegers. Both mines and counter-mines, are made in the same manner, and for like purposes, viz. to blow up their enemies and their works.

Galleries, made within the fortification, before the place is attacked, and from which several branches are carried to different places, are generally 4 and 4½ feet wide, and 5 or 5½ feet high. The earth is supported from falling in, by arches and walls, as they are to remain for a considerable time. But when mines are made to be used in a short time, then the galleries are but 3 or 3½ feet wide, and 5 feet high, and the earth is supported by wooden frames, or props.

The gallery being carried on to the place, where the powder is to be lodged, the miners make the chambers. This is generally of a cubical form, large enough to hold the wooden box, which contains the powder necessary for the charge. The box is lined with straw and sand bags, to prevent the powder from contracting dampness.

The chamber is sunk rather lower than the gallery, if the soil permits; but where water is to be apprehended, it must be made higher than the gallery; otherwise the besieged will let in the water, and spoil the mine.

The fire is communicated to the mine by a pipe, or hose, made of coarse cloth, whose diameter is about 1½ inches, called a *saucisson*, (for the filling of which, near half a pound of powder is allowed to every foot), extending from the chamber to the entrance of the gallery, to the end of which is fixed a match, that the miner who sets fire to it, may have time to retire before it reaches the chamber.

To prevent the powder from contracting any dampness, the saucisson is laid in a small trough, called an *auget*, made of boards 3½ inches broad, joined together lengthwise, with straw in it, and round the saucisson, with a wooden cover nailed upon it.

The quantity of powder, required to charge mines, depends upon the nature of the soil. That which is more tenacious, will require the greatest force to separate its parts. The density may be learned, comparatively speaking, by determining the specific [552] gravity of each kind of soil. The requisites in mining may be ascertained by four simple problems, which relate to the nature of the soil, the diameter of the excavation, the line of least resistance, and the charge.

Table of the quantity of Gunpowder, to raise a cubic fathom of different kinds of Soil.

NATURE OF THE SOIL.	DENSITY.	TENACITY.
	Weight of 1 cubic foot.	Quantity of powder to raise 1 cubic fathom.
1. Loose earth or sand.	95 lbs.	8 lbs.
2. Common light soil.	124	10
3. Loam or strong soil.	127	12¼
4. Potters' clay, or stiff soil.	135	13½
5. Clay, mixed with stones.	160	16
6. Masonry.	205	21½

The gallery and chamber being ready to be loaded, a strong box of wood is made of the size and figure of the chamber, being about one-third or one-fourth larger than is required for containing the necessary quantity of powder. Against the sides and bottom of the box is put some straw, and this straw is covered over with empty sand bags, to prevent the powder from contracting any dampness. A hole is made in the side, next the gallery, near the bottom, for the saucisson to pass through, which is fixed to the middle of the bottom, by means of a wooden peg, to prevent its loosening from the powder, or to hinder the enemy (if he should reach the entrance) from being able to tear it out. This done, the powder is brought in sand bags, and thrown loosely in the box, and covered also with straw and sand bags. Upon this is put the cover of the box, pressed down very tight with strong props; and, to render them more secure, planks are also put above them, against the earth, and wedged in as fast as possible.

This done, the vacant spaces between the props are filled up with stones and dung, and rammed in the strongest manner. The least neglect in this work will considerably alter the effect of the mine. Then the auget, or small trough, is laid from the chamber to the entrance of the gallery, with some straw at the bottom; and the saucisson laid in it, with straw over it. Lastly, it must be shut [553] with a wooden cover, nailed upon it. Great care must be taken in stopping up the gallery, not to press too hard upon the auget, for fear of spoiling the saucisson, which may hinder the powder from taking fire, and prevent the mine from springing. The gallery is stopped up with stones, earth and dung, well rammed, six or seven feet further from the chamber than the length of the line of the least resistance.[40]

Before closing this article, short as it is, compared with a full view of the subject, which belongs exclusively to engineering, we shall notice, from Belidor, the *globe of compression* in mines. If we imagine a large globe of earth, homogeneous in all its parts, and a certain quantity of powder lodged in its centre, so as to produce a proper effect without bursting the globe; by setting fire to the powder, it is evident that the explosion will act all round, to overcome the obstacles which oppose its motion; and as the particles of the earth are porous, they will compress each other in proportion as the flame increases, and the capacity of the chamber increases likewise: but the particles of the earth next to the chamber will communicate a part of their motion to those next to them, and those to their neighbours; and this communication will thus continue in a decreasing proportion, till the whole force of explosion is entirely spent; and the particles of earth beyond this term will remain in the same state as they were at first. The particles of earth, that have been acted upon by the force of explosion, will compose a globe, which Mr. Belidor calls the globe of *compression*. He observed, that, when a mine exploded, and threw up the ground over it, its action was, at the same time, felt in a circular direction, throughout the surrounding ground, to a distance at least equal to the oblique line drawn from the centre of [554] inflammation to the edge of the funnel.

Mines and counter-mines are now called offensive and defensive mines. The hole made by the explosion is called the *entonnoir*, crater, or funnel.

In the system of counter-mines, we have the *magistral gallery*, or gallery of the counterscarp, which is that extended below the covered way, from which branches are pushed to overthrow the works and batteries of the beseiger, that crown it; the *enveloping gallery* that communicates with the other passages, called the *galleries of communication*, and is nearly parallel with the first at the distance of from forty to sixty yards. Other galleries are pushed forward, leaving the enveloping gallery, projecting at least thirty yards, and having spaces between them of about fifty yards in width; so that the enemy's miner, whose work may be heard under ground about thirty yards, may not pass between any two of them without being discovered. These are called *listening galleries*. It may be observed, that, from these galleries, branches are carried forward to establish chambers under the works of the enemy. Those who wish to acquire information on this, and other subjects, connected with attack and defence, and on some branches of engineering, would do well to consult the French work of *Bousmard*.

There are likewise small mines called *Fougasses*, used in the defence of field works. They are seldom more than ten feet beneath the surface, and are placed at the expected points of attack, usually nine feet from the salient angles, and without the counterscarp. The chest of powder and the saucisson are placed as usual. Barrels or casks and even grenades are used.

Sec. XXXII. Of the Means of Increasing the Strength of Gunpowder for Mining.

We mentioned, in the article on gunpowder, that quicklime had the effect of increasing its strength. It has been suggested, to employ quicklime, for this purpose, when gunpowder is used in mining.

Bottée and Riffault (*Traité de l'art de Fabriquer la Poudre à canon, p. 301*) have given the result of some experiments on this subject, which we purpose to notice. These experiments, however, are not satisfactory on this head.

Dr. Baine, a physician of Foxano, in Tuscany, was the first who announced the fact, that quicklime would increase the explosive [555] effect of gunpowder. The increase he states to be one-third. The proportions are, twenty-three grammes of quicklime, and one *kilogramme* of powder.[41] The quicklime is powdered, and mixed with the gunpowder.

Various experiments were made, with the eprouvette of Regnier, which did not establish the truth of Dr. Baine's assertion. The Tuscan hunters use gunpowder mixed with lime.

The experiments were made by M. L. Maitre and colonel Charbonel. They employed pure dry powder, dry powder mixed with quicklime, moist powder pure, and moist powder mixed with lime. The object of these experiments was to ascertain, if the presence of quicklime added to the force of powder; either as a fourth component part and acting chemically, or by absorbing the moisture which the powder contains.

The charge of each was three ounces.

The result of the experiments is thus given:

Powder, dry and pure,	738	feet	2	inches.
Powder, dry, and mixed with quicklime,	690	—	1	—
	——		——	
Difference in favor of dry powder,	48		1	
Powder, moist and pure,	714	feet	1	inch.
Powder, moist, and mixed with quicklime,	642	—	2	—
	——		——	
Difference in favor of moist powder,	71		11	

It has been asserted, that the force of gunpowder is increased by water, alcohol, and ether, in consequence of the great expansibility of these fluids; but, according to the experiments of Bottée and Riffault, the range of the ball was much less when the three fluids were used successively, than when the dry and pure gunpowder alone was employed. We are informed by a gentleman, who saw the experiment made, that when gunpowder is mixed with an equal weight of fine saw dust, and fired, it will give the same range to a ball as the same weight of unmixed powder.

We find that col. Gibbs, (*American Journal of Science*, i. 87), in a letter to professor Silliman, mentions the use of lime in [556] increasing the strength of gunpowder. He gives a certificate of the person, whom he employed in blowing rocks, in which he used quicklime along with powder, in the proportion of one part of the former to two of the latter. In the certificate, it is stated, that a charge of this mixture was found to be equally powerful, or to "answer equally well with a like quantity of gunpowder," having made upwards of fifty blasts in this manner, and, as he states, several hundred in the usual way. He remarks, however, that, when the powdered lime was mixed with the gunpowder the day before, the effect was diminished. The colonel attributes the effect to the desiccation of the powder by the lime; and, as gunpowder absorbs more or less water, the lime, in its caustic state, takes it from the powder. If the lime should remain too long, he is of opinion that it would probably attack the water of crystallization of the saltpetre, and, according to count Rumford's idea, destroy a great part of the powder. "The examination of this subject," says Gibbs, "led me to consider the increase of the power of gunpowder in various situations, and of its use in the field. It is well known, that, after a few discharges, a cannon becomes heated, and the range is much greater, as well as the recoil. The charge of powder is, therefore, reduced about one-quarter, to produce the original effect. As I have not heard or seen any explanation of this fact, I shall take this opportunity of mentioning, that it appears to arise from the same cause as the first explained, *viz*: the desiccation of the powder, &c."

M. Humboldt, (*Bulletin de la Société Philomatique*, floreal, an. 3) it appears, suggested an improvement in mining, not by increasing the force of gunpowder, but in the charging of it; to leave a space occupied only by air, a fact well known to those who are accustomed to this work, although not always adopted. He states the effect of powder on a shell; that, if it be filled, it breaks only into two or three pieces; but if only half filled, it is shattered into a great number, which he attributes to the presence of air in the shell.

Sec. XXXIII. Of Incendiary Bombs.

These are used in sieges, and on water. Ruggeri gives the preparation of these bombs as follows, observing to melt the substances in the order they are mentioned.

1. Three parts of sulphur;
2. One part of pitch; [557]
3. Two parts of nitrate of potassa;
4. One part of mutton suet.

After melting these substances, and mixing them intimately, the mixture is removed from the fire, and two pounds of gunpowder are added, and thoroughly blended. It is again submitted to heat, and a sufficient quantity of quick match, to cover a good sized marron, is immersed. The marron is furnished with a fuse. The composition hardens on the match. The match is employed as before described. Water does not extinguish the fire, produced by the combustion of this composition. See *Carcasses and Fire-Balls.*

Sec. XXXIV. Of Murdering Marrons.

Marrons, which take this name, are those, whose effect is different from the incendiary bomb. The latter is calculated to set fire to houses, &c. while the former is designed to destroy the lives of persons.

To make a murdering marron, we prepare, in the usual manner, a cylindrical case, and fill it with gunpowder, and then wrap round it, a quantity of pack-thread. In winding on the thread, care must be taken to cross it in the manner mentioned in a former article. It is then finished by coating it with a mixture of glue and wax, or, in preference, pitch. This prevents the thread from unwrapping, and renders the case firm and less liable to break. A hole is then made in its side to the powder, in which we insert a piece of quick-match, to communicate fire to the contents of the case. A small fuse, similar to that of a bomb fuse, but shorter, and made of pasteboard, is also used; and, after it is fixed to the marron, musket balls, previously pierced with holes, are nailed round the marron, the nails passing through the balls into the case. After thus fixing as many balls as the surface of the case will admit, we cover them with a composition made of three parts of glue and one part of wax. When this coating is dry, a hemispherical case is adapted. This case is a small *sack* of paper, made round, and filled with gunpowder. It is placed at the bottom of the marron, and secured there with paper and glue. The match is conveyed to the orifice of the fuse of the marron; and, in short, a communication is so made from the one to the other, that, at a given time, the fire passes by means of the fuse to the marron, which then explodes, and throws the balls, with which it is furnished, in every direction.

Shells, made by uniting two hemispheres, containing powder, and furnished with balls and a fuse, are also a destructive weapon [558] of the same character.

Sec. XXXV. Of Incendiary Rope.

We have mentioned, under the head of *Tourteaux*, or tarred links and fascines, the compositions made use of for these preparations. The composition for incendiary rope is as follows:

Sulphur	12	parts
Saltpetre	6	——
Rosin	2	——
Camphor	2	——
Meal-powder	4	——

Grained powder	2	——

The rosin, sulphur, camphor, and saltpetre are melted, and mixed thoroughly together, and the kettle, which contains them, is removed from the fire; the gunpowder is then added, and intimately blended.

The mixture is again heated, and the rope is then immersed in it, and suffered to remain until it has imbibed sufficiently. It is then taken out, and allowed to cool.

After this operation, we melt, in a separate kettle, the following substances:

Rosin	4	parts.
Pitch (or tar)	4	——
Mutton suet	2	——

When they are melted, and mixed, the rope previously prepared as above, is thrown into the mixture, and then removed and hung up.

After this second process, we make, in an earthen vessel, a priming mixture, in which the rope is sometimes immersed, or such parts of it, as are to take fire promptly. This priming paste is composed of,

Meal-powder	4	parts.
Saltpetre	4	——
Sulphur	2	——
Spirit of wine, (or brandy), a sufficient quantity.		
Gum arabic	½	——

Incendiary rope is used more generally in the form of a ball, which is enclosed in a sack, and fired out of a common mortar. It [559]
was invented by an officer at Toulon. See *Carcasses.*

Sec. XXXVI. Of Balloons of Grenades, of Bombs, and of Flints or Stone.

Balloons of this kind are cases, or sacks, made sufficiently large, containing powder, and enclosing grenades, shells, and stones.

The balloon of grenades holds twelve charged grenades, containing different quantities of powder. They are finished like powder sacks, and *corded* with small cord, twine, or thread. The balloon of flints, river stones, or small pebbles, is made by enclosing these substances along with powder in a sack, as before stated. These balloons are employed for the defence of works, &c. See *Powder Sacks.*

The *Ballon à Bombes*, of the French, is the same. It is a bag, in which are placed *beds* of smaller bombs, that are charged and interlaid with gunpowder. The bag is put into another covering, that is pitched, with the neck closely tied up with pack thread, in which a fuse is fixed, as in ordinary bombs. The English say, that Colonel Shrapnel's invention of the spherical case shot, is of a superior kind. We purpose, therefore, to notice them in the following section.

Sec. XXXVII. Of Spherical Case-Shot.

