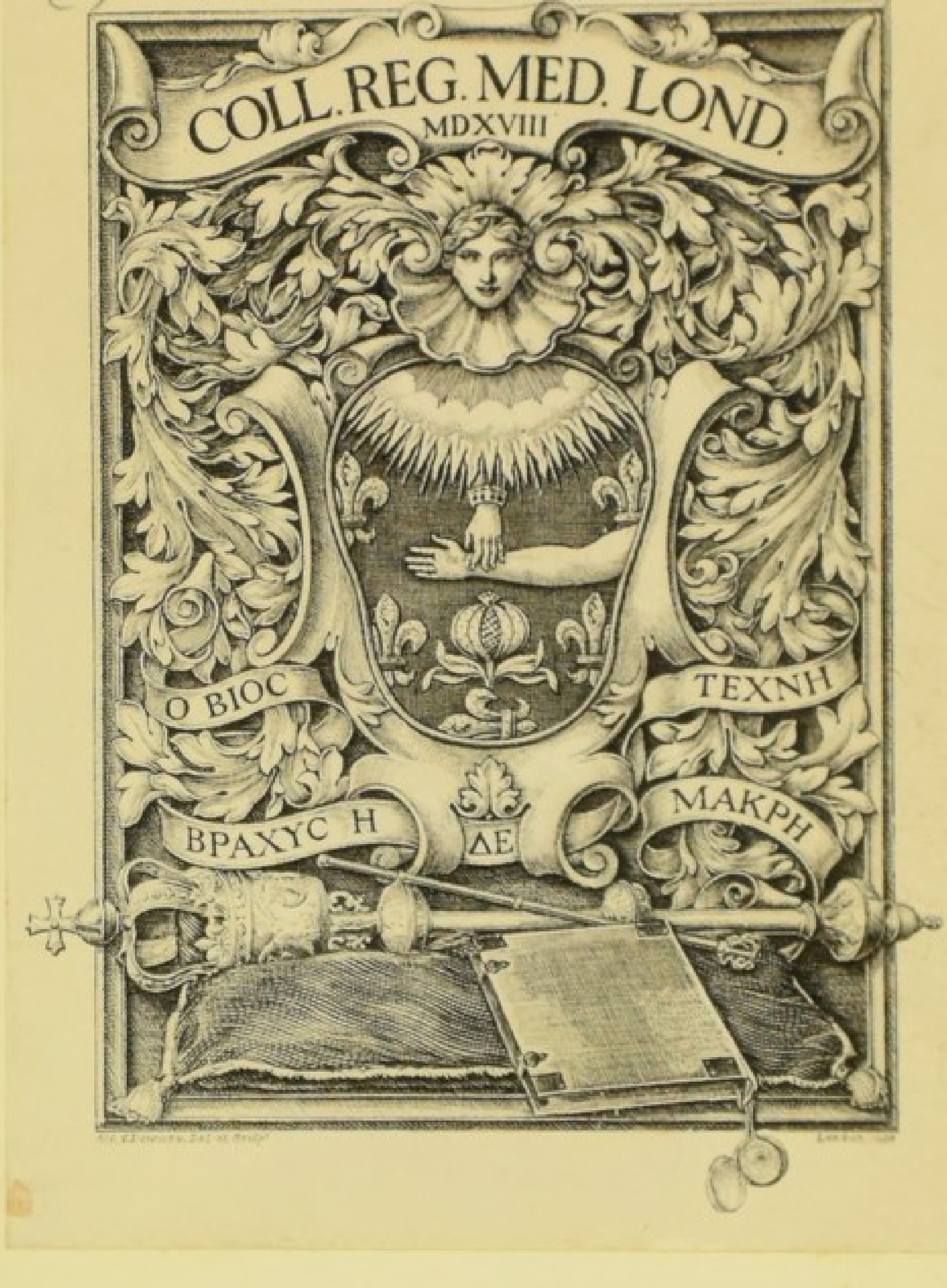
Practical and experimental chemistry / by E. Mitscherlich ... Translated, from the first portion of his Compendium, by S. L. Hammick.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Presented to the College
of Physicians by Dr Hamm

PRACTICAL AND EXPERIMENTAL

CHEMISTRY,

ADAPTED TO

ARTS AND MANUFACTURES:

BY

E. MITSCHERLICH,

PROFESSOR OF CHEMISTRY IN THE UNIVERSITY OF BERLIN.

TRANSLATED FROM THE FIRST PORTION OF HIS COMPENDIUM,

BY

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TO

MICHAEL FARADAY, Esq., D.C.L., F.R.S.

PROFESSOR OF CHEMISTRY AT THE ROYAL INSTITUTION,

DISTINGUISHED AMONG

THE GREAT MEN OF HIS AGE,

FOR HIS MANY VALUABLE DISCOVERIES IN CHEMISTRY,

WHICH HAVE CONTRIBUTED

TO RAISE THE SCIENCE IN THIS COUNTRY

TO

ITS PRESENT ELEVATED RANK,

THIS TRANSLATION

IS RESPECTFULLY INSCRIBED.

PREFACE.

Having in the years 1834 and 1835 visited Berlin, I availed myself of the opportunity of attending the course of Lectures on Chemistry, delivered in the University of that capital, by its celebrated Professor Mitscherlich. Having learnt to appreciate the value of his observations, as well as the accuracy of his experiments, I have been induced to undertake the translation of this work, with the hope it may prove both interesting and instructive to many, who have not had the opportunity of hearing the Lecturer himself. It has been thought advisable to adhere strictly to a literal translation, as more likely to convey the exact meaning of the author; and though there may be a degree of harshness in the style, yet as the difficulty of giving the true sense to some of the long compound words, peculiar to the German school, was great; it is to be hoped, therefore, its other merits may counterbalance these unavoidable defects.

It may be right to add, that the thermometer of Reaumur is generally used in foreign schools; but in this translation, the degrees have been reduced to the scale adopted by Fahrenheit, to meet the custom of this country.

I cannot omit this opportunity of making my sincere acknowledgments for the many acts of friendship I experienced from the Professor himself, who is no less distinguished for the greatness of his talents, than beloved for his amenity of manners.

THE TRANSLATOR.

36, *Cavendish Square,*
May 25*th,* 1838.

INTRODUCTION.

In preparing the present work for the press, I have not attempted to explain in a complete and scientific order, all the facts connected with Chemistry and its kindred sciences; such an object would be unnecessary, as the treatise of Berzelius answers every requisite purpose. This work, however, is principally adapted to students, for self-instruction, and to such persons as apply themselves more particularly to experiments: I refer more generally to those who study chemistry for their future occupation, to Physicians, Druggists, Manufacturers, and Agriculturists, and such as are anxious to acquire a general scientific knowledge, but not to those who would devote their whole time and attention exclusively to Chemistry, as Savans.

A Professor or Author of a work intended for the first lessons in Chemistry, must therefore endeavour so to select and arrange his experiments, as to render the science insensibly complete, by passing from simple to compound phenomena.

In order to follow up this plan, I have commenced with a description of experiments, more particularly of those from whence the most important general ideas may be formed.

All chemical are accompanied by physical phenomena; thus the nature of the sciences requires that both should be studied together: on this account I have, in various parts of this work, given a general review of such objects as conduce materially to the comfort and advantage of mankind.

E. MITSCHERLICH.

Berlin, 30th Dec. 1836.

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ERRATA.

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— — — 14, *for* 14 *read* 12
— 139, — 2, *for* gas *read* ether
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— 264, — 3 from bottom, *for* There are *read* These are
— 168, last line, *for* fluoret *read* fluoride.

PRACTICAL AND EXPERIMENTAL

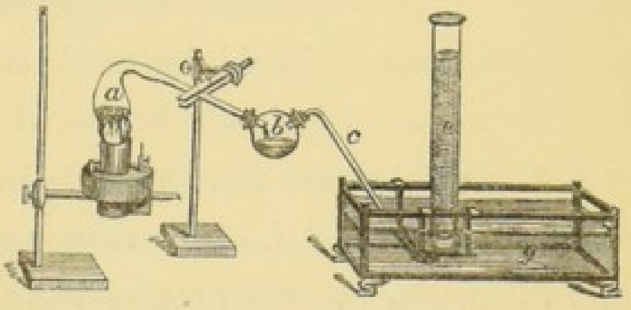
CHEMISTRY,

&c.