Ordinary case shot is a tin case or cannister, filled with iron balls, so as to make up the weight of the shot. The balls are seldom less than $1\frac{1}{4}$ oz, in weight. Little effect is to be expected from firing case shot beyond 300 yards, from the very great divergency of the balls. The following summary of the effects and advantages of this species of shot, which, as invented by Col. Shrapnel, is called the Shrapnel shell, will be sufficient for our purpose. It is extracted from a book lately published.

1st. The whole charge takes effect on the enemy at any distance. By the present mode of firing, the greatest part of the charge disperses as soon as it leaves the muzzle of the gun, and cannot be directed.

2nd. Grape, or case shot, may be fired with effect equally close and collected, to any distance within the range of the piece; and
the artillery need not advance within musket shot of the enemy, to make use of this kind of fire with its full effect, and are not so [560]
subject to have their guns charged either by cavalry or infantry.

3d. It requires less precision and exactness, to point a piece of ordnance charged with spherical case shot than with round shot; because case shot is a wide and dispersed fire, and the difficulty in elevation consequently less.

4th. Its comparative destruction with that of round shot will be, generally, as the number of the shot within the shells to one; that is to say, a three pounder, twenty-two to one in its favour; a six pounder, fifty to one, &c.; in which calculation is not enumerated any effect from the splinters of the shell.

5th. Small balls cannot be projected to very considerable distances, unless enclosed in heavy spherical cases, which, from their form and weight, are not much influenced by the resistance of the air, or diverted from their direction.

6th. The explosion of the shell makes no change in the direction of the shot within; they consequently complete the shell's track, or curve, which has sometimes been observed to be 400 yards.

7th. From the unevenness of the ground, such as hillocks, banks, fallow fields, &c. all shot which graze, most commonly lodge: whereas, by using this shell, the whole charge will be carried over these irregularities, and reach the object with its full contents of balls.

Sec. XXXVIII. Of the Fire-Rain, according to Casimir Siemienowicz.

The composition, which produces fire-rain, which we purpose to notice in this place, is taken from the "*Artis Magnæ Artilleriæ*" of Casimir Siemienowicz. He seems, however, to have taken it from a German author.

The fire rain is an incendiary fire-work, and calculated, like other incendiaries, for firing the houses of a besieged place or city, which are covered with shingles, laths, stubble, or reeds. Besides several other compositions, designated by artificers, that of fire-rain was so called from its supposed resemblance to a shower of rain.

To prepare this composition, the following method is used: We take 24 parts of sulphur, and melt in a copper, or iron pot, over live coals without flame, and then throw in 16 parts of saltpetre, and mix it with an iron spatula, to incorporate the whole. The pot
is now removed from the fire, and when the composition is become rather cold, stir into it 8 parts of grained powder. The [561]
composition is then poured on a marble slab, or metallic plate, where it is allowed to cool. It is then broken into pieces of the size of a walnut, which, when used, is interspersed with quick match, covered with gunpowder, and put into shells or bombs.

These bombs are made in the same manner, as those, which are formed in fire-works for exhibition.

Wood, covered with this composition, will burn in the same manner as the shells. The globe of fire is also similar to those for exhibition. The mortar is elevated at an angle of 45°, in order that the globe may go to the greatest height, and the greatest range; for the fall of the inflamed matter, which is dispersed in all directions by the powder, is more or less vertical, and, in that state, lights upon houses, &c. This effect, that of setting fire to one or more houses, depends greatly on the accuracy of their discharge from the mortar.

The following compositions are also used for the same purpose, observing to follow the same manner of mixing the ingredients:

1.	Sulphur	3 parts.
	Saltpetre	1 ——
	Meal-powder	1 ——
	Iron filings	½ ——
	Green Vitriol	½ ——
2.	Sulphur	1 part.
	Saltpetre	1 ——
	Grained powder	1 ——
3.	Sulphur	1 part.
	Galbanum	4 ——
	Saltpetre	4 ——
	Grained powder	1 ——

4.	Sulphur	5 parts.
	Saltpetre	2 ——
	Rosin	1 ——
	Meal-powder	1 ——

These compositions may be used in the manner already described. Two wooden hemispheres, filled with the preparation and joined together, is the usual mode of forming a fire bomb. The bomb or globe is then covered with strong canvass, and finished by dipping it, or smearing it with melted pitch. Over this, two or three covers of canvass are sometimes sewed. When the bomb is dry, we put it in a case, in the same manner as directed for the murdering, and incendiary bombs. The case is charged with fine meal- [562]
powder, &c.

The modern improvements, which are many, supersede the rain-fire. Fire stone, for instance, is a more powerful preparation. The incendiaries made with this composition, and the ordinary carcass, are more effectual for this purpose. That the Greek fire was an active composition, and produced very destructive effects on towns and shipping, there can be no doubt; notwithstanding the invention of gunpowder has completely changed the art of war, and superseded, as we have shown in our articles on *gunpowder* and *Greek fire*, the use of the incendiary composition of the Greeks.

Sec. XXXIX. Of the Effect of Mirrors in inflaming Bodies at a Distance.

As this subject may be of some interest to the reader, at least in relation to an important fact, that of the *concentration* of the calorific rays of the sun, which has had the effect of burning bodies at some distance, we deem the following facts not irrelevant.

The effects of burning glasses, both by refraction and reflection, are noticed by Empedocles and Euclid, who composed a treatise on the ancient optics and catoptrics. It has been thought, that the Romans had a method of lighting their sacred fire by some such means. Aristophanes, in one of his comedies, introduces a person as making use of a globe, filled with water, to cancel a bond that was against him, by thus melting the wax of the seal. Plutarch, in his life of Numa, says, that the instruments used to kindle fires, were metallic dishes, which were placed opposite to the sun, and the combustible matter in the centre, by which, it is probable, he meant the focus, conceiving that to be at the centre of the mirror's concavity.

Father Kircher was the first, who thought of substituting, for a concave mirror, several plane mirrors, so disposed, that the sun's rays reflected at their surface might converge towards the same point. He employed five only of these mirrors, which he so arranged, that the concurrence of the rays should take place at a distance of more than one hundred feet, and he found the heat there to be scarcely supportable. "Now," says Kircher, "if five mirrors produce so considerable an effect, what would a hundred or a thousand do, arranged in the same manner? They would excite so violent a heat, that it would set fire to every thing, and reduce [563]
all to ashes."

Orpheus compares his *jaspis* to rock crystal, and says that it kindles fire, and that he knew how to use rock crystal as a burning glass. Diodorus calls some kinds of jasper transparent, and sky-coloured. The jaspis, described in the Revelation of St. John (*chapter* xxi, verse 11, 18, 19,) may have been the same stone.

It is not our intention, however, to notice the history of mirrors, from the time of Moses, (*Exodus*, chap. xxxviii, verse 8,) or of Job, (*Job*, chap. xxxvii, verse 18) through different periods of time, to the present day; as the reader may find an interesting account on this head in Beckman, (*History of Inventions*, vol. iii, p. 154); but to state in particular the celebrated experiment of Archimedes, which has indeed astonished men of science, who have lived since that period. There can be no doubt of the fact, if we reflect for a moment, that some modern experiments have justified the conclusion which has been drawn; and, therefore, that the solar rays may be concentrated to such a degree, as to inflame bodies at some distance off: and as the heat produced is much greater than that of our hottest furnaces, incredible as it may appear, there can be no question as to the effect, which may be produced by a system of mirrors.

By means of burning mirrors, Archimedes burnt the Roman ships, which were beseiging Syracuse, and reduced them to ashes.

Descartes, among others, discredited the story as fallacious; but Kircher made many experiments, with a view of establishing its credibility. He tried the effect of a number of plane mirrors, and with five mirrors of the same size, placed in a frame, he contrived to throw the rays reflected from them to the same spot, at the distance of more than one hundred feet; and, by this means, he produced such a degree of heat, as led him to conclude, that, by increasing their number, he could have set fire to inflammable substances at a greater distance. He likewise made a voyage to Syracuse, in company with his pupil, Schottus, in order to examine the place of the supposed transaction; and they were both of opinion, that the galleys of Marcellus could not have been more than thirty paces from Archimedes.[42]

Proclus is also said to have destroyed the navy of Vitalian, beseiging Byzantium, near Constantinople, by means of burning [564]
glasses.

Among the moderns, the most remarkable burning mirrors have been those of Magine; of Septala of Milan, which was nearly three and a half feet in diameter, and which burnt at the distance of fifteen or sixteen paces; of Vilette, and Tschirinhausen; the new complex one of M. Buffon; that of Trudaine, and that of Parker. Tschirinhausen's burning glass was between three and four feet in diameter, and its focus was rendered more powerful by a second one.

It may not be improper to notice the construction, as well as the effect of some of these mirrors. La Brocquire, a traveller of the 15th century, says, that, at Damascus, they made mirrors of steel that magnify objects, and one of them, when exposed to the sun, reflected the heat so strongly, as to set fire to a plank fifteen or sixteen feet distant.

M. Buffon constructed a machine consisting of a number of mirrors, by which he seems to have revived the secret of Archimedes, and to have vindicated the credit of history in this point. The experiment was first tried with twenty-four mirrors, which readily set on fire a combustible matter prepared of pitch and tow, laid on a deal board at a distance of sixty-six French feet. He then pursued the attempt, and put together a kind of polyhedron, consisting of one hundred and sixty-eight pieces of plane looking glass, each six inches square; and by means of this, some boards of beech wood were set on fire at a distance of one hundred and fifty feet, and a silver plate was melted at the distance of sixty feet. This machine, in the next stage of its improvement, contained 360 plane mirrors, each 8 inches long, and 6 broad, mounted on a frame 8 feet high, and 7 feet broad. With 12 of these mirrors, light combustible matters were kindled at a distance of 20 feet; with 45 of them, at the same distance, a large tin vessel was melted; and with 117, a thin piece of silver. When the whole machine was employed, all the metals were melted at the distance of twenty-five, and even of forty feet. Wood was kindled in a clear sky, at the distance of 210 feet. Mr. Buffon afterwards constructed a machine, which contained four hundred mirrors, each six inches square, with which he could melt [565]
lead and tin at the distance of 140 feet.

Mr. Parker, an eminent glass manufacturer, in Fleet street, London, constructed the most powerful burning mirror ever made. He erected an out building at the bottom of his garden for the purpose of carrying on his operations. He succeeded in forming a most powerful burning lens. Its diameter was three feet. Platinum, iron, steel, flint, &c. were melted in a few seconds, on being exposed to its immense focus. A diamond weighing thirty grains was reduced to six grains, in the space of thirty minutes. It opened and foliated like the leaves of a flower, and emitted whitish fumes, (carbonic acid gas;) when close again, it bore a polish, and retained its form. Garnets, clay, &c. soon melted.

Seven hundred guineas were subscribed to indemnify the inventor, it having cost him seven hundred pounds. It was purchased, however, and presented by lord Macartney to the Chinese government, and remains now at Pekin.

M. Payard, (*Archives des Découvertes*, &c.) has invented a burning mirror, consisting of several plane mirrors so arranged as to concentrate the solar heat into a focus with great precision. The arrangement, it may be proper to state, is different from that heretofore used, and the effect is said to be very powerful.

A polygonal mirror, from a suggestion of the celebrated Buffon, was erected in the Botanic Garden at Paris, in 1747, and had also a very powerful effect. This mirror was composed of one hundred and sixty-eight plates of tinned or silvered glass, capable of moving in every direction and of being fixed at different degrees of inclination, so that there could be given to the whole, a form more or less concave, and the focus be thrown to different distances. This mirror set fire to wood at two hundred feet, and fused metals at forty-five feet.

As caloric, like light, follows the same laws with respect to its motion, and as the angle of incidence is equal to the angle of reflection, the radiation of heat, conducted after the manner of Pictet's experiment, has not only occasioned the combustion of gunpowder, but of other inflammable substances. But, for this purpose, the mirrors must be large and extremely bright. That heat radiates in all directions, and is reflected, and that the calorific rays may thereby be concentrated, are facts which are now universally admitted. The application of this principle, by using concave mirrors sufficiently large, has, we are informed, produced [566]
the explosion of gunpowder. They were placed about twelve feet apart. In the focus of one a live coal was put, which was

constantly blown with a double bellows, and in the focus of the other some gunpowder. In all our experiments with the ordinary reflectors, we could never produce any thing like the heat necessary to inflame gunpowder. That the principle is substantiated by experiment is evident; for the rays of a heated body, or a substance which produces heat, as a lamp or candle, placed in the focus of a concave mirror, are reflected in parallel lines, and if another concave mirror be placed opposite to it at some distance, the calorific rays will be thus intercepted and reflected back in a focus. This *focus*, therefore, like the focus of a burning glass, is the concentration of all the parallel rays of heat.

Sec. XL. Of Incendiary and Poisoned Arrows.

The bow is a very ancient weapon of offence, made of steel, wood, horn, or other elastic substance, which, after being bent by means of a string fastened to its two ends, in returning to its natural state, throws out an arrow with great force. That the bow was a weapon of offence among the nations of antiquity, the inhabitants of Asia and Africa, and the Aborigines of this country, and that it was used in Europe, before the invention or use of fire-arms, are facts, of which we have abundant proof. Bows are much the same in all countries. It has generally two inflections or bendings, between which, in the place where the arrow is drawn, is a right line. The Grecian bow was adorned with gold or silver. The Scythian bow was distinguished from those of the Grecians and other nations, by its incurvation, which was so great, as to form a half moon, or semi-circle. The Persian bows were made of reed. The Indians used the same material, as well for their bows as their arrows. The Lycian bows were made of the cornel tree; and those of the Ethiopians, which surpassed all others in magnitude, were made of the palm tree. The Romans, although they did not admit bows in the infancy of their republic; yet they considered them as hostile weapons. They employed auxiliary archers in all their wars. The Amazonians, as well as the primitive Grecians, in drawing their bow, did not pull back their hand towards their right ear, according to the fashion of the ancient Persians, and of modern ages; but, placing their bow directly before them, returned their hand upon their right breast.

While noticing this subject, we may also observe, that Louis XI first abolished the use of bows in France, introducing, in their [567]
place, the halberd, pike, and broadsword. The long bow was much in use by the English archers, and many laws were passed encouraging its use. In the time of Henry VIII, the parliament complained of the disuse of long bows.

The bow is now laid aside altogether as a war weapon. The arrows, made use of, were armed with barbed iron, and, among the aborigines of this and other countries, with a stone, formed in a particular manner, many of which are picked up in this country. We have found them at West Point. The natives were in the habit of poisoning their arrows, by using a particular composition, not known; the effect of which, however, when the arrow penetrated into the flesh, is always destructive.

Roggewein, (*Voyage for the Discovery of Southern Lands*) speaking of Batavia, observes, that, at this place, there are some of the Macassars, so famous for their little poisoned arrows, which they blow through a trunk. This poison is the juice of a tree, that grows in Macassar, and in the Bougie islands. They dip the points of their arrows in this juice, and then let them dry. The wound they give is mortal.

The natives of Ceylon are very dexterous with the bow and arrow; so also are the Hottentots, according to Kolben, in his *Voyage to the Cape of Good Hope*. A Hottentot arrow consists of a small tapering stick or cane, of about a foot and a half in length, pointed with a small thin piece of iron bearded, and joined to the stick or cane by a barrel. Their bows are made of olive, or iron wood, and the strings, of the sinews and entrails of beasts. When they attack a lion, tiger, or leopard, which they do with wonderful resolution and dexterity, they employ slings (*hassagayes*) and arrows, which for that purpose are usually poisoned.

Ellis (*Voyage for the Discovery of a North-West Passage*) speaks of the bows and arrows of the Eskimaux Indians, and the facility with which they use them, but not of poisoned arrows. Moore, (*Travels into the interior of Africa*) observes, that a native took him to his house, and showed him a great number of arrows, daubed over with a black mixture, said to be so venomous, that, if the arrow did but draw blood, it would be mortal, unless the person who made the mixture had a mind to cure it. For the man observed to him, that there were no poisonous herbs, whose effects might not be prevented by the application of other herbs.

Poisoned arrows, according to various historians, were used in the remotest periods of antiquity. The mode of treating wounds in [568]
the twelfth century, by using membrane like the present gold-beaters' skin, may be mentioned in relation to this circumstance. The Emperor, John Commenus, accidentally wounded himself in the hand with a poisoned arrow, while hunting, and applied a piece of skin to the wound. The emperor, however, died in consequence of the wound, after it had become inflamed under the pellicle; which, in large wounds, and when the skin is suffered to remain too long, is commonly the case, though the poison alone we are informed, would have been a sufficient cause of death. Other instances are also mentioned of death being occasioned by the poisoned arrow.

On the subject of poisoned arrows, the following outline is given on the authority of the author of the *Dictionnaire de l'Industrie*, vol. 3, p. 50.

The juice of the *Mancenilier*, or the *Lianes des Marais*, called in Guyanne *Curare*, is employed by some savages. The Arabs use the juice of a milky shrub, which they name *chark*, and called by the Persians *gulbut samour*. Indian arrows are said to be poisoned with the venom of serpents. The islanders of Java rub their darts with the blood and venom of the lizard *Gecko*, which they kill by whipping it to death. The needles of the Macassars, they poison with the juice of a tree, which is said to belong to the *ahouai* of America. At Ceylon they extract the venomous matter from the *Nerium*, or *laurel rose*. The ancient Gauls are said by M. Paw to have poisoned their arms with the juice of the *Caprisiguier*. In some cantons of the Pyrenees and Alps, they express the juice of the roots of the Aconitum, (thora), which they put on weapons.

M. Charles Coquebert, in a memoir read to the Philomatic Society, in 1798, observes, that the ancient European inhabitants employed three plants to poison their arrows; namely, *Veratrum album*, *Helleborus viridis*, and *Aconitum Lysocitonum*.

There have been obtained from the Society Islands some poisoned arrows, and a pot of the composition, in which they are dipped. It has the appearance of a black fluid extract, and seems to be an infusion or decoction of some plants, probably mixed with other substances.

With respect to the poisons obtained from the animal kingdom, they are principally liquid juices. Fontana, in particular, has paid
attention to this subject. The poison of the viper, which is contained in two small vesicles of the mouth, when the animal bites, is [569]
forced, through the fangs, into the wound. If the vesicles be extracted, or the liquor prevented from flowing into the wound, the bite is harmless. Sharp instruments, as arrows, when they penetrate the skin, being covered with the poison, will have the same effect. Fontana made a set of experiments on the dry poison of the viper, and a similar set on gum arabic, and obtained the same results! Small birds and quadrupeds die immediately, when they are bitten by a viper; but to a man, the bite is not always fatal. The experiments and observations of Francini, (*Abridg. Phil. Trans.* ii, 8,) Mead, (*On Poisons*, p. 35,) Tyson, (*Phil. Trans.* vol. xii,) Fontana, Redi, Russel, the late Dr. Ramsay, of Charleston, (*Phil. Mag.* xvii, 125,) and Dr. B. S. Barton, (*Amer. Phil. Trans.* vol. ii, p. 100,) furnish an abundance of facts on the venom of the viper, and some on the antidotes to the bite. Dr. F. G. Gren, late professor at Halle, in Saxony, (*Principles of Modern Chemistry*, ii, p. 47), observes, in speaking of the experiments of Fontana, as the poison of the viper exhibits all the characteristic properties of gum, whether the gum be merely the vehicle of a peculiar venomous substance, which, upon investigation, escapes the notice of the senses? or whether this action upon living bodies, so different from its usual nature, be imparted to the gum, merely by a change in the proportions of its radicals, so slight as to be unobservable in its chemical analysis?

Mr. Misson (*Travels through Germany and Italy*) observes, that, at the arsenal at Venice, he saw some pocket cross bows, and steel arrows, with which the late lord of Padua used to kill such as passed by, without their knowing from whence they received their wounds.

Arrows were sometimes employed by the Grecians, for conveying their Greek fire. It seems, according to Gibbon, (*History of the Decline and Fall of the Roman Empire*, vol. vii, 284), that, among the different means of discharging it, that with the bow and arrow was one. For this purpose, flax or tow was dipped in the composition, and wrapped round the arrow, which was discharged the moment it was inflamed.

The Indians, and Africans in particular, have been very ingenious in poisoning several kinds of warlike instruments. The blades
of swords, the barbs of arrows, balls, &c. they have prepared in such a way, as to be extremely poisonous.[43] See *Poisoned Ball.* [570]

With respect to incendiary arrows, it will be sufficient to remark, that the barb, for this purpose, was furnished with a composition, which, when inflamed, was projected by the bow to the spot designed to be set on fire. They were not much employed, and at the present day, are entirely out of use. Tow, for instance, previously prepared with pitch, meal-powder, and turpentine, or a composition equally combustible, when wrapped round the head of an arrow, and thrown at the moment of its inflammation, would, in many cases, set fire to buildings. But, as the present system of employing incendiary fire-works, presents advantages decidedly in its favour, it is hardly probable, that the bow and arrow will ever be employed by civilized nations for that purpose. The ancient *catapulta* was particularly calculated for throwing incendiary compositions.

The catapulta was an engine, contrived for throwing arrows, darts, and stones, upon the enemy. Their power was so great, that they would project a stone of a hundred weight with an almost incredible force. Josephus, in noticing this machine, says, that the stones thrown out of it, beat down the battlements, knocked off the angles of the towers, and had a force sufficient to level a deep file of soldiers.

Sec. XLI. Of Pyrotechnical Sponge.

This name is applied to the German *black match*, or tinder, used chiefly to receive the file from flint and steel. We have, on a former occasion, noticed the preparation of the substance called spunk; namely, by immersing the fungus in a solution of saltpetre, and then drying it.

There are various species of agaric. The mushroom is a genus belonging to the order Fungi, and the *boletus igniarius*, spunk, or touch-wood, called also female agaric, is employed, not only as a match, but as a styptic. The fungous excrescences, which grow upon old oaks, ash trees, firs, &c. are all used for the same purpose. The Germans take the soft inner substance in preference to the hard, and after beating with a hammer to render it still softer, they boil it in ley, then dry it, and boil it again, in a solution of nitrate of potassa, and finally dry it in an oven for use. [571]

The *amadou* of the French, is the same as our spunk, or pyrotechnical sponge. It is always made, like the latter, from various kinds of agaric, which constitute the spongy excrescence of trees. The French prepare it for use in the manner before stated. They prepare *amadou*, also, by soaking blue paper in a solution of nitre. They sometimes employ it in the state of tinder, and, for this purpose, burn it to a coal.

In the East Indies, there is a white spongy plant, which, when reduced to a kind of charcoal, furnishes a very good tinder.

Spunk, or pyrotechnical sponge, is generally made in Germany.

In the preparation of ordinary *tinder*, the best mode of carbonizing the old linen, instead of burning and then smothering the flame, is to char the rags in close iron vessels. It may be made more quick by soaking it in a solution of nitre, and then drying it.

Dry turf, or peat, is susceptible of inflammation by the spark, and, if previously soaked in a solution of nitre, the effect, we are told, is much the same as with spunk. Professor Beckman (*History of Inventions*, i, p. 333), remarks, that a spark falling accidentally on a turf moor, during a dry summer, often sets it on fire; and the conflagration it occasions, often lasts so long, that it cannot escape notice. Of the earth taking fire in this manner, there are many instances to be found in the ancients. One of the most remarkable, is that mentioned by Tacitus, (*Annal.*, lib. xiii, cap. 57), who relates, that not long after the building of the city of Cologne, the neighbouring land took fire, and burned in such a manner, that the corn, villages, and every production of the fields, were destroyed by the flames, which advanced even to the walls of the city. This was certainly a morass set on fire.

Gmelin (*Travels in Russia*, 1768-69, vol. i, p. 22) speaks of a morass in Siberia, where a village was erected, which, on account of its situation, the inhabitants deserted. This morass was set on fire, and when he was there, had been burning for more than six months; and being very inflammable, produced much devastation. [572]

Turf, which consists of a congeries of vegetable roots or fibres, partly in a dry and decomposed state, or partly carbonized, when separated from earthy matter, and treated in the same manner as the medullary excrescence of wood, may be advantageously employed in like manner; but it is to be remarked, that for this purpose, the small and more friable, and consequently the more decomposed part, should be preferred. That turf, or peat, has been used for fuel, from time immemorial, there can be no doubt; since it is furnished in some countries very abundantly, and its inflammability has been long known.

Sec. XLII. Of Extinguishing Flame with Fired Gunpowder.

The different methods for extinguishing fire in chimnies, by using salt, sulphur, &c. to *smother* the flame, as it is called, depend on one principle, that of producing either a gas or vapour, which supplies the place of atmospheric air, and as it is a non-supporter of combustion, extinguishes the flame. Carbonic acid gas would have the same effect as the sulphurous acid gas, produced by the combustion of sulphur, or the vapour of salt.

So long, however, as the air is permitted to have a draught, the fire will continue to burn; and hence, without making any remarks on the bursting of chimnies, by closing all the avenues, by which the air enters, as the fire must exert a lateral pressure, this plan is generally adopted.

It has been suggested, and in fact the suggestion is by no means new, that the *smoke* of fired gunpowder would extinguish flame. Some recommend firing a pistol up a chimney for this purpose, and others again, throwing gunpowder into the fire.

In the *Dictionnaire de l'Industrie*, iii, p. 31, I find some remarks on this subject. Besides the use of gunpowder, the vapour of water is recommended; but having some objections, among which, that of accelerating the current of air in particular, it is laid aside. Intercepting the passage of air seems to be preferred.

It appears, that the person, who first suggested the use of gunpowder for this purpose, was a Zachariah Greyl, of Augsburgh, in 1720.

The effect was attributed to the *vapour* of the gunpowder destroying the elasticity of the air; and the same effect is said to take place when the vapour of sulphur, or of volatile acids, is employed. It is hardly necessary to add, that this conclusion, of the diminution of the elasticity of the air, on which depends its fitness for combustion, (according to the theory then advanced), is altogether hypothetical; and the cause of the extinction of the flame, must be sought for in the substances themselves, producing an atmosphere, which is decidedly a non-supporter of combustion. [573]

The *Journal de Paris for* 1785, and the *Affiches de Province* of the same year, recommend the use of brimstone. In the same work, page 454, it is said, that marine salt is employed with success for the extinguishing of fires; and that, when a certain quantity is thrown upon the fire, it evaporates in an instant, and displaces, by its *fumes*, the atmospheric air. In 1723, M. Hoffer invented his machine; and in 1781, M. Cadet de Vaux made some experiments before Leroy, Lavoisier, and Macquer, on the means of rendering bodies incombustible by saline substances, and different modes of extinguishing flame.

In 1722, the Germans announced, that, by means of a certain quantity of gunpowder, flame at all times might be extinguished. The secret, for such it was then considered, has been revived; for the same plan has lately been recommended by a modern writer. M. de Reaumur communicated to the French academy, an account of this contrivance, by which it appears, that the machine was a large box, or cask, that contained a large quantity of water; in the centre of which, was placed a case of sheet tin, containing some pounds of cannon powder. To this was attached a fuse. When it was inflamed, the gunpowder would burst the vessel, and disperse the water in every direction. See the *Journal des Savants*, 1725, p. 671.

In the *Dictionnaire de l'Industrie*, a prompt and certain method is recommended for cleaning the tunnel of chimnies. This is rather a novel plan. Of its efficacy we know nothing. It consists in taking a powder, composed of three parts of saltpetre, two parts of salt of tartar, and one part of flowers of sulphur, (or fulminating powder), and exploding it on a shovel up the chimney. The explosion indeed may detach the loose pieces of soot; but it cannot remove the harder crust, and besides, it would endanger the chimney taking fire.

We know that various contrivances have been used for the same purpose; and of the chimney cleansing machines, calculated to diminish the number of infant victims of a filthy and disgusting operation, that of Mr. Smart appears to possess every advantage, which (or a plan similar to it) is now in use in our cities. A description of this machine, and another by Hornblower, are given in Gregory's *Mechanics*, vol. ii, p. 138. The invention of Mr. Hornblower consists of a vessel, into which air is condensed, that communicates with a tube, charged with small gravel, which being blown up the chimney, brings down the soot. [574]

Sec. XLIII. Of the Inflammable Dart.

This dart is made in the following manner. We take a common rocket case, of one inch exterior diameter, and charge it solid with the ordinary rocket composition. Some use one spoonful of earth, and three spoonfuls of the composition for fire lances, piercing the case, and attaching a quick match. This, however, appears altogether unnecessary, as the rocket composition is sufficient for the purpose. The match, in either case, is fixed in the end to set it off. To the end of the case is attached a dart, made of iron, and very sharp. This dart is secured in the head, in such a manner as to be kept firm. A stick is then lashed to the case in the usual way. It may be sent in the direction required. It appears, however, that, although it is calculated to be thrown on an enemy, it has not been much used; nor can it be considered an active weapon, compared with others, employed for similar purposes. One use for which it is recommended, is for the defence of buildings.