OXYGEN.

If in a glass retort *a*, the neck of which is firmly fixed in the receiver *b*, red oxide of mercury is gradually heated by a spirit lamp, bubbles of air pass from the mouth of the glass tube *c*, which is also fixed by means of a cork into the other extremity of the receiver, and expel the water with which the cylinder was filled. The inverted cylinder is placed on a stand of wood in a water-bath (Fig. 1). The first bubbles that enter is atmospheric air, which becomes expanded in the retort from the heat; as, in a temperature raised from 32° to 212° Fahrenheit, atmospheric air expands to a third of its volume.

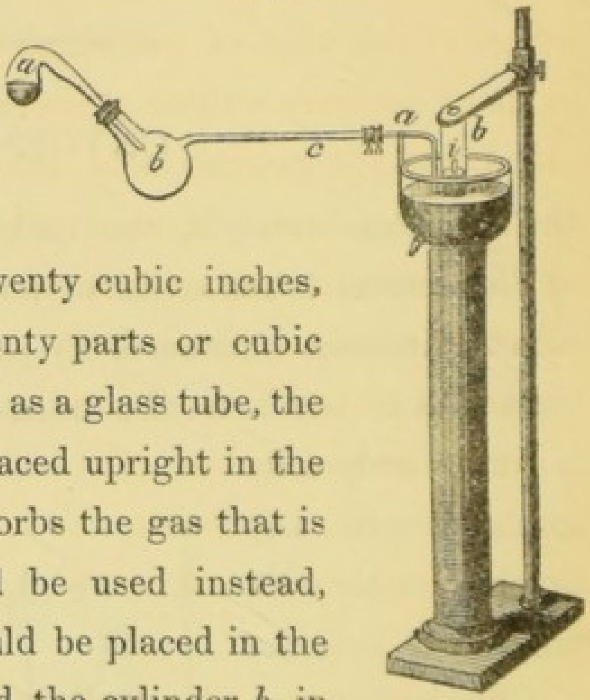
Fig. 1.



The red oxide of mercury, like many other bodies, changes its colour with a high temperature, but recovers it on cooling. The red tinge becomes very deep, and soon black; the interior of the neck of the retort is coated; and drops of a fluid metal form, which flow into the receiver, and the bubbles increase: these phenomena continue as long as any trace of a red body is found.

In order to calculate accurately, by measure, the volume of the body which displaces the water, and to determine by weight the size of the metal that is formed, it will be necessary to employ a graduated cylinder *b*, which would contain, for instance, twenty cubic inches, (and is divided into twenty parts or cubic inches, as Fig. 2,) as well as a glass tube, the extremity of which is placed upright in the cylinder. As water absorbs the gas that is formed, mercury should be used instead, the curved tube *a i* should be placed in the vessel of quicksilver, and the cylinder *b*, in which the open end, *i*, of the tube is placed, is pushed deep into the mercury; the air contained therein escapes through the other open end, *a*, of the tube, which is connected with an elastic tube. The small quantity of air remaining in the cylinder, is calculated in proportion to the rising or falling of the tube; so is the level of the mercury, either within or without the cylinder. By taking, for instance, a hundred grains of oxide of mercury, and heating it till none remains in the retort, and allowing it to cool till the

Fig. 2.



air in the vessels acquires the same temperature as it before had, the air returns into the apparatus, consisting of the retort *a*, the receiver *b*, and the glass tube *c*.

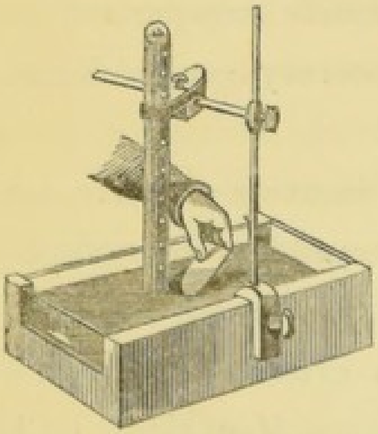
The apparatus contains the same quantity of air in volume as formerly, and what in addition is retained in the cylinder is formed by heating the oxide of mercury. The fluid metal procured in this manner weighs 92 grains, and the cylinder contains 18·6 cubic inches of air; 18·6 cubic inches of this kind of gas weigh about eight grains. The oxide of mercury weighs therefore as much as the liquid metal, and the gaseous body, into which it is separated by the action of heat. Mercury is the only metal that is fluid at the common temperature of the atmosphere; it is, as all other metals, a simple body. The other body, which is separated by heat from the red oxide of mercury, is equally a simple body called oxygen, and, in a gaseous form, oxygen gas; gas is, therefore, the scientific term for air. The power by which it combines with mercury is called chemical affinity.

Chemical affinity of ingredients, in oxide of mercury and many other substances, can be destroyed by means of a high temperature; other combinations can be decomposed by simply adding a body which has a greater affinity for one of the substances. Thus, for instance, if oxide of lead be heated with carbon, the oxygen combines with the carbon, and the lead is parted with; there are many other means by which we can separate compound bodies. Those substances which cannot be decomposed, by any means as yet discovered, are termed simple bodies.

Oxygen cannot be distinguished, as far as external appearances go, from carbonic acid or other colourless kinds of gas. A match, heated to redness, kindles when dipped into a vessel filled with oxygen, and burns briskly: in atmospheric air it only burns, but does not inflame. An ignited match burns in atmospheric air, but is immediately extinguished in carbonic acid gas, and kindles with a flame in oxygen gas. All lighted bodies burn much quicker in oxygen than in atmospheric air.

If we fill a glass tube with mercury, and invert it in mercury, placing at the same time a small bit of phosphorus underneath, as it is lighter than mercury it floats on the top; and admitting a small glass full of oxygen gas, the phosphorus being previously heated to fusion, each bubble of gas, when it reaches the phosphorus, causes it to ignite, and the gas entirely disappears. With a sufficient proportion of phosphorus, (Fig. 3) we can cause a large quantity of oxygen gas to disappear in the same manner by ignition. If sufficient oxygen remains, but no further ignition takes place, then, too, the phosphorus itself becomes changed, and we find a body with properties quite different from those either of phosphorus or oxygen, namely, phosphoric acid, which, as is proved by experiment, is a combination of these two substances. If atmospheric air is employed instead of oxygen, about a fifth

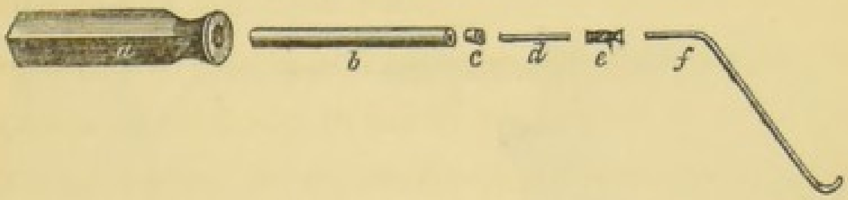
Fig. 3.



part disappears, and phosphoric acid is equally formed: in the gas which remains, burning bodies do not ignite; from whence we may conclude, that atmospheric air contains oxygen, which is the cause of the usual phenomena of combustion, and another species of gas, namely, azote.