Sec. XLIV. Of the Firebrand.

The *boute-feu* of the French, which we have translated into firebrand, as the most appropriate term in the present instance, is used as an incendiary, and is nothing more than a long stick, furnished at one of its ends with two iron prongs, with sometimes the figure of a dragon's head, on which is rolled thick rope, previously prepared in the same manner as tourteaux. One end of this rope passes between the iron prongs. The boute-feu is calculated to set fire to buildings, &c. after the retreat of an enemy. It is only a convenient and expeditious mode of communicating fire. One end of the stick is pointed, and usually covered with iron, so as to stick in the ground.

Sec. XLV. Of the Fire Flask. [575]

The fire flask, or fire bottle, is a bottle, either square or round, and charged with grain-powder, mixed with fire-stone, which is introduced and compressed with a stick. The bottle is then covered with a cloth, sewed on it, which is coated with pitch. The mouth is secured with parchment. When used, a match is inserted, and inflamed. It is then thrown by the hand.

Sec. XLVI. Of the Trompe-Route.

The *trompe-route* of the French is a light made use of at sea, to deceive the enemy. It is nothing more than a common fire lance, one inch in diameter, and twelve inches long, fixed in the centre of a round plank, which, when lighted, is let down upon the water. As it floats from the ship, the lights of the latter being darkened, the enemy, in pursuit, will follow the light, and by this means the ship escapes.

Sec. XLVII. Of Fire-Pots for Ramparts.

Rampart fire-pots are used, when an enemy approaches a work. They are furnished with grain-powder, and charged grenades without fuses, and sometimes also with fire stone. The pots are ordinary potters' ware, and, when they contain the ingredients, are covered with parchment. A match passes through the opening of the pot, and when used, is inflamed with a port-fire. The following composition is also used for rampart pots.

Composition for Rampart Fire-Pots.

Saltpetre,	12	parts.
Meal-powder,	12	——
Sulphur,	4	——
Antimony,	4	——

These ingredients are mixed in a mortar with the oil of petroleum, or, if this cannot be had, good spermaceti oil, and made into a thick paste, about the consistence of dough, and then rolled into balls. The pots generally hold two rows of these balls, distributing through them grained powder. They are then finished by using fire stone composition, beaten into pieces, and mixed with an equal quantity of grained powder, and covered with meal-powder to facilitate the inflammation.

The pots are covered over with parchment, as in the former case. It is doubtful, whether fire pots, prepared in this way, have any [576]
advantages over those, made in the manner first described.

As to the shape of fire-pots, some are cylindrical, and others of the common figure. Sometimes they are furnished with an iron hoop, with a hook of iron, by which they are suspended. They are used, when equipped in that way, more for sea service, as a defence against small boats. They are hung over the side of the vessel, so as to come in contact with the boats. When designed in particular for that use, they are charged with the following composition:

Composition for Fire-Pots, for sea service.

Grained powder,	6	lbs.
Meal-powder,	2	—
Saltpetre,	1	—
Sulphur,	½	—
Charcoal,	10	oz.

With this composition, grenades are used, which are put into the pot with powder, fire-stone, &c. and a match is fixed as before mentioned.

We are told, that fire-pots, prepared in this manner, are a defensive, as well as a dangerous weapon, and that a vessel in the Indian seas was actually saved by them, when attacked by pirates. It appears, that she endeavoured to escape from her pursuers, and finding it in vain, the crew thought of making, and employing fire-pots, for their defence; as the number of the pirates was greater than their own crew. The effect was, that, not expecting that kind of reception, they were obliged to abandon their enterprize.

There is an incendiary fire-pot, which differs from that used in fire-works for exhibition, by being made of copper and very stout. It is charged with pieces of fire-stone, previously rolled in a paste of meal-powder and brandy. A charge of powder is put in the pot, and quick-match is fixed, which must be sufficiently long to hang over the pot, and then the fire-stone is thrown in. When the match is inflamed, the powder takes fire, and disperses the fire-stone. The better plan is to have a communication to the powder below, as in the pots of ordnance, or mortars for throwing fire-balloons. We see no particular advantage to be derived from the use of this pot; as a carcass or fire-ball, thrown out of a mortar, will do more execution, and at a greater distance than any of these contrivances. The carcass rocket, however, may be an exception, if we believe the account we have of it. As an incendiary, the fire- [577]
stone, put in a shell with powder, is more effectual than the fire-pot, we have just described.

Sec. XLVIII. Of Inflammable Balls.

Count Rumford (*Bibliothèque Physico-Economique*, 1812) has invented a composition, which is very inflammable, and, as it is used in balls, is for that reason so called. Equal parts of clay, pitcoal, and charcoal of wood, are mixed together, (having previously reduced them to powder), and made into a consistence with water fit to roll into balls. These balls are then dried for use.

They may be rendered more inflammable, by soaking them in a strong solution of saltpetre.

Count Rumford, when he recommended the use of clay with coal, was aware, that, in the combustion of coal, a considerable part of the heat was lost; whereas, although clay is incombustible, a greater part of this heat is retained by the clay, and given out gradually.

The inflammable ball may be considered more in the character of an economical fuel than in any other.

The only inconvenience attending these balls is, that, when prepared without nitre, which must add to the expense, they do not readily inflame; and, therefore, a fire must first be kindled, before they are used.

While noticing the use of clay in this manner, we may remark, that the *economical brick*, as it is called, is made nearly in the same way.

Two parts of clay, separated from stones, are mixed with one part of pitcoal. After the fire is kindled, the coal burns in the same manner, and the clay bakes.

Another composition is given in the *Bibliothèque Physico-Economique*, for March, 1812. It is composed of potters' clay, cow dung, street dirt, saw-dust of wood, turf, horse dung, straw, and tan. Besides these, pitch, tar, oils, and other combustible substances, are occasionally used, either with the above, or mixed with pitcoal in powder.

Observations on this preparation may be seen in the work quoted, or in the *Archives des Découvertes*, v, p. 137.

Sec. XLIX. Of Pauly's Inflammable Powder.

We mentioned, in a note to the article on guns, that M. Pauly had invented a musket, or fowling piece, which was discharged by [578]
percussion, instead of flint and steel, by using a priming powder made of chlorate of potassa.

It may be proper, however, to state, that the Rev. Dr. Forsyth made use of a similar powder, and for the same purpose, many years ago, of which we have already spoken. M. Thenard also has given a formula for a preparation of a similar powder.

A description of M. Pauly's improvement may be seen in the *Archives des Découvertes*, for 1812, p. 158, and in that of 1814, p. 174, where the composition of the powder is noticed; and also in the *Bulletin de la Société d'Encouragement*, for 1814.

This powder is composed as follows:

Chlorate, or hyperoxymuriate of potassa	8 oz.

Flowers of sulphur	3 —
Charcoal of light wood	2 —

They are mixed together with Cologne water, or in its place with brandy, to which a small quantity of the solution of gum arabic is added.

The ingredients must be made as fine as possible, and intimately blended together.

This powder may be inflamed by a hammer, or by the condensation of air in a piston, a mode recommended by Pauly.

We have seen a fowling-piece, constructed according to M. Pauly's plan, and also the priming powder used.

Sec. L. Of Extemporaneous Fire.

There are several preparations, which have the effect of producing fire either by friction, or chemical action. Some of these preparations, we have noticed. The causes of spontaneous combustion may be referred to chemical decomposition, and the change of quiescent into distributable heat. We remarked, that a mixture of chlorate of potassa and sugar is inflamed, when brought in contact with sulphuric acid; that, in the slaking of quicklime, the heat is sufficient to inflame oils; that pyrites by decomposition very frequently sets fire to combustible bodies; that oil of turpentine is inflamed by nitric acid; that pyrophorus, when exposed to the air, takes fire, and also phosphorus by slight friction; and that, in all cases of combustion, either friction, an increase of temperature, or the action of some body, which is brought in contact, are necessary to produce the effect. [579]

Water, when added to some substances and preparations, will produce fire. Thus potassium readily decomposes it, and the potassuretted hydrogen gas, which is produced in flames. The same may be said of phosphuret of lime and water; for the phosphuretted hydrogen gas inflames, when it comes to the air.

On some occasions, these substances may be employed as incendiaries.

Hanzelet remarks, that the following composition will produce inflammation with water.

Extemporaneous Fire.

Linseed Oil	3 lbs.
Spirit of Turpentine	1 —
White of egg	¼ —
Quicklime	8 —

It is doubtful, however, whether this composition will have that effect; although the heat produced by the slaking of quicklime is very considerable, and, as we remarked, spontaneous combustion, in several instances, has been referred to its agency. Lime, in the act of slaking, absorbs, and chemically unites with, water, which becomes solidified, converting it into a hydrate, whilst its latent caloric is set at liberty. This is a process, which puts quiescent heat in motion, to become distributable heat. See *Introduction.*

If the quantity of free caloric, thus generated, be sufficient, the turpentine and oil will necessarily inflame.

We may add, therefore, that a rapid transition of caloric, from a latent to a free state, as in combustion, is all that is required to produce effects of this kind; and, in short, all cases of spontaneous combustion may be accounted for on this principle; by considering the cause, which acts in those instances so powerfully, and in some instances instantaneously, and which changes caloric from a quiescent to a distributable state.

Dr. Irvine refers all cases of combustion to a change in the capacity of bodies for caloric; which depends on the nature of the products: if they have a greater capacity, no flame ensues, and the caloric remains more or less quiescent; if they possess a less capacity, flame is the consequence. There are exceptions to this doctrine.

In the emission of caloric, Dr. Black supposes, that it is given out, in consequence of the resulting attraction of the new [580] compound for caloric being less than that of its ingredients, when separate. M. Curadou (*Journal de Physique*, 1809) observes, that, in preparing the *artificial stone*, one-half of which is composed of water, by mixing one part of sulphuric acid with two parts of clay, and a sufficient quantity of water, a higher temperature is produced than that of boiling water. In this instance, we find that, in the formation of sulphate of alumina, which envelopes the silica, the water is solidified, as in many other cases, and, while it forms a solid substance, the caloric of fluidity is liberated. The heat, he remarks, is sometimes so great as to set fire to inflammable substances.

Sec. LI. Of the Indian White Fire.

This preparation (*feu blanc Indien* of the French) is described in the *Archives des Découvertes*, &c. vol. ii, p. 300. It appears, that it was kept secret in France, and was used by the French astronomers for signals.

In 1807, M. de Zach published some account of it, in his *Astronomical and Geographical correspondence*.

The case, in which the composition is put, is ten inches in diameter and four in height; but may be of any size, according to the quantity of the composition to be burnt, and the degree of light required. It was seen 40 miles at sea. General Ray lighted, on the English coast, a case of this fire, which was seen very distinctly on the French coast.

Composition of White Fire.

Saltpetre	24 parts.
Sulphur	7 ——
Red arsenic	2 ——

This powder lights without explosion, and illuminates with great brilliancy. Care must be taken not to breathe the Arsenical vapours, which are produced by the combustion.

A case of six inches in diameter, and six inches high, burns three minutes. The light is said to injure the eyes.

The price of this powder is equal to that of ordinary gunpowder.

The match, which accompanies this preparation when it is sold, is made in the following manner: Pulverize four parts of saltpetre, two parts of gunpowder, two parts of charcoal, and one part of sulphur, and pass them through a sieve. Provide then a [581] number of paper cases, made in the usual manner, or a roller, about the diameter of a quill, and two feet in length, and charge with the composition.

This match, when used, is attached to a stick. It will resist the action both of wind and rain.

An artificer of Marseilles proposes the following composition for matches.

Sulphur	8 parts.
Saltpetre	4 ——
Gunpowder	2 ——

Sec. LII. Of the Pyrophore of Defence.

An apparatus for defence, called the *Pyrophore*, was announced in a French publication in 1815. It may be applied, according to the author, in 24 hours for the defence of towns, roads, passages, and defiles.

The pyrophore itself is a square box furnished with a lid, and sufficiently large to contain fifty pounds of gunpowder. When it is filled, and to be used, it is fixed with cords, or chains, in such a manner as to be conveyed to a given point. The lid is furnished with cross pieces, which open it when necessary.

At the sides of the box are rings, made very strong and fixed in bolts, which go through the sides, and clenched. To each of these rings, a cord or chain is attached, furnished at each end with a *crotchet*.

This cord or chain runs upon two fixed pulleys, placed for instance, at the two extremities of a battery, and is managed by artillerists. The pyrophore is under cover. When it is conveyed to a certain place, where a bar or grate is fixed, it is stopped, by the contrivance before mentioned, the lid is raised, and the powder falls into a kind of funnel or gutter, at the end of which the explosion is made, to take effect.

It appears that the inventor had in view the conveyance of a given quantity of powder to a particular place, and by carrying a light to it by means of a cord, similarly fixed, to inflame it, when it had arrived at its destination.

It is impossible to make a machine of this kind effective; for the difficulty in arranging, and finally managing it, the enemy taking means to guard against it, are certainly obstacles, and strong objections to its use. Other means of defence, which we have pointed out, are preferable; although we admit, that, in *some* situations, a contrivance of this sort might be advantageously used, where, for instance, we wish to deposite a quantity of powder, to be in readiness for the approach of an enemy, without exposing men to [582] an attack. What is more destructive than the thundering barrel, which is furnished with grenades, &c. &c. if set off among the assailants? See, for a minute account of this contrivance, the "*Pyrophore, ou Moyen de defense générale*, par un garde national: 20 pages grand in 8vo. avec un planche. *Paris Dondey Dupré*, 1815," and also the *Archives des Découvertes*, tome 8. p. 281.

VOCABULARY [583]

OF FRENCH TERMS, WHICH OCCUR IN THE WORK.

Aigremore. Pulverized charcoal, proper for fire-works.

Aigrette. An imitation in fire of the aigrette; like the aigrette of glass.

Ailerons. They are used in making rockets.

Amadou. A kind of tinder made with agaric.

Ame. This is more particularly used to express the kind of work, put in the head of a rocket. The term, however, is arbitrary.

Amorce. Priming: a paste of powder and spirit of wine.

Arquer. A name given to a particular shaped case.

Artifice, feu d'. Fire-works; artificial fire.

Auget. The wooden trough to contain the saucisson, which communicates fire to a mine.

Baguette. A rammer, roller, former, &c.

Baguette à charger. Rammers or chargers, pierced with holes in their length, more or less, to receive the piercer. They are applicable to the charging of rockets, if they are to be driven hollow; if not, solid rammers are employed.

Baguette à feu. Fougette; East Indian rocket. See page 529.