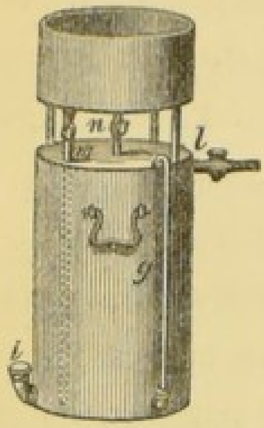
Oxygen is of all bodies the most interesting, as an ingredient of atmospheric air, as a substance which supports combustion, and as a principle of the greater part of the chemical combinations we are engaged on. To be able to study the properties of this most important body, it must be prepared in a larger quantity than can be obtained from a substance so expensive as oxide of mercury. For this purpose we make use of a mineral, a chemical combination that is found in nature, called peroxide of manganese, which, when pure, consists of 100 parts of manganese, and 57·82 parts of oxygen. If these substances are heated, the whole quantity of oxygen will not be separated from the metal, as in the red oxide of mercury; a combination of the metallic manganese, with a less quantity of oxygen remains, in which 100 parts of manganese are combined with 38·55 of oxygen. This decomposition is most easily effected in a bottle of cast iron (Fig. 4), which should contain about a pound; into its mouth a gun-barrel *b* is inserted, into the end of which a cork, *c*, is placed, fitted with

Fig. 4.



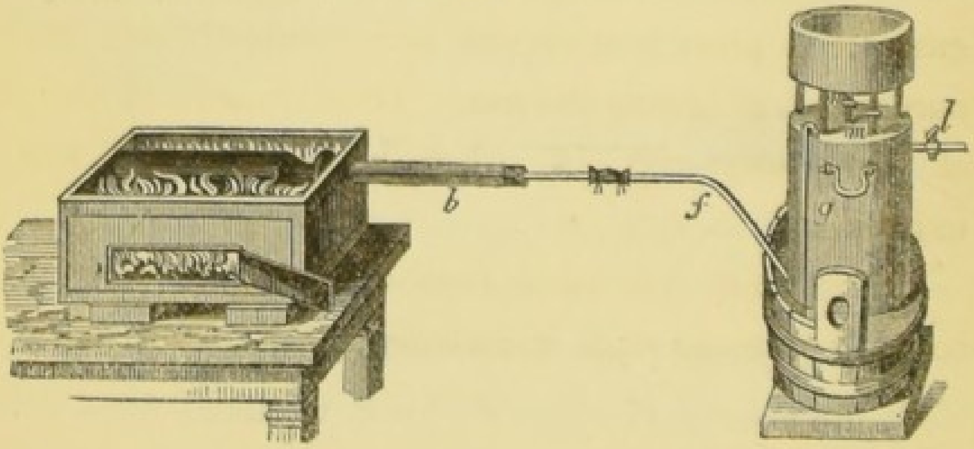
a glass tube, *d*, which is connected with another tube, *f*, by means of an elastic pipe, which passes into a gasometer.

Fig. 5.



This gasometer (Fig. 5) consists of two cylindrical copper vessels, placed one above the other, fixed by five pieces of the same metal, two of which are hollow and supplied with cocks. The tube *m* reaches the bottom of the under compartment, the other tube, *n*, merely passes through the upper surface; so the communication between the upper and under cylinder may be interrupted. At *l* is also a small tube with a cock, and below, at *i*, a large opening closed with a screw. To fill the cylinder with water, it must be poured into the upper compartment; it flows into the lower one through the pipes *m* and *n*, and the air is forced out through the pipe *l*: when the water begins to run out of this, it must be closed, and the remaining air finds its way through the tube *n*. This gasometer is thus filled, and the cocks are shut (Fig. 6). The bottle containing the peroxide of

Fig. 6.

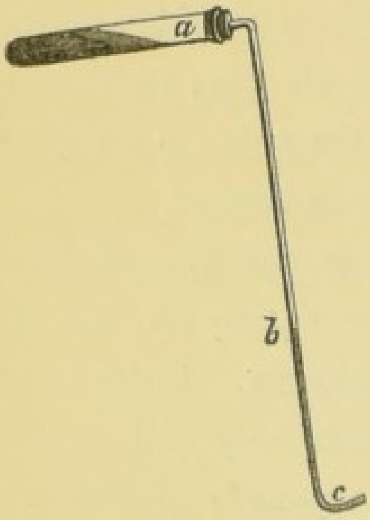


manganese must be laid in a square stove between bricks, and covered with hot coals. The peroxide of manganese, as commonly found in commerce, is not pure, but often contains a hydrate of the peroxide of manganese, which consists of water in combination with manganese and oxygen, besides several other substances. If the retort containing the hydrated peroxide is heated, first the water, then the part of the oxygen which is found in combination with the manganese, are given off. As soon as a burning match placed before the opening of the iron pipe inflames, connect it with a pipe, *f*, whose curved end passes through the opening, *i*, of the gasometer. The gas that is disengaged escapes through the opening of the glass tube, and passes in bubbles through the water, which is expelled through the opening *i*. The glass tube, which, both above and below, is connected with the internal chamber of the gasometer, serves for the purpose of showing how much gas is contained in it, as the level of the water in the glass tube corresponds with that within the gasometer.

A gun-barrel, whose touch-hole is closed, half filled with peroxide of manganese, answers equally as well for the formation of small quantities of oxygen. Instead of a gasometer, glass bottles will serve perfectly well for the purpose of collecting the gas. Three pounds of peroxide of manganese give off, when heated, a cubic foot of oxygen.

Oxygen gas, produced from peroxide of manganese, contains carbonic acid, if carbonic combinations are mixed with the mineral; and as it is seldom found free from such combinations, no pure oxygen gas can be procured from it. If, however, we wish to obtain the gas perfectly pure for chemical experiments, we take for that purpose chlorate of potash, consisting of chloric acid and potash. Chloric acid is a chemical combination of chlorine (a simple body) with oxygen; and potash consists of a metal (also a simple body) called potassium and oxygen. Potash and chloric acid combine, forming a crystallized salt, which by a high temperature fuses, and, by a stronger heat, becomes so decomposed, that the chlorine and potassium combine, and the oxygen, which was found combined with potassium and chlorine, is given off: from 100 parts of this salt we obtain 39 parts of oxygen. By placing in a small glass tube, *a*, (Fig. 7,) as much chlorate of potash that the fused salt may fill a third part, and by connecting it with a pipe, *b*, and heating the salt over a lamp, the water mechanically confined escapes from the crystals, which, becoming heated, at first fuse, and are then decomposed. The decomposition continues until all the oxygen is disengaged, and what remains in the tube is chloride of potassium. The tube is closed with a little wax; when we wish to make use of pure oxygen, we remove the wax under mercury, and heat the tube, when the

Fig. 7.

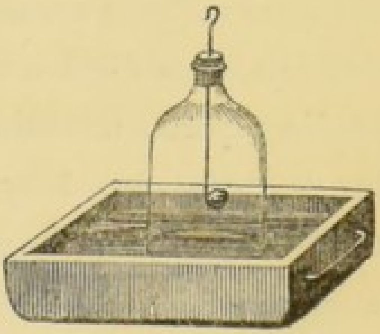


development of the gas takes place. As very little oxygen gas is required for experiments, we may use the apparatus for other purposes.

All simple bodies, with the exception of one only, namely fluorine, combine with oxygen; some directly, and others through decomposition. Sulphur, phosphorus, carbon, hydrogen, and many metals, combine directly with oxygen. In order that such a combination should take place, these substances must be quickly heated to a certain temperature; iron and carbon to a red heat; phosphorus, on the other hand, combines at ordinary temperature with the oxygen gas of the atmosphere.

The union of oxygen with other bodies, at a high temperature, is termed combustion; and as atmospheric air consists of oxygen, and another gas, azote, which is a non-supporter of combustion, in the proportion of one of the former to four of the latter, the phenomena of burning bodies are much more brilliant in pure oxygen gas, than in atmospheric air. By placing a small piece of phosphorus in a spoon, suspended in a bell-glass filled with oxygen, (Fig. 8,) and lighting the phosphorus with a heated piece of wire, the whole glass is filled with a light which equals in brilliancy that of the sun. A lighted bit of sulphur, introduced in the same manner, burns with a beautiful blue flame; a lighted coal burns with resplendency. If we fasten to a piece of watch-

Fig. 8.



spring a bit of lighted sponk, and place it under the glass, the sponk kindles, and ignites the watch-spring, which throws down burning sparks, and is entirely consumed, if sufficient oxygen gas be present. If we wish to fill a jar from a gasometer (Fig. 9), we place it, filled with water, over the pipe *n*; we open the cock, and the gas escapes through the pipe into the jar and displaces the water contained therein. The gasometer answers very conveniently for experiments on combustion. If we open the cock *m*, the water flows below, and compresses the oxygen gas, which escapes through the tube *l*, and a watch-spring or a piece of iron wire previously heated to redness, when placed in the stream of gas, burns most brilliantly. We can also ignite the watch-spring, by passing a stream of oxygen through a spirit lamp, which is afterwards removed (Fig. 10).

Fig. 9.

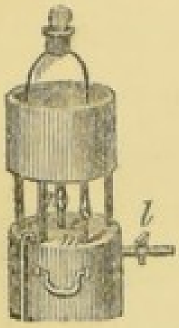
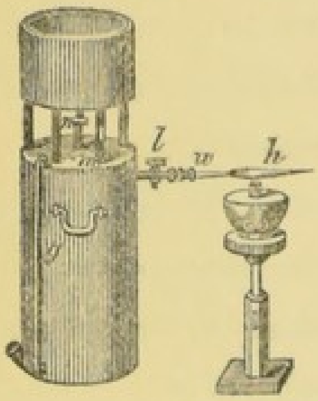


Fig. 10.



Phosphorus produces a flame of intense light; iron, on the contrary, only single whitish sparks in a state of fusion, which have so high a temperature, that if we burn a watch-spring in a glass filled with oxygen, having a thin bottom, the falling sparks melt the glass. We profit by the high temperature produced by a combination of oxygen with other bodies, in melting substances otherwise infusible. We screw on for this purpose, a point of brass or platinum, *w*, (Fig. 10,) and pass a stream of gas through the spirit lamp; from the combination of oxygen gas with the combustible ingredients of spirit of wine, such a degree of heat is generated, that platinum wire immediately fuses in the flame.

From the combination of oxygen with simple bodies, we procure a great many compound substances, which are the more numerous, as the oxygen, inasmuch as it unites with simple bodies under various circumstances, can combine in different proportions.

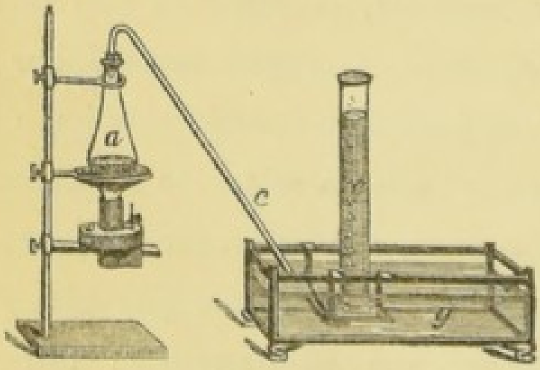
Phosphorus, for instance, combines, if it burns and becomes ignited, with more oxygen, than if it became kindled in atmospheric air at a common temperature. Iron, if it attracts oxygen from water, under the influence of sulphuric acid, combines with less oxygen than if it were oxidized by the decomposition of nitric acid. Manganese combines in five different proportions with oxygen, and, in this respect, surpasses all other metals.

From their chemical affinity for each other, we divide the combinations of oxygen into five different classes. Some of these combinations unite again with each other; such a compound body, for instance, is sulphate of oxide of copper. Sulphuric acid consists of oxygen and sulphur; oxide of copper, of copper and oxygen: such a union of two oxygenated combinations is called a salt. As sulphuric acid combines with oxide of copper, so many other oxygenated combinations are formed; for instance, phosphoric acid, which consists of phosphorus and oxygen; nitric acid, of azote and oxygen; carbonic acid, of carbon and oxygen. This class of compounds, which thus unites with oxides, is called acids; those compounds, on the other hand, which unite with an acid, as, for instance, oxide of copper, oxide of lead, and other metallic oxides, are called bases. If one and the same body furnishes two degrees of oxidation, which, combining with acids, produce salts, then that combination containing the most oxygen is termed a peroxide, and the other a protoxide : so the lowest degree of oxidation of iron, consisting of 100 parts of iron, 29·47 parts of oxygen, is protoxide of iron ; the highest degree, formed of 100 parts of iron and 44·205 parts of oxygen, is the peroxide of iron.

A suboxide is that combination of oxygen which requires more oxygen to be able to combine with acids : these combinations are, however, rare.

Superoxides or peroxides are termed oxygenated combinations, which sometimes must give off oxygen to be able to unite with acids. The best example of this class is the peroxide of manganese : if we pour sulphuric acid on it, no decomposition takes place ; but, by heating it over a spirit lamp, (Fig. 11) there is given off a gas, which is soon recognized as oxygen; and there remains in the retort a combination of sulphuric acid with protoxide of manganese. The peroxide of manganese must give off half of its oxygen to form a base, which may combine with the sulphuric acid ; it consists of 100 parts of metal and 57·82 parts of oxygen. We see that the

Fig. 11.



same body combines in various proportions with oxygen, and this combination takes place according to a regular law.

Protoxide of manganese consists of	100 parts metal,	28·91	oxygen.
Oxide of manganese	100	43·365	—
Peroxide	100	57·82	—
Manganic acid	100	86·73	—
Permanganic acid	100	101·185	—

From this example we see that the weight of oxygen in the same quantity of metal has the same ratio in five different combinations, as 2 : 3 : 4 : 6 : 7, and in multiples and in simple proportions oxygen combines with other simple bodies.

In the salts a simple ratio takes place between the oxygen of the base and the oxygen of the acid, which is fixed by the proportion of the oxygen of the acid to that of the other degrees of oxidation; thus in manganic salts, the oxygen of the base, is to the oxygen of the acid, as 2 to 6, and in permanganic salts, 1 to 7.

HYDROGEN.

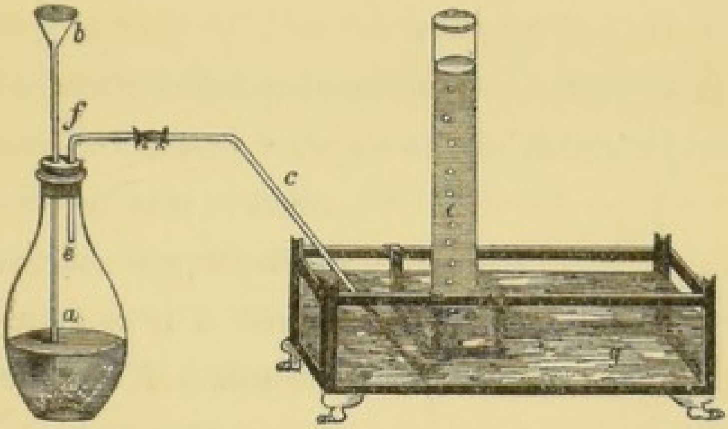
By means of a high temperature, oxide of mercury is decomposed into metallic mercury and oxygen. In all combinations of the more noble metals with oxygen, a similar decomposition takes place; oxide of lead is, on the contrary, not decomposed by heat. To separate the lead from the oxygen, it is necessary to add another body which has a greater affinity for oxygen than lead, for instance, carbon; this combines with the oxygen of the oxide of lead, and the lead is found in the metallic state. The same also takes place with water. Though, by a high temperature we cannot decompose it, still, by adding potassium or sodium to water, a combination takes place of either sodium, or potassium with oxygen: potash or soda and a gaseous body are formed. We observe this decomposition in the most convenient manner, by placing sodium in an inverted cylinder filled with water. The sodium, being lighter than water, rises to the surface, and the gas that is disengaged, as the sodium becomes oxidized, displaces the water. This simple body is termed hydrogen; to obtain it in the largest quantity and in the most convenient manner, zinc is made use of. Moistened with water, this substance does not decompose water, but if sulphuric acid be added thereto, air bubbles are disengaged from the zinc, which is dissolved. If we heat this solution till all the water is evaporated, there remains a salt, which consists of a combination of sulphuric acid and oxide of zinc; the oxide of zinc acting as a base to the sulphuric acid.