Baguette à rouler. A former, on which the pasteboard or paper is rolled, in forming cases for rockets, port-fires, &c. &c.

Baguette de fusée volante. Rocket stick. A stick, attached to the rocket, before it is set off.

Baguette en massive. Rods or rammers, which are not bored.

Bague suspendue aux cendres d'un fil. A ring suspended to the ashes of a thread.

Ballon. Balloon; a bomb or shell, made of pasteboard, which is thrown in the air by means of a mortar.

Ballon à bombes. A large globe, filled with bombs, grenades, &c. fired by means of a fuse, and thrown into the works of the enemy.

Ballon d'Artifice. A bomb, or spherical case, containing sundry compositions.

Ballons d'air. Air-Balloons.

Ballons d'eau. Water-Balloons.

Battage. The process of pounding, grinding, and mixing, with water, the three substances, composing gunpowder, to reduce them [584] to a proper consistency. It is performed in wooden mortars, with wooden pestles, furnished with a brass box to agitate the water. The time, employed in the battage in France, is from 14 to 22 hours.

Bateau-poisson. A diving boat.

Billot à charger. A billot for charging; used occasionally in the place of a mallet.

Boîte. A species of small mortar. It is used, also, to express a piece of wood or pasteboard, used in the arrangement of some fire-works.

Bonnetage. The covering of priming over a case, or fuse.

Bouffées. Literally puffs, or blasts: in Pyrotechny, a kind of fire-works, used in theatres, to represent the flames, issuing from gulfs, or the caves of Cyclops. They are also called Cornets, from their resembling horns in their shape.

Boute feu. Lintstock.

Bouton. The extremity of the culot is sometimes so called.

Brin. Frame. The frame on which are placed or fixed, fire-pots, saucissons, &c. Hence *pots de Brin*, &c.

Carabé or Karabé. Yellow amber.

Carte de Moulage. Means in general, the paper for cases.

Chapiteau d'artifice. Conical head of a rocket.

Chasse. Charge of grained powder for mortars, &c.

Chevelure de feu. A species of furniture for rockets, in the form of serpents.

Chelingues. A marine term. A kind of flat bottomed boat, used on the coast of Coromandel.

Corde à feu. Match rope. Slow match. A match to preserve a small quantity of fire.

Courantin. A messenger, runner, or flying dragon; a rocket, that flies along a rope or string. See page 345.

Courantin simple. A line-rocket. A rocket fixed on a cord, stretched horizontally on which a rocket moves.

Courantin double. Two line-rockets.

Courier pigeon. Carrier pigeon. See page 490.

Culot. Bottom; the thickest part of a shell, opposite to the eye; also called reinforcement. The round iron plate, fixed upon the sabot, or shoe, for cannister shot, or at the bottom of the cannister, to project the shot with more force:—The bottom, or block, which supports the piercer and mould for charging rockets, (see plate, fig. 1):—That part of a cannon cartridge, which remains in the piece after firing.

Camouflet. A small fougasse, to act against the enemy's miners, who are heard at work, to suffocate them and poison their branch. [585]

Dauphin. A fire-work in water.

Debonneter une fusée. The paper cover, put over the priming of a fuse.

Eaux de cuite. Literally, water of boiling. The strongest lixivium obtained in extracting nitre from plaster rubbish. It must mark more than five degrees of Baumé's areometer, and is called water of boiling, on account of its being sufficiently strong, to be immediately subjected to boiling, for further concentration.

Eaux forte. Lixivia from plaster rubbish, which mark between three and five degrees of the areometer.

Eaux faibles. Lixivia from plaster rubbish, whose strength is under three degrees of the areometer.

Eclair, ou jet de flame. Several fire-works are so called from their effect.

Eclatante. A case charged with brilliant fire.

Epoussetage. The process of separating the dust from gunpowder; also of separating mealed powder, from that which is not reduced.

Eprouvette. Gunpowder triers: an instrument for proving gunpowder.

Etoile. Star.

Etoiles à pet. Stars which explode.

Entonnoir. The crater or tunnel of a mine, as formed by its explosion.

Etoupille. Quick match, leader, match of communication; cotton or thread mixed in a paste, composed of meal-powder, spirits, and a small portion of gum.

Etrangler. Strangling; choaking. The closing of a case, and tying it.

Fanaux de Mer. Ship lights;—Beacons for vessels in the night;—watch-lights.

Feu blanc Indien. Chinese fire.

Feu brilliant. A bright vivid fire. Thus the fire, produced by steel and iron, in fire-works, is denominated a brilliant fire.

Feu commun. Common fire. A fire produced by the mixture of powder and charcoal.

Feu mort. Dead light; dead fire. See page 485.

Feux de Gouvernement. State or public fire-works.

Filagere. The thread used for strangling.

Flamboyante. A species of rocket, which, from its effects in the atmosphere, is called the comet. [586]

Foudres. Thunderbolts, lightnings; in pyrotechny, the preparations, used to imitate thunderbolts; thunder powder.

Foudroyante. A case or rocket, which imitates thunder: Fougette. (See Baguette à feu.)

Fougasse. A small mine.

Fougues. Small rockets, without sticks.

Fourneau. Furnace. A mine. The chamber of a mine.

Fusée. Any sort of composition, put in a cylindrical case. In English, however, the term fuse is confined to particular compositions; as fuse for bombs, howitzes and grenades.

Fusées chevelues. Bearded rockets. See page 424.

Fusées d'amorce. Priming fuses.

Fusées volantes. Flying or sky-rockets.

Garniture. Garniture, furniture, embellishment, ornament: in pyrotechny the small fire-works, such as stars, serpents, marrons, &c. which are put into the pots of sky-rockets, into fire-pots, &c. The petards with which the pots of incendiary rockets are charged.

Gargousse. Cartouch, cartridge. It more properly means the sack, or bag for containing the charge of powder for a cannon, *when the bag is made of paper or parchment*; but when it is made of serge, it is called sachet. (See sachet.)

Girandole. Chandelier: in pyrotechny, two or more horizontal wheels, placed above one another and turning upon the same vertical axis. When of different sizes, these wheels resemble a chandelier; hence the name.

Girande. A cluster, or assemblage, of several hundreds or thousands of rockets, thrown up at the same time. Several clusters may be arranged in different boxes, and fired separately with regular intervals, or all at the same time. In either case, the assemblage is called a Girande. It is also called *gerbe*. See gerbe, and page 455.

Gerbe. Sheaf; a fire-jet case, charged with the composition for brilliant or Chinese fire, which is thrown out in such a manner as to represent a luminous sheaf. A group of fuses, or fire-jets, fired at the same time, also bears this name: A Chinese tree.

Grenage. The graining of gunpowder.

Glace Inflammable. Inflammable ice.

Lissage. The glazing of gunpowder.

Lardon. This term generally signifies all those small fire-works, which are sold in shops; such as serpents, squibs, crackers, &c.; [587]
but, more strictly, it signifies the largest, and strongest kind of serpents.

Lance à feu. Squib, fire-lance, or simply lance.

Lance de feu. A species of lance used by garrisons against scaling parties.

Lance à feu puant. Stink-fire lances, used by miners.

Lanterne. Literally lantern; a copper spoon, or ladle, used instead of cartridges for conveying the charge to the bottom of a cannon. They were formerly used in all pieces, but at present only in siege and garrison pieces.

Larmes à feu. Fire-tears, or drops; tears.

Lianes des Marais. A species of convolvulus; bind weed.

Marquise. Marchioness; a rocket having an interior diameter of two-thirds of an inch. When it has the diameter of five-sixths of an inch, it is called a double marquise.

Machine Infernale. Infernal machine.

Mosaique. Mosaic; the imitation of mosaic in fire-works.

Meurtrières. Literally Murderers: applied to those modifications of any species of fire-work, which fit them for the destruction of an enemy.

Partement. See fusée de partement.

Partement, fusées de. Sky-rockets, having an interior diameter of half of an inch. When the diameter of the rocket is only one-third of an inch, it is called *Petit Partement*.

Paratonnerre. Lightning rod.

Patte d'oie. A goose's foot: a kind of fire-works, so called from their resemblance to a goose's foot:—A term in mining to signify three small branches, which run out at the extremity of a gallery.

Pots à feu. Fire pots: they are thrown upon the enemy in the attack or defence of places; but are not so much used as fire-balls and carcasses: pot granado.

Pots des Brins. See page 364.

Pots de Chasse. See page 360.

Pots des Saucissons. The pots of saucissons.

Pluie d'or. Golden rain.

Poudre d'or. Gold powder.

Porte feu. Port-fire; also a leader.

Pièce pyrique. This name is generally given to all kinds of fire-works; composed of fixed and turning pieces, which would require a great number of words to describe separately; but it is more particularly given to a kind of mechanical contrivance of fixed and turning wheels, one of which communicates fire to the other, and vice versa. See page 412.

Ricochet. A bound, leap, or skip, such as a flat piece of stone makes, when thrown obliquely along the surface of a pond: The [588]
bounds, which are made by balls, fired with small charges, and under angles of little elevation, either upon land, or water: Fire-works, which leap or roll on the ground.

Roche à feu. Fire-stone.

Séchage. The process of drying either gunpowder or fire-works.

Saucisson. Sausage: in pyrotechny, a sort of fuse or petard, still larger than the lardon:—A cylindrical bag of powder to convey fire to a mine:—A bundle of sticks, used in fortification.

Soleil montant. Rising sun.

Sachet. Satchel: the bag or sack of a cannon cartridge, when made of serge.

Tourteaux. Links: see page 500.

Tourteaux goudronnés. Tarred links.

Tourbillon. Whirlwind, vortex: a table wheel.

Tourbillon de feu. A whirlwind of fire; fire-wheels, which rise or fall in the air; also called rising or falling suns.

FOOTNOTES:

[1] We deem an outline of the nature and effects of caloric as, in some respects, indispensably necessary; for caloric, it is to be observed, is an agent, whose effects are recognised in every species of fire-work.

[2] That the terms *hot and cold* are relative, as to our feelings, fact and observations abundantly prove. Dr. Fordyce (*Phil. Trans.* vol. 64 & 65) heated a room by stoves to two hundred and sixty degrees of Fahrenheit's scale, and remained in it for some time without great inconvenience. But different metallic substances, as the lock of the door, his watch and keys lying on the table, could not be touched without burning him: and although an egg became hard, and his pulse beat one hundred and thirty-nine per minute, yet a thermometer placed in his mouth was only two or three degrees hotter than common. He perspired profusely. Jenning's steam bath will heat the air in contact with the naked body from one hundred to one hundred and twenty degrees, a *heat* sufficient, as it is in the aqueous vapour, resulting from the combustion of alcohol or strong spirit, to induce a copious diaphoresis in less than half an hour. Having tried this experiment in several cases, I can only say, that I effected in the course of an hour, what, under ordinary circumstances, would require twelve or twenty-four, viz. a *copious perspiration*, and that too without the exhibition of sudorifics. The practice is an old one not only among civilized nations, but aborigines. It is nevertheless worthy of adoption.

Frozen mercury cannot be touched without experiencing a sensation similar to that of an ignited body, although directly opposite to heat.

[3] A writer of the last century remarks, that "he cannot possibly admit the sun to possess the least manner of heat, but rather to contain the capabilities of fire, like a stick, or a flint, though with a faculty of expressing it, by its own action, which the others have not. I imagine its beams not to be hot, in their rectilineal direction, but productive of this effect, from reflection, only. If the rays of the sun were fire, in the first instance, those consequences would naturally follow, that our friend and correspondent *Tria* so well describes in his *Day of Judgment,* 'The rivers were dried up, and liquid ore supplied their burning channels. The clouds were turned to fire, and shot through the astonished sky. The air was flame, and breathing was no more. The firmament was melted down, and rained its sulphur o'er the prostrate globe, &c.' The sun emanates light only, in the direct line, but owes its heat to reflection. We feel it, therefore, more intensely, in a valley, than on a hill. Why are the Alps and Pyrennees crowned with eternal frosts, while the shepherds, with their flocks, are sheltering their scorching heads from the heat of the sun, at the foot of them? Why do the upper regions of the air shower down their hail and snow, to be thawed and melted here below? Why shall a *lens* of ice receive the rays above, so coldly, and transmit them so intensely hot, beneath? Why is it warmer, in summer, though the sun is farther off, than in winter, when 'tis so much nearer to us? Because of our situation, in regard to it, only. In the first case the rays are vertical, in others lateral; and perpendicular reflections are stronger, than oblique ones. We judge of fire above, from what we feel below, &c."

The summit of Ætna, notwithstanding the fire of the volcano, is covered almost all the year with snow. Fazello, speaking of this says, that "this region extends nearly twelve miles; and, even in summer, is almost perpetually covered with snow, and extremely cold: which is the more wonderful as the summit continually produces, nourishes, and pours forth flames amid the ice and snow with which it is enveloped." Solinus says, "Ætna, in a wonderful manner, exhibits snows mixed with fires; and retains every appearance of the severest winter, amid her vast conflagrations."

Silius Italicus, and Claudian, and Pindar, who lived 500 years before the Christian era, bear testimony to the antiquity of this fact.

'Where burning Ætna, towering, threats the skies,
Mid flames and ice the lofty rocks arise,
The fire amid eternal winter glows,
And the warm ashes hide the hoary snows.'

Silius Italicus, from the Latin.

'Amid the fires accumulates the snow,
And frost remains where burning ashes glow;
O'er ice eternal sweep th' inactive flames,
And winter, spite of fire, the region claims.'

Claudian, from the Latin.

----'Snowy Ætna, nurse of endless frost,
The mighty prop of heaven.'

Pindar, from the Greek.

The height of Ætna is generally estimated at 11,000 feet above the sea. In 1755, it issued out a torrent, not of mud, as was supposed, but of snow and ice melted by the lava. The same thing happened at the volcano of Cargarossa in South America.