Neither zinc nor iron has so great an affinity for oxygen, as to separate it from the hydrogen of the water at a common temperature, but, by adding a little sulphuric acid, the affinity of the acid for the oxide increases the action, and water is decomposed.

For the preparation of hydrogen gas, we make use of a flask with a cork, in which there are two holes, through one of which a long glass tube furnished with a funnel, *b*,

(Fig. 12,) and through the other a second pipe, *f*, which passes under the inverted cylinder, which stands in a water-trough. In the flask, small bits of zinc (plates of zinc which are broken up, or zinc that has been fused and dipped in water) are placed; then water, and, by degrees, sulphuric acid are introduced through the funnel.

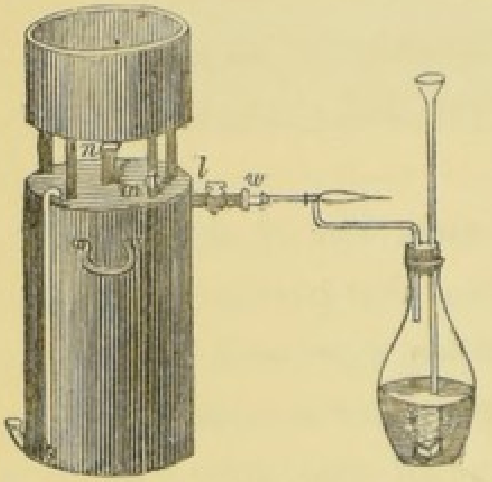
Fig. 12.



The gas which is given off, as the glass tube *a*, is below the surface of the water, can only escape through the pipe *f*; it rises in bubbles to the top of the cylinder, and expels the water. When three or four cylinders have thus been filled, the gas next evolved should be examined, which will be found colourless as atmospheric air, and inflammable. Remove the jar from the trough, and ignite the gas that is given off; it burns with rather a bright flame, and if we place a dry cylinder over the flame, it is immediately stained: the gas which escapes, combines with oxygen of the air during combustion, and forms water. Though the flame of hydrogen be ever so small, it is however exceedingly hot; so high a temperature cannot be produced by any other chemical combination, as by the ignition of hydrogen. If oxygen gas be conducted through a flame of hydrogen, substances are fused with great ease in the extremity of the flame, which are otherwise almost infusible, as clay, chalk, and platinum.

This experiment may be accomplished by means of a spirit lamp (Fig. 13) placed before a gasometer, if the pipe which is used for the escape of hydrogen gas be only curved a little, and turned upwards. If two measures of hydrogen gas be mixed with five of atmospheric air, and ignited, a violent noise or detonation takes place, proceeding from the combustion of hydrogen. The azote of the atmosphere contributes nothing to combustion: but if, instead of the five measures of atmospheric air, one measure of oxygen be employed, then a more violent detonation takes place.

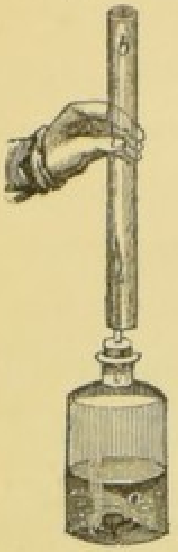
Fig. 13.



In a great number of chemical combinations and decompositions a similar detonation takes place, the explanation of which is very interesting. If we take a pencil case or a box, the cover of which shuts tightly, and we suddenly pull it off, we remark a similar slight noise; if we draw it off slowly, we do not observe it at all. If the cover is drawn off rapidly, the atmospheric air which is contained in the box, is dilated, and the external air cannot enter the space, where the air is rarefied, between the cover and the box; the moment, however, the cover is off, the air enters, and the rapid collision of the external and internal air causes the sound.

From oxygen combining with hydrogen, both being in a gaseous state, the result is water, which, at first, has a very high temperature, but from the coldness of the surrounding atmosphere, it soon cools, and becomes a fluid. Fluid water occupies a thousand times less space than heated vapour, and the sudden condensation of atmospheric air produces a louder detonation than that of the box. Thunder, too, though on a larger scale, is somewhat similar; by means of an electric spark, (lightning,) the atmosphere, through which it traverses, is suddenly compressed, and immediately after expands: thunder is produced by the compression and the immediate subsequent dilatation of air. These detonations succeeding each other, may produce quite a musical sound. For instance, by taking a glass tube of two feet long, and setting the air in vibration by means of a common fork, or of a tuning fork, which produces five hundred small oscillations in a second, we may with equal facility, by means of a flame of hydrogen, extract musical tones from the air. Allowing hydrogen gas, which has been prepared in the usual manner, to flow from a flask, through a pipe with a narrow opening, and igniting it as soon as all the atmospheric air has escaped from the flask; and placing an open tube at intervals over the flame till it diminishes to a certain point, the tone is heard; at the same time an elongation of flame, as well as a trembling motion, takes place.

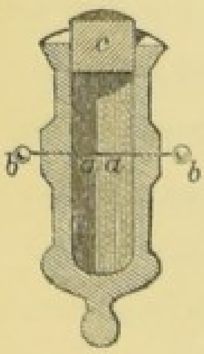
Fig. 14.



The phenomenon of this sound is produced in the following manner: by means of a regulated current of air, small portions of hydrogen gas mix with the atmospheric air and explode, and again mix and explode; and thus a sudden expansion and condensation of air take place. If the number of small detonations approach the number of vibrations which the column of air produces in the glass pipe (Fig. 14) in a second, the fundamental note of the column of air is obtained; if the number amounts to twice as many, then we hear the next highest octave.

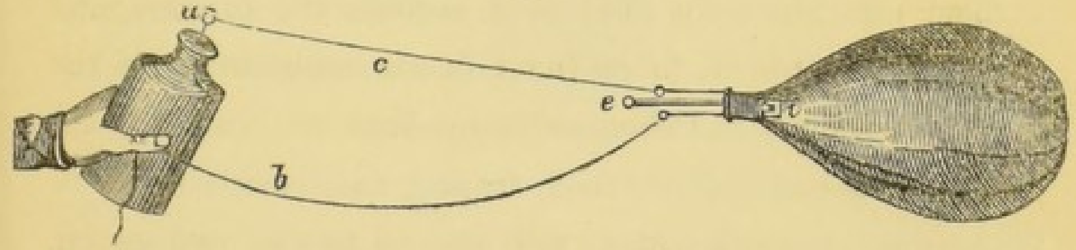
An electric spark can, equally as well as a lighted match, ignite a mixture of hydrogen and oxygen gases; this circumstance, taking place in a closed vessel, gives occasion to various experiments. We may give the tube in which this mixture is effected the form of a pistol or cannon (Fig. 15). On the inner side of the tube are two wires, the extremities of which are opposite each other, *a a*, which have small knobs *b b*, on the outer side. From the discharge pipe we allow some hydrogen to enter the tube, which is then closed with a cork *c*. By touching one of the knobs with the finger, and bringing the other near the

Fig. 15.



conductor of an electrical machine, the spark passes from one point *a* to the other, and ignites the mixture. The combination is accompanied with a violent explosion, and the cork is driven out. The following experiment is more instructive. Fill a large bladder (Fig. 16) with two proportions of hydrogen and one of oxygen, by connecting the glass pipe (after all the air is expelled from the bladder) with the cock of the gasometer, and we can thus regulate the true proportion of gases which we wish to enter the bladder. Two wires should pass through the cork, the extremities attached to two others of considerable length; these are connected with the outer coating of a charged jar: if we touch the wire *c* with the ball *a*, the electric spark enters at *i*, and ignites the mixture of gases, the bladder bursts, and we observe a large body of flame.

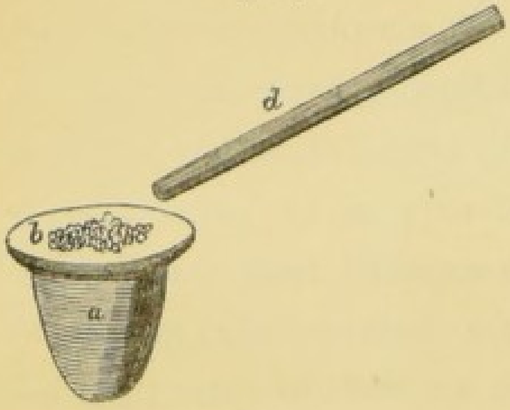
Fig. 16.



A burning match or an electric spark are not the only means of igniting a mixture of hydrogen and oxygen; a wire of platinum heated to 140° Fahrenheit, a plate of platinum or cold piece of platinum sponge (metallic platinum in a finely divided state) effect the same object.

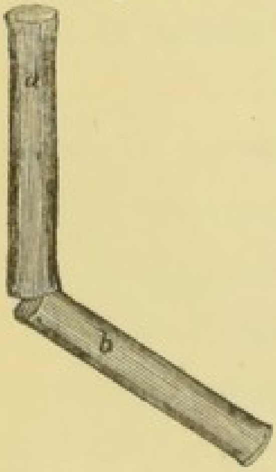
If we lay a piece of platinum sponge on a platinum cover, or any other plate *b*, (Fig. 17,) which is placed on a crucible, and can be easily removed, and allow hydrogen gas to pass through a glass pipe *d*, the heat commences, which is so developed by its combining with the oxygen of the air, that the platinum at first becomes red hot, and then ignites the hydrogen. This property of easily combining with oxygen, through contact with other bodies, distinguishes hydrogen, although other kinds of inflammable gas possess it equally as well. In general, every finely divided metallic body combines readily with oxygen, and promotes, if it belongs to the noble metals, the combination of oxygen with inflammable gases.

Fig. 17.



By filling a cylinder with hydrogen, and leaving it uncovered only a few minutes, the gas no longer retains its inflammable property, it so soon escapes: if, however, we hold it with its mouth down, the gas remains much longer.

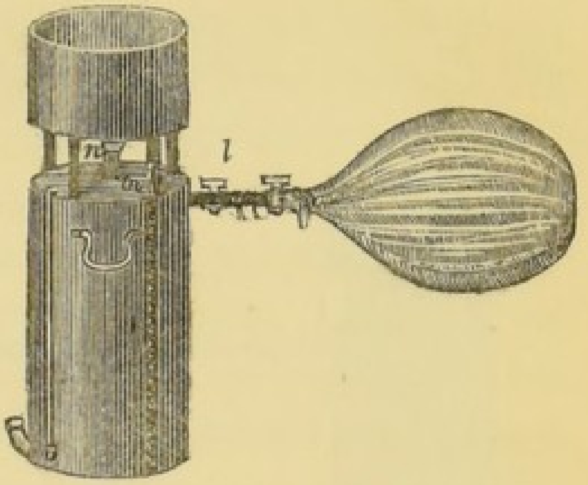
Fig. 18.



If we fill a long glass tube with hydrogen, and then remove it from the trough, a large flame is produced, on holding a lighted match over the mouth of the cylinder. If we turn a cylinder, *b*, (Fig. 18,) filled with hydrogen gas, so that over its mouth another is placed, and draw off the glass from the under tube, *b*, the gas immediately kindles by applying a lighted match, the hydrogen therefore ascends.

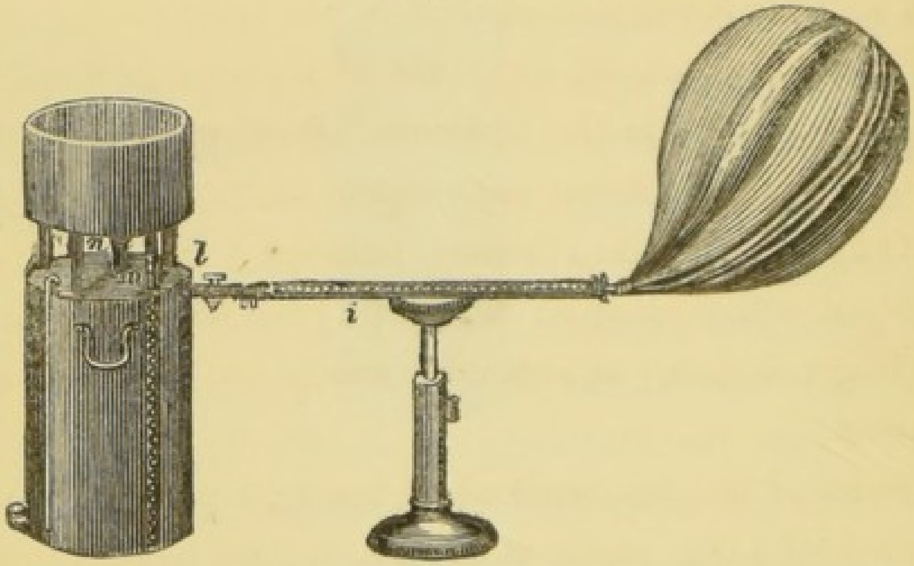
All these experiments prove that hydrogen is much lighter than atmospheric air. We observe this better by filling a bladder with hydrogen. To a well dried bladder a cock is affixed, (Fig. 19,) which, after the atmospheric air is expelled by compression, is attached to a gasometer. By turning the cock *n*, the water flows through from the upper copper vessel into the under one, and the gas compressed in the gasometer readily escapes through the cock *l* into the bladder, which is soon filled. The bladder being detached, we dip the extremity of the pipe into a lather of soap; by gently compressing the bladder, we have bubbles of soap, which, being filled with hydrogen, rise quickly in the air. If, in a similar manner, we fill the bladder with a mixture of oxygen and hydrogen, in the same proportion as they form water, then the bubbles of soap also rise in the air, and, if ignited, explode loudly. When treating of atmospheric air, directions will be given in what manner the weight of hydrogen gas may be accurately calculated, and how we have discovered it to be about $14\frac{1}{2}$ times lighter than the atmosphere. A balloon of gold-beater's skin, filled with hydrogen, soon ascends; if it is six inches in diameter, it weighs about 35 to 36 grains, and the hydrogen gas which enters it, about 5 grains; these both amount

Fig. 19.



to 40 or 41 grains. We fill a balloon in the same manner as the bladder, only with this difference, that we allow the gas to pass through chloride of calcium: this substance has so great an affinity for water, that, by its contact with moist gas it absorbs the moisture, and the gas very soon

Fig. 20.



becomes dry. The chloride of calcium is placed in a tube, *i*, (Fig. 20,) through which the hydrogen gas is conducted.

Hydrogen gas, employed for such experiments, is usually impure, and not more than ten times lighter than atmospheric air, therefore the air, which occupies the same space as the balloon, weighs 50 grains; 9 or 10 grains heavier than the hydrogen gas and balloon taken together.

If the balloon is formed of letter paper, it may be somewhat larger. In aerostation a balloon is used prepared of silk, which is varnished over. A balloon of twenty feet in diameter contains about 4000 cubic feet of gas, and, beside the silk, it carries 250 pounds: one of 30 feet in diameter contains about 14,000 cubic feet of gas, and can carry

928 pounds. Hydrogen combines only with a few simple bodies; with some directly, as, for instance, with oxygen and chlorine, by igniting a mixture of these bodies with hydrogen; with others, by means of decomposition of combinations already formed, as, for instance, with sulphur: by pouring on sulphuret of iron, water and sulphuric acid, the water becomes decomposed in the same manner as if we had taken metallic iron; the sulphate of protoxide of iron is formed, and the hydrogen of the water combining with the sulphur, forms sulphuretted hydrogen gas.

Only three metals, selenium, tellurium,[1] and arsenic can combine with hydrogen; the others have no affinity for it: hydrogen is found in almost all animal and vegetable substances.

Some of the combinations of hydrogen possess the properties of acids, which unite with various bases, forming salts, as hydrochloric acid. The combination of hydrogen with azote forms ammonia, a very strong base; and some of its combinations are neutral, neither acid nor base prevailing; as, for instance, arseniuretted hydrogen.