The celebrated Herschel, (Phil. Trans. 1801, and Nich. Jour. 1. 13), in considering the construction of the sun, infers it to be a habitable globe more magnificent than our earth, or other planets, and that its lucid substance is not a liquid nor an elastic fluid; but that it exists in the manner of luminous clouds, swimming in the transparent atmosphere of the sun, or rather of lucid decompositions taking place within that atmosphere. The *Philosophical Transactions*, 1795, p. 72, also contains remarks on this lucid matter. Having rejected the old terms of spots, nuclei, penumbræ, and luculi, he has substituted those of openings, shallows, ridges, nodules, corrugations, indentations, and pores. The openings are places where the luminous solar clouds are removed, which he thinks are produced by a wind or gas from the sun's body. Shallows are depressions below the luminous clouds, and are caused by the propelling gas, which produces the openings. They are tufted like masses of clouds. Ridges are elevations of the luminous clouds. The length of one of the longest was found to be 75,000 miles. They generally surround the openings. Herschel thinks it probable, from appearances, that the luminous matter is disturbed at top by the transparent elastic fluid, which issues from the openings. Nodules are small elevations of the luminous matter. Corrugations are smaller elevations and depressions of the same matter. Indentations are the dark places of corrugations. That they are not much depressed, is deduced from their visibility near the margin of the sun. They are of the same nature as shallows, and of different sizes. Pores are the low places of indentations. The doctor is of opinion, that the phenomena before described could not appear, if the shining matter were a liquid; because, by the laws of hydrostatics, the openings, shallows, indentations, and pores would be filled up. Still less could these phenomena exist with the supposition of elastic fluidity. The shining matter, he concludes, must exist in the manner of empyreal luminous or phosphoric clouds. The planetary atmosphere of the sun, its great height, its density, as inferred from the power of gravitation, which is known to be twenty-seven times stronger at the sun's surface than with us, and other subjects are also discussed. He supposes the gas to pass from the sun itself upwards to the region of the clouds, so as to generate pores, corrugations, &c. He concludes finally, that if this view of the solar appearances be well founded, there will be no difficulty in ascertaining the actual state of the sun with regard to its energy in giving heat and light.

In a paper on the "*Construction of the Heavens*," the doctor thinks it probable, that the great stratum called the milky way is that in which the sun is placed, though perhaps not in the centre of its thickness. The celebrated astronomer Lalande supposes the *spots* before mentioned to be parts of the solid body of the sun, but admits not a luminous atmosphere, but a luminous ocean. For the observations of Dr. Young, see his *Natural Philosophy*, and of sir *Isaac Newton*, his *Principia*, &c. Consult also Biot.

Sir Isaac Newton has asserted, according to Nicholson, (*British Encyclopedia*) "that the density of the sun's heat, which is proportioned to his light, is seven times as great in Mercury as with us, and that water there would be all carried off in the shape of steam, for, he found, by experiments with the thermometer, that a heat seven times greater than that of the sun's beams in summer will serve to make water boil." That fixed stars are of the same nature as the sun, since they agree with it in several particulars, as in the property of emitting light continually, and in retaining constantly their relative situation with but little variation, is generally admitted. They are supposed also to emit heat as well as light. The sun is, therefore, considered a fixed star comparatively near us, and the fixed stars, which seem as centres to other systems of worlds, as suns at immense distances from us. Taking the distance of the sun from us to be, as is found by calculation, 95,000,000 miles, we may infer, that every thing must be scorched up at its surface; but this question is put at rest, if we consider that the sun's rays act on a calorific medium, as the cause of changing quiescent into distributable heat. May not light itself, by some process unknown to us, produce calorific rays? That heat and light are both material, and possess some properties in common, that for instance, of reflection and refraction, are facts well known; but to account for the peculiar agency of light, if it be admitted, is a problem, which, perhaps, will never be settled?

[4] *Fire* must have been a very potent instrument in the hands of Hannibal, if we believe what Livy and Pliny assert respecting the means he employed in crossing the Alps, which took him fifteen days, after meeting with almost every obstacle. Livy tells us, that Hannibal softened the rock by pouring vinegar upon it, after it had first been made hot under flaming piles of huge trees! M. Rollin quotes Pliny to prove that vinegar has the *force* to break stones and rocks!

This story is altogether fabulous; for in the first place, had he vinegar sufficient; and, secondly, who ever knew that vinegar had force, or even the power of dissolving primitive rocks, such as granite or gneiss; and, thirdly, if it possessed the power stated by Pliny, and had he a sufficient quantity, where was his wood? For Polybius assures us, that Hannibal had no wood to make a fire with, and that there was not a tree in the place, where he then was, nor near it. That Hannibal passed over the Alps into Italy, and at an inclement season of the year, is certain, and that it was one of the greatest achievements that an enterprising commander ever accomplished, is generally admitted.

[5] Respiration is a mechanical and chemical process, and consists in alternate inhalation and exhalation, which, in consequence of the oxygen gas in the air, effects a change in the venous blood that enters the lungs from the pulmonary artery. Now as this blood is charged with carbon, to which its dark purple colour is owing, it is carried off in union with oxygen in the form of carbonic acid. Hence carbonic acid is produced in respiration and the venous blood is changed into the bright red arterial blood. A common sized man will consume about 46 thousand cubic inches of oxygen *per diem*; equivalent to 125 cubic feet of air, and makes about twenty respirations in a minute, or for every seven pulsations breathes twice.

[6] Of this fact the reader may form some idea, when he is informed, that Newton's Principia, Biot's *Physique*, *Hatchette*, *Gregory*, &c. &c. form the class books of instruction, works which require deep study, and profound thought.

[7] Various applications of chemistry, among which that to gunpowder, drew my attention at an early period of life. In the Aurora of Philad. I published a series of essays on this and other subjects, which, from the letters received at that time, I flatter myself tended in some degree to advance the manufacturing interest in the United States; an interest, which is connected with our individual and national prosperity, and the *permanent* and *practical* independence of the republic. These essays were entitled "Application of chemistry to the arts and manufactures," and published in 1808. I have since enlarged that plan in the Artist's Manual, &c. 2 vols. 8vo. While noticing this subject we may add, that, having the honour of being one of the few of the original society of Philadelphia for the promotion of National Industry, whose essays excited, as they claimed, the attention of the citizens of the United States, much is due to the indefatigable labours of some of the members of that association. We are greatly indebted to the able and masterly pen of Samuel Jackson M. D. Professor of Pharmacy in the college of Apothecaries, of Philadelphia, for many of the best essays it produced, whose disinterested motives, liberal and exalted mind, and pure patriotic feeling prompted him to the laudable undertaking; and whose essays were full, clear, and comprehensive. Viewing his talents, his worth, his merit, we may truly add, that he is not only an honour to the country which gave him birth, but an ornament to the age in which he lives. The able address of the Philadelphia Linnæan society, penned and signed by him, the late Samuel Benezet M. D., and the author, as a committee, although written many years ago, contains the principles, which are now advocated for the support and encouragement of national industry. This address was calculated, however, to promote, at the same time, the interests of Natural History.

[8] Incombustible cloth made of this substance was formerly in use, not only for domestic purposes, but, also to retain the ashes of the dead from those of the funeral pile. Cloth made of amianthus, when greased, or soiled, may be cleansed by throwing it into a bright fire. It is then restored to a dazzling white colour. Pliny, the naturalist, saw table cloths, towels, and napkins of amianthus taken from the table of a great feast, thrown into the fire, and burnt before the whole company; and by this operation, he says, they became better cleansed than if they had been washed.

Pontoppidan (*Natural History of Norway*) remarks, that he has a piece of paper made of the Norway asbestus, which, when thrown into a fierce fire, is not in the least wasted, but what is written on it totally disappears. In Norway, the stone flax is prepared by beating it in water, till the fibres separate, which are repeatedly washed, and then dried in a sieve. It is afterwards spun, observing to moisten the fingers with oil.

[9] In the year 1601, a horse, which had been taught to perform a number of tricks, was tried, as possessed by the devil, and condemned to be burnt. Joblonski affirms in his *Lexicon, &c.* that he was condemned to the flames in Lisbon. Nothing was a greater imposition on mankind than the Oracles. The imposition of causing statues to speak, as the head of Orpheus in the island of Lesbos, the Æsculapius of Alexander, &c. may be readily perceived, when Lucius relates, that, in the case of Alexander's oracle, he took instead of a pipe, the gullet of a crane, and transmitted the voice through it to the mouth of the statue! Bishop Theophilus, in the fourth century, broke to pieces the statues at Alexandria. He found some which were hollow, and placed in such a manner against a wall, that a priest could slip unperceived behind them, and speak to the ignorant populace through their mouths. Professor Beckman observes, "that the Pagan priests, like our jugglers, were afraid that their deceptions, if long practised, might be discovered. They considered it, therefore, as more secure to deliver the answers themselves, or cause them to be delivered by women instructed for that purpose, or by writings, or by any other means. We read, nevertheless, that idols, and the images of saints once spoke; for at present the latter will not venture to open their mouths. If their votaries ever really heard a voice proceed from the statue, it may have been produced in the before-mentioned manner." We think, that a contrivance, similar to the bull of Phalaris, in the place of hollow statues, would furnish a good reality.

The oracle of Apollo at Delphos, says Percy, having been consulted about the manner of stopping a plague then raging at Athens, returned for answer, that the plague should cease, when Apollo's altar, which was cubical, should be doubled. The philosophers of Athens immediately applied themselves to discover the duplicature of the cube, which henceforward was called the Delian Problem, and continued for a long time to be an object of the keenest pursuit to the curious. The first who discovered the solution was Hippocrates Chias.

[10] Signs in the heavens were believed by the ancients; and even with regard to natural occurrences, they produced melancholy and awful reflections. Augustus Cæsar was so afraid of thunder and lightning, that, though he carried about him a skin of a sea-calf, which was in those days accounted an excellent *paratonnerre*, yet, whenever he saw a tempest coming, he used to fly for refuge to some vaulted place underground. Caius Caligula rivalled Augustus in this respect; for Suetonius observes, that when it thundered, he would wrap his head in some covering; or, if in bed, leap out of bed and hide himself under it.

[11] By means of a solar microscope, I have seen the animalcula in vinegar several inches in length, some of which had the appearance of eels, and in motion.

[12] There is a sort of mountebanks not only in Ceylon, but in many other parts of the East Indies, who make a trade of taming serpents, which they pretend to do by *incantation*, and carry them about by way of show. I once witnessed the *taming* of a serpent, a black snake about four feet in length, by an English gentleman at Harrowgate, in the neighbourhood of Philadelphia. He was remarkably fond of snakes for *pets*, and had them not only to follow him, but also to be about in the house among his children, who became familiar with them; and, although young myself, I observed that they were passive and obedient, and knew by instinct their *dependence* on his favours.

The *incantation*, that Mr. C—d used, was simply this: The snake was put into a room, and Mr. C. took in with him a bowl of milk, and the door was closed. Having taken off his coat, and put on a glove, he proceeded towards his antagonist, who, being prepared for the attack, made at him, but was repulsed; a second and third attempt was made, but he was thrown back as before. The snake finding himself *mastered*, did not think proper to renew the combat, and crawled into the corner panting for breath. Mr. C. now took some of the milk and placed it before him, without the least fear, and after he had finished it, he gave him more. This he continued until the snake was satisfied. After which, to the astonishment of all who witnessed the experiment, he took it up, and having wound itself round his arm, he carried it home. Whether he examined his mouth, destroyed the fang, or the vesicular sac, (if it had one), I do not recollect; but this same snake was afterwards a *great favorite*, and would follow his master like a dog, and even play about with the children. I mention this incident to show, that serpents possess considerable instinct, and are, like domestic animals, conscious of their friends and benefactors, and may be trained in the same manner.

In the island of Ceylon, there is a small animal called the Indian Ichneumon, which destroys snakes in abundance; but, what is remarkable, he only attacks them in an open place, where he has an opportunity of running to a certain herb, which he knows instinctively to be an antidote against the poison of the bite, if he should happen to receive one. The monkeys of India, knowing the malignity of snakes, make a business of hunting and destroying them at night; after seizing them, they carry them to a stone, and beat their heads until the fangs are destroyed, and then exultingly throw them in the air. The poison is lodged in two small vesicles, and when the animal bites they are squeezed, and the poison is forced through the fangs into the wound. If the vesicles be extracted, or the liquid prevented from flowing into the wound, the bite is harmless.

[13] The great cave on Crooked Creek, was discovered about the year 1800, by Mr. Baker. He proceeded only a small distance into it. On the succeeding day, he brought his wife, and two or three children to explore it. He carried a torch, which he accidentally dropped. During two days and two nights, this family wandered in total darkness, though sometimes within the hearing of a cataract, when, fortunately, Mrs. Baker, in attempting to support herself on a rock, perceived that it was wet. She conjectured that it was caused by the mud, which they had brought in upon their feet. Baker immediately ascended the rock, and saw the light of day.

[14] There can be no doubt, as we observed, that miasma is variously compounded; but there is no certainty, as to what it is composed of, or what modifications it may assume. That it is, however, a chemical combination, and may be decomposed, and destroyed by chemical agents, appears equally true. The disinfecting apparatus of Morveau, sundry fumigations, &c. are used for this purpose. The proper destroyers of these gaseous poisons, are nitric acid vapour, muriatic acid, and chlorine. The two last are the most effectual. How would chlorine gas act on prussine gas, or cyanogen? Would it not deprive it of its carbon, forming the chlorocarbonic acid, and thus set the azote at liberty, or might it not unite with the nitrogen, and form a chloride of nitrogen? Suppose the cyanogen to be combined with

hydrogen, the decomposition of the hydrocyanic acid would be effected first by the chlorine combining with the hydrogen, forming muriatic acid, and secondly with the carbon, forming chlorocarbonic acid. If hydrogen, in any other combination, should exist, would not the chlorine in every case decompose such compound, and thereby destroy its deletereous properties by taking away its hydrogen? I think it will be proved, some time or other, that the miasma, which produces yellow fever, is a compound of carbon and azote, with hydrogen, acting under particular circumstances and conditions.

Various other means, besides those we have stated, have been recommended to prevent the effect of contagious matter, such as odoriferous substances, preparations of camphor, aromatic vinegar, called the vinegar of four thieves, &c. but all come short of the effect, and may be regarded as nostrums. The vapour of burning sulphur, or sulphurous acid, is used in the East against the plague; but this is inferior to either of the other acids, of which chlorine, formerly called oxymuriatic acid, is to be preferred. A mixture of four parts of common salt, one of black oxide of manganese, and two of sulphuric acid, or muriatic acid poured on manganese or red lead, will generate chlorine gas. Morveau's disinfecting apparatus contains the above mixture. The free use of this gas in apartments, &c. &c. cannot be too strongly recommended.

[15] On this subject, see a paper by Mr. Howard in the English Philosophical Transactions, for 1802, and by Vauquelin in the *Journal des Mines*, No. 76.

[16] For the history of saltpetre, the reader may consult, with advantage, Beckman's *History of Inventions*.

[17] "The affinity of charcoal for oxygen is so considerable, that instances have been known of its undergoing spontaneous combustion by simple contact with the air. An occurrence of this kind took place at the powder mills of Essonne, in France. (An. de Chim. 36, p, 93.) A large quantity of recently burnt charcoal had been ground in the usual manner, and was deposited in a large receptacle for future use; some days after, the door of the magazine being opened, in order to remove a part of the charcoal, an extraordinary heat was perceived, and immediately a train of fire was observed, spreading over the surface of the charcoal, and which was not extinguished without much difficulty." Aikin's *Chemical Dictionary*, vol. i, p. 238.