COMBINATIONS OF OXYGEN AND HYDROGEN. (*Water.*)

Oxygen and hydrogen are gaseous; the body resulting from their combination is, on the contrary, fluid, (water,) which occupies a space 2,000 times less than that filled by the two species of gas before combination. By mixing these two gases in a vessel inverted over mercury, in such

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[1] Since the publication of this work, a fourth metal, antimony, has been discovered by Mr. Lewis Thompson to combine with hydrogen.

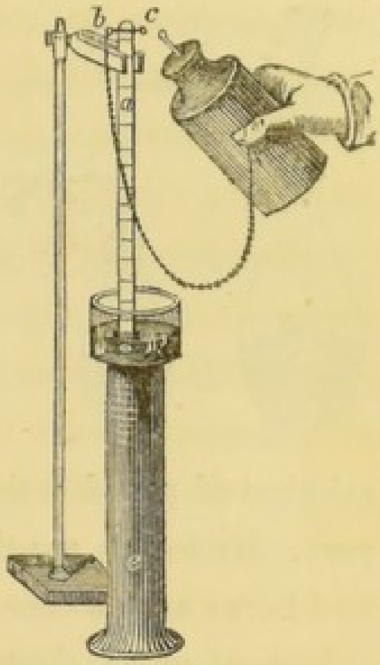
proportions as to form water, and igniting the mixture, the gases will disappear, mercury filling the whole tube, except a small space occupied by the water that is formed.

To determine this proportion, we make use of a strong glass tube, dividing it into equal parts. This division is made by means of a measure, for which we employ a small glass vessel (Fig. 21). We fill this vessel with mercury, and this serves as a unit. This unit may be either a cubic inch or a cubic centimeter: the large tube we fill by means of this measure, and mark at every measure, poured in, the height of the mercury with a diamond.

Fig. 21.

We must now introduce the mixture of gases into the cylinder, inverted over mercury. There are two methods adopted for igniting it; we may employ either an electric spark, which is the best plan, or spongy platinum. For the electric spark, two holes are bored in the glass pipe, opposite each other, in which two wires of iron or platinum are firmly fixed. We then attach to the wire, *b*, a small conductor, so as to set the wire in connexion with the earth, and touch the outer end of the chain with the cover of a charged jar: the spark passes from the extremity of one wire to that of the other. We may as well employ a charged Leyden jar, by bringing the outer coat of the jar into communication with a wire, (Fig. 22,) then touch it with the knob of the jar, and the spark passes from the extremities of the wires into the interior of the glass cylinder. To perform this experiment with exactness, we must fill the graduated glass tube with mercury, and place

Fig. 22.

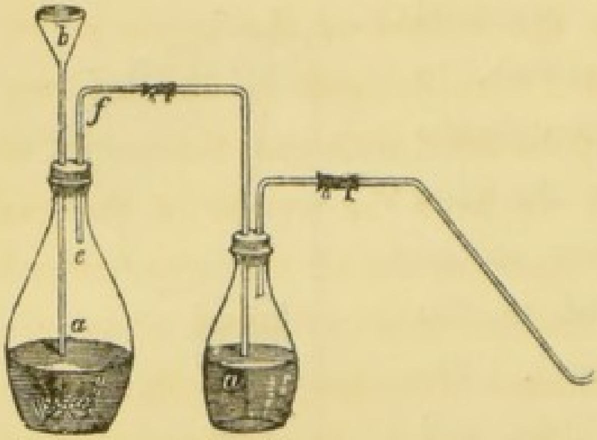


it in a trough of mercury, then allowing oxygen gas, prepared from the chlorate of potash, to enter; we determine accurately the quantity by volume; as the pipe sinks deep in the mercury, so the mercury in the tube and in the bath attain the same level. We next raise the tube a little, and allow pure oxygen gas to enter, regulating the quantity as with hydrogen. If, in an experiment, we take somewhat more than two measures of hydrogen, to one of oxygen, we shall find, after the ignition has taken place by means of an electric spark, some oxygen remains, exactly as much as was added in excess; if we take too much hydrogen, there remains, after combination, exactly as much of hydrogen, as we had used more than the above proportion.

It follows, from this experiment, which must be performed with the greatest exactness; that hydrogen and oxygen combine with each other, in the proportion of two volumes of the former to one of the latter, to form water. All bodies in a gaseous form combine one with another in similar simple proportions.

For this and similar experiments, we prepare perfectly pure hydrogen, by passing it over a solution of potash. To the glass tube, by which the hydrogen escapes, we attach a second, which passes into a second jar (Fig. 23), con-

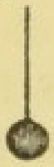
Fig. 23.



taining a solution of potash. The gas, thus developed, must traverse in single bubbles the solution, and is then collected. The foreign substances which the hydrogen contained, are removed by the solution of potash; the zinc we make use of must also be pure. Hydrogen gas thus prepared, is quite free from smell, and burns with a colourless flame.

Instead of an electric spark, we can employ platinum sponge, to cause a quantity of hydrogen and oxygen in a glass tube, inverted in a bath of mercury to combine, so as to form water. For this purpose we take one part of platinum sponge and 4 parts of clay, so as to form a small ball (Fig. 24), which must be heated before using. Thus the combination of hydrogen and oxygen goes on gradually, after we have placed the ball in the mixture. The specific weight of this gas, we can ascertain with the greatest exactness.

Fig. 24.



By the specific weight of a gas, we mean the weight of a particular gas in comparison with that of atmospheric air: if a gas and atmospheric air occupy the same space, the weight of the atmosphere is taken as a unit.

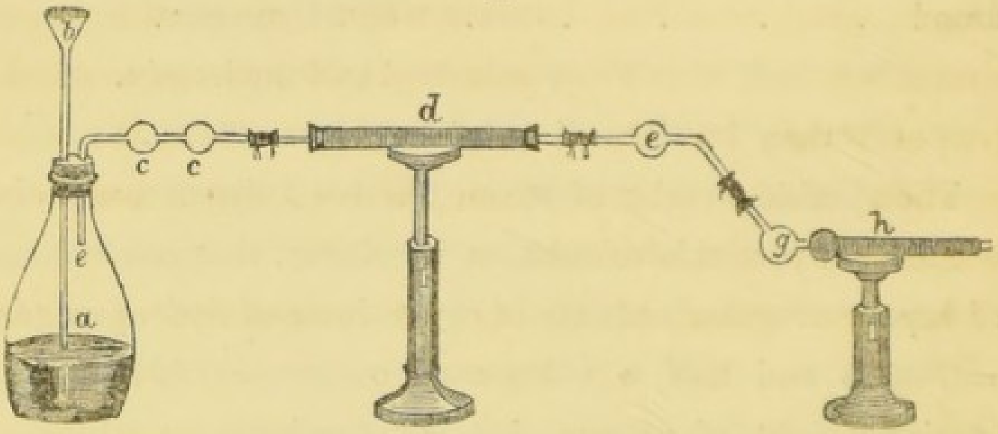
The specific weight of the gas we calculate thus: a thin glass globe, furnished with a stop-cock, is filled with atmospheric air, then exhausted by an air pump, and weighed;

it is again filled with the gas, whose weight we wish to ascertain. By deducting the weight of the empty globe, from its weight when filled with air, and in like manner, from the weight of the globe filled with gas, the weight of the globe when empty; we have the weight of the gas which occupied the same space, as the air that was pumped out. Of hydrogen gas, this amounts to 0·0688, of oxygen to 1·1086: now two volumes of hydrogen combine with one of oxygen gas, forming water: these, according to weight, 2 × 0·0688=0·1376, hydrogen with 1·1026 oxygen, forming 1·2402 water; in 100 parts of water there are found . . . . . 88·91 oxygen,
11·09 hydrogen,

then 1·2402 : 1·1026 : : 100 : 88·91.