[18] This apparatus will heat the air in a room to 84° in the coldest weather, and is particularly calculated for cotton mills, and other purposes. His invention is considered to be a judicious application of a well known principle. Count Rumford heated rooms in a similar manner by steam, which may be seen in the Repository of Arts vol. xv, p. 186. A Mr. Green of Wandsworth, England, obtained a patent in 1793, for warming rooms, by heated air, heated with steam. Steam pipes, however, are now in use in the United States. In consequence of the great quantity of latent caloric in steam (about 1000 degrees) which is given out as free heat in its condensation, this principle has been judiciously applied not only to the warming of apartments, but to the boiling of dye kettles, and other purposes. See an account of Woolf's steam apparatus, subsequent pages.

[19] The principal workmen they describe, are a master powderer, a master carpenter, a master cooper, a head boy, (*Garçon*) employed in the pulverization of the substances, another for the fabrication of charcoal, one for every mill, besides workmen for aiding in the charring, for the mill, &c.

[20] *Traité sur l'art de fabriquer la poudre à canon*, par MM. Bottée et Riffault may be consulted.

[21] This is a mixed gas, composed of carburetted hydrogen, and carbonic oxide.

[22] His son wrote a work, having the following title: "Thoughts concerning that last and most perfect work of nature, and chief of metals, gold, its wonderful properties, generation, affection, effects, and fitness for the operations of art; illustrated by experiments," from the Latin. Hamburgh, 1685, 8vo.

[23] In the year 1777, Lord Mahon, afterwards Earl Stanhope, exhibited some experiments, to prove the certain, cheap, and simple method of securing houses against fire, without making use of either brick, stones, tiles, iron, or any such incombustible material. A building, entirely constructed of wood, and of lath and plaster, with a very small quantity of sand laid under the floors, which were of deal, was attempted to be set on fire by means of a large quantity of dry burning fuel, faggots, straw, pitch and other combustibles, with which the lower room of this building was filled, from the floor to the ceiling almost in every part. The whole mass of fire burnt out without doing the least damage. Those who were in the next story, directly over the conflagration, did not perceive the least degree of heat. A wooden stair case, made in the same manner, also resisted the flames.

[24] The imitation of thunder, rain, hail, &c. for theatrical purposes, is variously performed. Mr. Nicholson, in describing an exhibition he saw in London, (See Phantasmagoria,) remarks, that thunder was imitated very accurately, by means of sheet iron plates. The noise of rain and hail may be imitated by procuring a thin hollow cylinder of wood, about ten inches wide, and two or three feet long; dividing its inside into five equal parts, by boards, placed obliquely, of five or six inches, observing to let there be between them and the wooden circle, a space of about one-sixth of an inch, and then introducing about four or five pounds of shot, and turning it upside down. The shot will pass through the various partitions, and resemble the fall of rain. If large shot be used, the noise will be increased, and resemble hail.

According to the *Dictionnaire de l'Industrie*, (article *Tonnerre artificiel*), thunder is imitated, by making a hexangular case of sheet iron, and putting stones or small balls into it, and rolling it more or less swiftly. Another mode is to roll cannon balls on a floor, on which is loosely nailed, at certain distances apart, strips of wood or lath. A clap of thunder is imitated by letting fall on each other, very suddenly, a number of sheet iron plates, having them previously suspended, or strung on a cord, which must be vertical. In 1784, M. Michael, (*Journal de Paris*) made a machine, which imitated thunder, so completely, as either to produce the most violent clap, or the most distant rumbling, with intermediate variations. Parchment, stretched over a frame, has likewise, been used for the same purpose. The distant thunder may be represented in this manner; but, to produce a sharp noise, or clap, something more is required.

[25] Whoever walked the streets of Rome, at night, without a lantern, was under the necessity of creeping home in perfect darkness, and in great danger, like Alexis, in Athenæus. Antioch, Rome, and a few other cities had public lanterns in streets which were most frequented. Libanus, who lived in the beginning of the fourth century, in praising his native city, Antioch, says, that "the light of the sun is succeeded by other lights, which are far superior to the lamps lighted by the Egyptians on the festival of Minerva of Sais. The night differs from the day only in the appearance of the light. With regard to labour and employment, every thing goes on well. Some work continually; but others laugh and amuse themselves with singing." In another passage, in the oration to Ellibichus, the same author tells us, that the ropes from which the lamps that ornamented the city were suspended, had been cut by some riotous soldiers, not far from a bath. "Proceeding," says he "to a bath, not far off, they cut, with their swords, the ropes, from which were suspended the lamps that afforded light in the night-time, to show that the ornaments of the city ought to give way to them." Jerome also makes it appear, that Antioch was lighted with lamps; for, he remarks, that, in an altercation between a Luciferan and an Orthodox, an adherent to the schismatic Lucifer disputed in the street with a true believer, till the streets were lighted, when the listening crowd departed, and that they spat in each other's face, and retired. Edessa, in Syria, was lighted in the fifth century, and the governor of that city ordered, that a part of the oil, which was before given to the churches and monasteries, should be burnt in the streets. While illuminations were considered emblematical of public rejoicing, the reverse was considered a token of public sorrow; to denote which, on occasions of great misfortune, it was customary not to light the streets. Valerius quotes a passage of Libanius in proof of this assertion, where it is said, that the people of Antioch, in order to mitigate the anger of the emperor, bethought themselves of lighting either no lamps, or a very small number. In 1588, Paris was lighted up with *falots*, or vases filled with pitch, rosin, and other combustibles. The Abbé Laudati let out torches and lanterns in Paris, in 1662.

[26] In the *Archives des Découvertes*, &c. several new lamps are described, as follows: A lamp, invented by count Rumford noticed by him in a memoir on the light of lamps, and the means of increasing it; a new lamp with a double current of air, by Lenormand; star lamp by Bordier; reverberatory lamp for towns, &c. by de Thirville and Bordier; a modified thermo-lamp by Winsor; a new lamp by Baswell; the economical lamp of inflammable gas, by Murdoc, and economical lamp by Lambertin; the cupola lamp by Vivien; new lamp with a porcelain reflector by L'Ange; the hydrodynamic and chemical lamp, by L'Ange; the portable lamp by count Rumford; horizontal reflectors, with parabolic surfaces in revolving, and parabolic reflectors, simple and double, by Argand and Bordier Marcet; improved lamp, by Marcet; thermo-lamp by Sobolewsky and Horrer; watch lamp by Dumouceau; various lamps, with carburetted hydrogen; the polyflame lamp, of Rumford; the curved lamp by Connain; the enamellers' lamp, and hydropneumatic lamp by Tilley, &c. Davy's safety lamp is described in Brande's *Chemistry*, and in Ure's *Chemical Dictionary*. See *Aphlogistic lamp.*

[27] A solution of muriate of copper gives a green, of sulphate of copper and muriate of soda, a light green; of sulphate of copper, and ammonia in excess, a deep blue; a decoction of cochineal, or of brazil wood, and a solution of tin, a deep red or scarlet, &c. These solutions may be used for that purpose.

[28] Having mentioned in this article, the use of candles for illumination, it may not be improper to observe, that they were also employed for cooking, as will appear from the following incident. In 1172, Henry II, of France, collected together the *feigners* of Languedoc, in order to mediate a peace between the count of Toulouse, and the king of Arragon, at which Guillaume Gros de Martel gave a sumptuous dinner, the viands being all cooked by the flame of *wax tapers*!

[29] In the *Archives des Découvertes et des Inventiones Nouvelles*, are several new inventions and improvements, relative to fire arms, among which are the following: New fire arms, invented by Pauly, which are said to carry a ball double the distance of ordinary muskets, and to possess other advantages; for a particular account of which, the reader is referred to the *Bulletin de la Société d'Encouragement*, No. 99; another kind, by MM. Pauly and Prelat, which primes itself, &c. and goes off by percussion; an improvement in guns by using platina bushing, &c. by Lepage, with the use of priming,

composed of powder made of chlorate of potassa in lieu of saltpetre; the improvement of Regnier in guns; improvement in the use of platina for guns, to be used with the oxymuriated powder, by Debourbet; a gun which fires fourteen times in succession without new loading, by M. Henri; an improved carabine, which is discharged by percussion, by M. Gosset, &c.

[30] Since 1792, musket-balls are seven-twelfths of an inch in diameter, and twenty go to the pound instead of eighteen. In the British service, eleven bullets to the pound are used for the proof of muskets, and fourteen in the pound, or twenty-nine in two pounds, for service; seventeen for the proof of carbines, and twenty for service; and twenty-eight in the pound, for the proof of pistols, and thirty four for service. The diameter of musket-bullets differs but one-fiftieth part from that of the musket bore; for if the shot but just rolls into the barrel, it is sufficient.

The diameter of any bullet is found, by dividing 1.6706 by the cube root of the number, which shows how many of them make a pound, or it may be done in a shorter way. From the logarithm .2228756 of 1.6706, subtract continually the third part of the logarithm of the number of bullets in the pound, and the difference will be the logarithm of the diameter required. Thus the diameter of a bullet, whereof twelve weigh a pound, is found by subtracting .3597270, a third part of the logarithm of 12, from the given logarithm .2228756; or, when the logarithm is less than the former, a unit must be added, so as to have 1.2228756, and the difference .8631486 will be the logarithm of the diameter sought, which is .7297 inches; observing that the number found will always be a decimal, when the logarithm, which is to be subtracted is greater than that of the pound; because the divisor is greater than the dividend in this case.

Hence, from the specific gravity of lead, the diameter of any bullet may be found from its given weight: for, since a cube foot weighs 11325 ounces, and 678 is to 355, as the cube 1728 of a foot, or 12 inches, is the content of the sphere; which therefore is, 5929.7 is to 16 ounces, or a pound, as the cube 1728 is to the cube of the diameter of a sphere which weighs a pound; which cube therefore is 4.66263, and its root 1.6706 inches, the diameter sought.

[31] A term used in the French Navy, to signify a wooden case or box, in which cartridges are brought out of the powder-magazine for the purpose of serving the guns; also a spoon or ladle, made of copper, and fixed to a long pole, which serves to convey gunpowder into a piece of ordnance.

[32] If sugar of lead cannot be had, and a substitute is required which in fact is the same, we may dissolve white lead in vinegar, until the latter is saturated. This may be used with water in the same manner, using, however, more of it as it is in solution.

[33] Lee's adventure, just related, brings to mind another, by a man of same name, not, however, with a submarine torpedo, or any thing of that kind; but with a *sublunar* aerostatic vessel, made about two or three years ago, at Camden, opposite Philadelphia. This was a balloon of an oblong shape, intended to float in the air like a ship on water, and furnished with oars or wings. It was filled with hydrogen gas. The object was to direct it, (a desideratum in aerostation), like a vessel on water; but the aeronaut, having arose in his car to the height of a lombardy poplar, which came in contact with it, and judging a retreat was preferable, leaped on a limb, where he had the misfortune to be caught by the seat of his pantaloons, and appeared, as it were, suspended between heaven and earth, to the no small diversion of thousands of spectators. The balloon ascended to some height, and then turned, throwing out his sand bags, &c. which, in the city, were taken for the unfortunate aeronaut, and produced, of course, a contrary feeling. Lee called on me the next day, and, in explanation of the cause, observed, that, when he ascended to the height mentioned, he found the centre of gravity was shifting, and thought it prudent not to venture. I observed, that it was well he changed his gravity, but was sorry to find, that he had transferred his centre a posteriori.

[34] A friend, who was a prisoner on board of Hardy's ship, very facetiously observed, such was the dread of torpedoes by the British, that they were literally afraid of *eating a potato, lest it should contain a torpedo*!

[35] We are informed, that some rockets, which were made at the U. S. Arsenal at Troy, were charged with the usual rocket composition, and a small portion of quicklime, in consequence of which their power was greatly augmented; a useful hint for their improvement.

[36] Star composition:—meal-powder 5 parts, saltpetre 16 parts, sulphur 8 parts, antimony 2 parts.

[37] Four inches more likely.

[38] General Lallemand (Treatise on Artillery, vol. i, p. 26,) observes, that the Congreve rocket is thirty inches in length, and three and a half inches in diameter; that a part of its charge consists of fire stone and small grenades; that their range is equal to a long gun, but their direction is very uncertain; so much so as to render them of little service, except to set fire to objects with extensive surfaces; and that they will not pierce through solid buildings, and in battle are at best only fit to frighten horses.

[39] In a note to Gibbon, page 283, we read, "The naphtha, the oleum incendiarum of the history of Jerusalem (Gest. Dei per Francos, p. 1167,) the oriental fountain of James de Vitry (l. iii, c. 84,) is introduced on slight evidence and strong probability." The name by which Cinnamus call the Greek fire, corresponds with the locality where naphtha was found, between the Tigris and the Caspian sea. Pliny (Hist. Natur. ii, 109,) says, it was subservient to the revenge of Medea, and according to the etymology, naphtha was signified.

[40] The *Fougasses* and *Camouflets*, used in mining, are employed for different purposes. The fougasses are small mines, whose line of resistance is only six to six and two-thirds feet. They are used to defend large posts. Bomb fougasses are nothing more than fougasses, charged with bombs containing powder. To estimate the effects of bomb fougasses, artillerists have ascertained the exact quantity of powder contained in each kind of bomb. A bomb of eight and a half inches weighs forty-six and a half pounds; it requires four and a half pounds of powder to fill it; but one pound will burst it. The eighteen inch bomb, or *cominage*, weighs nearly five hundred and seventy-one pounds, and contains forty pounds of powder Thirteen pounds of powder will burst it. The *camouflet* is a small fougasse, made to act against the enemy's mines, to suffocate and poison their branch. The *camouflet* is also used to act against the sides of the crater of a mine that has been sprung. See *Science of War and Fortification*, vol. 2d, p. 286.

[41] The *gramme* is the French unit of weight, and is equal to the weight of a cubic centimetre of pure water; it weighs 18.84 grains, French. The kilogramme is equal to 1000 grammes. (2 lbs., 5 drachma, 49 grains, French.)

[42] Among other inventions, by this philosopher, such as the detection of the adulteration of the crown of Hiero, mentioned by Vitruvius, the cachleon or Archimedes' screw, the Helix for launching large ships, the Trispaston for drawing immense weights, Pneumatic and Hydrostatic engines, sphere, which exhibited the celestial motions;—there are two in particular, which relate to the defence of Syracuse, as well as the destruction of the enemy. Besides his burning mirrors, Polybius, Livy, and Plutarch assert, that his inventions for defence consisted of Tormenta, Balistæ, Catapults, Sagittarii, Scorpions, Cranes, &c. Archimedes died in the 143d Olympiad, 210 years before the birth of Christ.

[43] Certain plants, we have said, are made use of for this purpose. Botanists have certain rules for distinguishing poisonous plants, from those which are innocent. Professor Eaton (Manual of Botany, &c. p. 17) observes, that plants with five stamens and one pistil, with a dull coloured lurid corol, and of a nauseating sickly smell, are always poisonous; as tobacco, thorn-apple, henbane, night-shade. The degree of poisonous property diminished, when the flower is brighter coloured, and the smell, less nauseous. He also observes, that umbelliferous plants of the aquatic kind, and of a nauseating scent, are always poisonous; as water-hemlock and cow-parsley. But if they grow in dry land, and their smell is pleasant, they are not poisonous; as fennel, dill, &c. Snap dragon, foxglove, and plants, generally, with labiate corols, and seeds in capsules, are poisonous, and also those plants which exude a milky juice when broken, unless they bear compound flowers; as milk-weed and dog-bane. It is understood, also, that plants having any appendage to the calyx or corol, and eight or more stamens, are generally poisonous.

INDEX.

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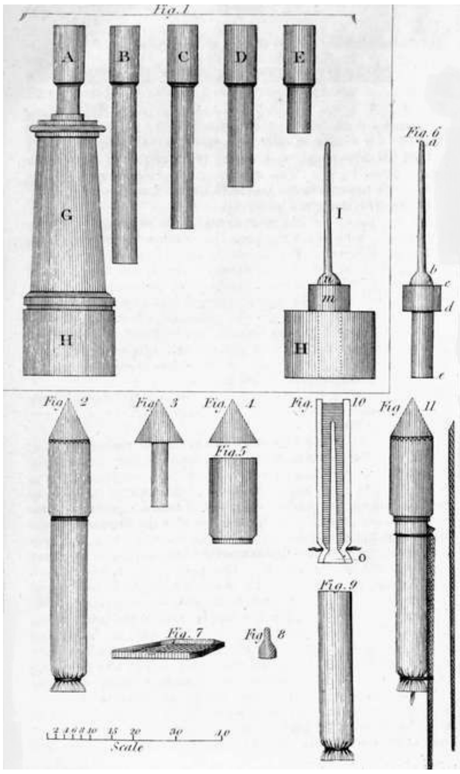

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DESCRIPTION OF THE PLATE. [611]

Fig. 1.—A. is the entering rammer or driver. It is bored in such a manner, that the whole of the broach, or piercer above the nipple, n, may be admitted. The cavity of the bore is cylindrical, and equal in diameter to that of the foot of the broach. This driver serves to fix the rocket case, over the broach, in the mould G, and to form the cup, o, fig. 10, for receiving the priming.

B. is the driver of the first charge. It is bored in such a manner, as to admit the broach to within two-fifths of the interior diameter of the case, from its base. Its bore is cylindrical, and has the diameter of the broach, at the height of two-fifths the interior diameter of the case.

C. is the driver of the second charge, and admits the broach two-thirds of its length; the diameter of its bore being the same as that of the broach, at one-third of its height.

D. is the driver of the third charge, and admits one-third of the broach; the diameter of the bore being that of the broach, at two-thirds of its height.

E. is the last driver, and is solid; the charge being above the summit of the broach. See page 231.

Fig. 1. and Fig. 6.

Fig. 1. (cont.) and Fig. 6.—The broach or piercer I, fig. 1, (a section of which is represented in fig. 6), is a truncated cone, having a hemispherical summit. The cone is the part from a to b, fig. 6. The diameter of the base of the cone at b, ought to be two-fifths of the interior diameter of the case, and the diameter at the summit, one-fifth, which is also the diameter of the small hemisphere at the top. The height from b to a, ought to be seven times the interior diameter of the case, or 17.5 times the diameter of the base b. The part n, fig. 1, and from b to c, fig. 6, is rounded. Its diameter ought to be that of the interior of the case, and its height, seven-tenths of that diameter. This is called the nipple, and is the part, which gives shape to the cup o, fig. 10. The part m, fig. 1, and from c to d, fig. 6, is cylindrical, and may be made of any height or diameter, provided the latter is not less than that of the cone. It is generally one-twentieth more than the exterior diameter. This part ought to penetrate into the bottom of the charging mould, G, fig. 1, and fit closely, so as to be firm. The part from d to e, fig. 6, is the blade or tongue of the broach. It is rectangular, and enters into the block H, fig. 1, where it is firmly fixed. The size of this part is arbitrary, as well as that of the block H, fig. 1. [612]

Fig. 2.—The Rocket finished.

Fig. 3.—Conical Mandril or Former, for the head of the Rocket.

Figs. 4 & 5.—Head of the Rocket and *Pot de fusée*.

Figs. 7 & 8.—Mealing table and Mullar.

Fig. 9.—The Rocket case choaked, and prepared for charging.

Fig. 10.—Section of the Rocket, after charging.

Fig. 11.—The Rocket with its stick. For want of room, the stick is represented in two pieces.

TRANSCRIBER'S NOTE

For consistency and clarity, a space (when absent) has been placed between the number and the unit of weight lb. and lbs. giving for example '21 lbs.' in place of '21lbs.'

Fractions, usually in the form '14 3-4' in the original text, have been converted to the form '14$^3/_4$' in this etext.

Also, in a few larger tables with italic styling on some text, this italic styling has been removed, for consistency with the .txt version. In a few cases a word has been abbreviated to conserve table space: cal. = caliber; diam. = diameter.

Some instances of *Tome* in French citations have been changed to Tome (no italic), for consistency.

Some accents and spelling in French citations have been corrected.

For consistency, instances of 'fireworks' and 'fire works' have been changed to the predominant form 'fire-works'.

Obvious typographical errors and punctuation errors have been corrected after careful comparison with other occurrences within the text and consultation of external sources.

Except for those changes noted above and below, misspelling in the text, and inconsistent or archaic usage, have been retained. For example: meal-powder, meal powder; quick-match, quick match, quickmatch; siege, seige; musket, musquet; hazle; dodecaedron; deposite; inclose.

Pg xiv. 'Meutrieres' replaced by 'Meurtrières'.
Pg xiv. 'Siemienowick' replaced by 'Siemienowicz'.
Pg xviii. 'accesssion' replaced by 'accession'.
Pg xxv. 'alchohol' replaced by 'alcohol'.
Pg xxxi. The references to 40° have been retained (should be 4°).
Pg xxxv. 'indispensible' replaced by 'indispensable'.
Pg xl. 'knowlege' replaced by 'knowledge'.
Pg xliv. 'Siemienowick' replaced by 'Siemienowicz'.
Pg 19. 'pluverized' replaced by 'pulverized'.
Pg 19. 'foretel' replaced by 'foretell'.
Pg 22. 'Belhelaive' replaced by 'Belhelvie'.
Pg 24. 'Heroditus' replaced by 'Herodotus'.
Pg 26 Footnote [8]. 'Pontoppidon' replaced by 'Pontoppidan'.
Pg 26 Footnote [8]. 'seive' replaced by 'sieve'.
Pg 31. 'Heroditus' replaced by 'Herodotus'.
Pg 34. 'Tunesteick' replaced by 'Tunestrick'.
Pg 44. 'skreen' replaced by 'screen'.
Pg 53. 'Bradenburgh' replaced by 'Brandenburgh'.
Pg 67. 'Rifault' replaced by 'Riffault'.
Pg 68. 'indispensible' replaced by 'indispensable'.
Pg 74. 'exhilirating' replaced by 'exhilarating'.
Pg 100. 'salpetre' replaced by 'saltpetre'. (twice)
Pg 100. 'decribed' replaced by 'described'.
Pg 107. 'occured' replaced by 'occurred'.
Pg 107 Footnote [17]. 'occurence' replaced by 'occurrence'.
Pg 134. 'combustbile' replaced by 'combustible'.
Pg 138. 'one-hundreth' replaced by 'one-hundredth'.
Pg 140. 'eprovette' replaced by 'eprouvette'.
Pg 140. 'pulverized quick-lime' replaced by 'pulverized quicklime'.
Pg 142. 'processess' replaced by 'processes'.
Pg 148. 'frankincese' replaced by 'frankincense'.
Pg 158. 'by some. It is' replaced by 'by some it is'.
Pg 159. 'guages' replaced by 'gauges'.
Pg 163. 'tranverse' replaced by 'transverse'.
Pg 172. 'which see.' replaced by 'which see below.'.
Pg 188. 'XXXVI' replaced by 'Sect. XXXVI'.
Pg 192. 'westtern' replaced by 'western'.
Pg 193. 'nesessary' replaced by 'necessary'.
Pg 197. 'absord' replaced by 'absorb'.
Pg 203. 'harpsicord' replaced by 'harpsichord'.
Pg 206. 'metalic' replaced by 'metallic'.
Pg 221. 'Siemenowitz' replaced by 'Siemienowicz'.
Pg 232. 'Britanica' replaced by 'Britannica'.
Pg 234. 'paste-board' replaced by 'pasteboard'.
Pg 235. 'whe r ' replaced by 'where'.
Pg 236. 'Peirre' replaced by 'Pierre'.
Pg 237. 'bass' replaced by 'brass'.
Pg 241. 'repecting' replaced by 'respecting'.
Pg 244. 'Britanica' replaced by 'Britannica'.
Pg 245. 'cases is' replaced by 'case is'.
Pg 251. 'abbe Raynal' replaced by 'Abbé Raynal'.
Pg 256. 'Eygpt' replaced by 'Egypt'.
Pg 257. 'groupes' replaced by 'groups'.
Pg 258. 'Tuilleries' replaced by 'Tuileries'.
Pg 259. 'Tuilleries' replaced by 'Tuileries'.
Pg 262. 'Brittish' replaced by 'British'.
Pg 271. 'pastebord' replaced by 'pasteboard'.
Pg 274. 'parts length' replaced by 'parts in length'.
Pg 276. 'breakes' replaced by 'breaks'.
Pg 277. 'Volcono' replaced by 'Volcano'.
Pg 278. 'sucession' replaced by 'succession'.
Pg 284. 'esssential' replaced by 'essential'.
Pg 287. 'ingedients' replaced by 'ingredients'.
Pg 287. 'will to exhale' replaced by 'will exhale'.
Pg 314. 'artficial' replaced by 'artificial'.
Pg 324. 'phosporus' replaced by 'phosphorus'.
Pg 325. 'pealed' replaced by 'peeled'.
Pg 328. In the table '286' replaced by '280' and '338' by '330'.
Pg 328. ': 160 :' replaced by ': 100 :'.
Pg 331. 'section iv' replaced by 'section iii'.
Pg 332. 'counter-ter weights' replaced by 'counter-weights'.
Pg 343. 'desscribed' replaced by 'described'.
Pg 345. 'unrol' replaced by 'unroll'.
Pg 345. 'couratines' replaced by 'courantines'.
Pg 351. 'fiit' replaced by 'fit'.
Pg 359. 'thicknes' replaced by 'thickness'.
Pg 362. 'case whirl' replaced by 'case whirls'.
Pg 382. 'pyrimids' replaced by 'pyramids'.
Pg 383. 'air' replaced by 'airs'.
Pg 384. 'Votaic' replaced by 'Voltaic'.
Pg 406. 'Sec. XIV.' replaced by 'Sec. XV.'.
Pg 413. 'Archimedian' replaced by 'Archimedean'. (twice)
Pg 414. 'star weeel' replaced by 'star wheel'.
Pg 418. 'Archimedian' replaced by 'Archimedean'.
Pg 431. 'Alchohol' replaced by 'Alcohol'.
Pg 440 Footnote [28]. 'meditate' replaced by 'mediate'.

Pg 440 Footnote [28]. 'Guillume' replaced by 'Guillaume'.
Pg 443. 'ladle-full' replaced by 'ladleful'.
Pg 453. 'sauccissons' replaced by 'saucissons'.
Pg 454. 'sauccissons' replaced by 'saucissons'.
Pg 454. 'squills' replaced by 'quills'.
Pg 455. 'mosique' replaced by 'mosaique'.
Pg 460. 'richochet' replaced by 'ricochet'.
Pg 475. 'parallelopepids' replaced by 'parallelepipeds'.
Pg 476. In the table, 'comsition' replaced by 'composition'.
Pg 488. 'Shrapnell' replaced by 'Shrapnel'. (twice)
Pg 491. 'Siemienowich' replaced by 'Siemienowicz'.
Pg 514. 'Dictionaire' replaced by 'Dictionnaire'.
Pg 517. 'passsing' replaced by 'passing'.
Pg 519. 'He how' replaced by 'He now'.
Pg 526. 'two-third' replaced by 'two-thirds'.
Pg 533. Duplicate phrase 'Elevation for extreme range' removed from the table.
Pg 535. 'their being' replaced by 'there being'.
Pg 535. 'richochet' replaced by 'ricochet'.
Pg 542. 'the' removed from header 'Base of the conical head' in the table.
Pg 560. 'Siemienowick' replaced by 'Siemienowicz'. (twice)
Pg 570 Footnote [43]. 'fennell' replaced by 'fennel'.
Pg 580. 'seive' replaced by 'sieve'.
Pg 581. 'pullies' replaced by 'pulleys'.
Pg 585. 'de Gouvernment' replaced by 'de Gouvernement'.
Index:
Pg 590. 'Bertholet' replaced by 'Berthollet'.
Pg 590. 'Cagliostra' replaced by 'Cagliostro'.
Pg 590. [Callinicus:] '673' replaced by '544, 548'.
Pg 593. 'Copal' entry moved to correct alphabetic order.
Pg 596. 'Grœcus, Marcus' replaced by 'Græcus, Marcus'.
Pg 598. Section for 'J' moved after section for 'I'.
Pg 598. [Inflammable:] 'Gingembrie' replaced by 'Gengembrie'.
Pg 598. 'Jassamine' replaced by 'Jessamine'.
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Pg 602. [Pliny:] 'Porcena' replaced by 'Porsena'.
Pg 604. 'Rochus' replaced by 'Rochos'.
Pg 606. 'Seneka' replaced by 'Seneca'.
Pg 609. [Watson:] 'Landaff' replaced by 'Llandaff'.
Pg 609. 'Will-with-the-whisp' replaced by 'Will-with-the-Wisp'.