The specific weight of steam has been discovered to be 0·6201. From this calculation it follows, that one volume of vapour of water consists of one volume of hydrogen gas, =0·0688 and half a volume of oxygen=0·5513. The specific weight of vapour, that is, of substances which at a common temperature are solid or fluid, and which, at a higher one, we find in the form of a gas, we determine thus. We allow about 30 times less of a solid or fluid body to enter a broad glass tube, as it would contain in a gaseous form: we close the glass tube, after we have heated it uniformly throughout, either in boiling water, or any other fluid, until all the air and the surplus substance, which was introduced, are expelled from the tube, which is only filled with vapour. If we fix the temperature at which the tube is closed, the weight of the tube, and the substance, as well as the globe filled with dry air, we then calculate how much there was, at the temperature at which the tube was closed, and how much vapour was contained in the tube, after it was closed. A totally different method gives also the same proportion. Many metallic oxides are decomposed by hydrogen, if only heated a little; for instance, oxide of iron, cobalt, copper, and many others. From the loss of weight which the oxide suffers, and the weight of the water formed, we can discover the composition of water. In a flask, *a*, (Fig. 25,) we generate slowly hydrogen

Fig. 25.

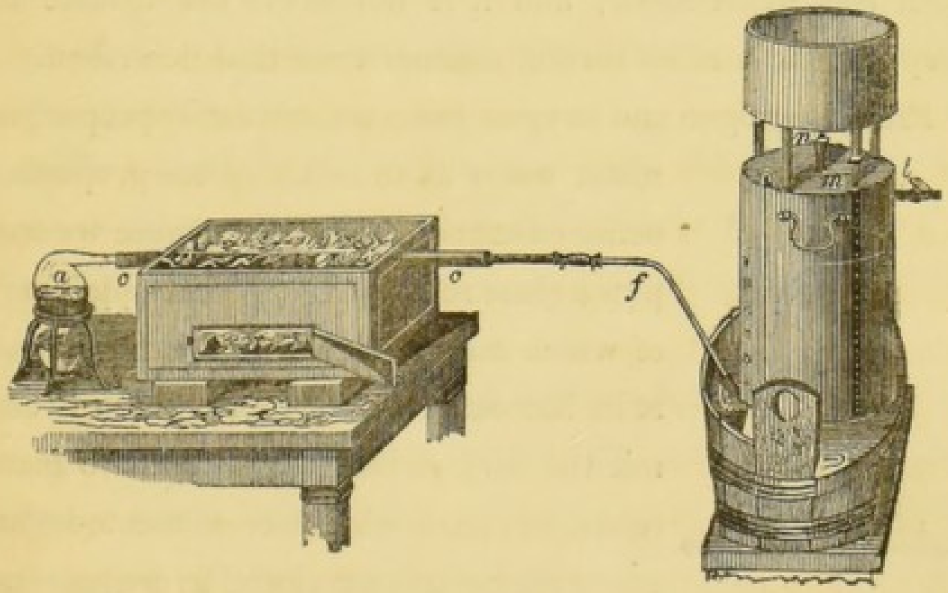


gas, in the usual method; in general some vapour is mixed with it, therefore, in the second pipe, two globes, *c c*, are blown, where the water may collect. The vapour which is not condensed becomes entirely withdrawn from the hydrogen gas in the pipe *d*, where chloride of calcium is placed, so that it passes over quite dry into the globe, *e*.

In this ball is a metallic oxide, for instance, that of copper; if this is heated with a spirit lamp, after the apparatus is filled with hydrogen gas; it becomes soon red hot, and its oxygen combines with hydrogen, forming water; and thus a high temperature is produced. Before the operation, we weigh the ball *e*, at first empty, then with the oxide of copper, and thus the weight of oxide of copper is ascertained; we weigh also the globe *g*, and the chloride of calcium. After the operation, we weigh the ball, *e*, and find, from the loss of weight, how much oxygen has been given off from the oxide of copper. The weight of water that is formed, we find, by adding together the weight of the globe *g*, and the chloride of calcium pipe *h*. The weight which the water has gained, in addition to the oxygen given off from the oxide of copper, is the amount of hydrogen which combines, forming water. From this experiment we find, with great accuracy, not only the composition of water; but are also enabled to ascertain, the composition of the metallic oxide, where oxygen has been withdrawn by the hydrogen.

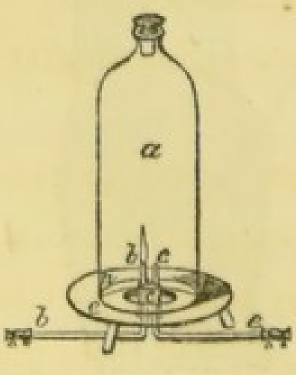
Another method of finding the composition of water,

Fig. 26.



which, however, furnishes us with no exact results, but only presents an interesting example of decomposition ; is the decomposition of water by means of iron. In a gun-barrel we place some twisted iron wire, more particularly in that part which will be heated in the fire (Fig. 26). At one end is a retort, hermetically sealed, containing water, which is made to boil by means of a spirit lamp : at the other end is a glass pipe connected with the gasometer. If the vapour comes in contact with red-hot iron wire, it becomes decomposed; the oxygen of the water combines with the iron, forming oxide of iron ; the hydrogen is given off, and is collected in the gasometer. By taking the increased weight of the iron, we find about the quantity of oxygen, which was combined with the hydrogen, contained in the gasometer. The weight of the hydrogen gas we calculate from the weight of the water, which flows out of the gasometer, displaced by the hydrogen gas. The iron that is employed is never pure, so we can never obtain any accurate results from this experiment; and it is not worth the trouble to prepare it in a more careful manner than that described.

Fig. 27.



From hydrogen and oxygen gases we can easily prepare as much water as to admit of its properties being examined. For this purpose we employ a glass retort (Fig. 27), the upper part of which may be closed by a stopper, and at its bottom is a hole large enough to admit the cork *c*, through which two glass tubes, *b e*, pass, which are connected with two gasometers containing hydrogen and oxygen gas. We first allow through the tube *e* oxygen gas to enter the vessel, and hydrogen from the pipe *b*, and then ignite it, having closed the opening with a cork. The hydrogen gas must only produce a small flame, and only so much oxygen must be admitted, that for two volumes of hydrogen, there may be but one of oxygen, which can be easily seen by the glass tube of the gasometer. The walls of the vessel soon become stained; and after some time, drops form, which collect in the bottom, *h*. The water which is thus obtained is as pure as distilled water.

Peroxide of Hydrogen.

The peroxides of many other metals act towards acids, in the same manner as the peroxide of manganese; either the oxygen is disengaged, which the peroxide contains in larger proportion than its base, or the acid admits of a higher oxidation; or, as is the case with many hydracids, it combines with the hydrogen of one part of the decomposed acid, forming water, from whence the substance combined with hydrogen gas is separated; as, for instance, hydrochloric acid.

The peroxides of barium, strontium, calcium, potassium, and sodium, present quite a different decomposition; the oxygen unites with the water, and forms a higher degree of oxidation.

We divide the peroxide of barium into small particles, and mixing it with water form a thick paste, in cold diluted hydrochloric acid, which we prepare by mixing together, one part of concentrated hydrochloric acid, and three parts of water, to which we add two per cent. of phosphoric acid. By means of continual agitation pure peroxide of barium is dissolved, without any chlorine or oxygen being disengaged. As soon as the fluid begins to be sufficiently saturated, the metallic oxides separate; for instance, oxide of manganese, iron, aluminium, as insoluble combinations of phosphoric acid; and if more phosphoric acid is added than is necessary to saturate this base, then the superfluous phosphoric acid is precipitated in combination with barytes, and the fluid may be separated from the residuum, by means of filtration through thick paper. The fluid that passes through clear, consists of a solution of chloride of barium, and a new combination of hydrogen in water: by adding finely pulverized sulphate of oxide of silver, which is only slightly soluble in water, these form chloride of silver and sulphate of barytes, both of which are insoluble in water. By a cautious addition of a proper quantity of sulphate of oxide of silver, the solution only contains peroxide of hydrogen.

If we wish to procure peroxide of hydrogen free from water, we employ concentrated solution of peroxide of hydrogen in water, adding to the solution of chloride of barium and peroxide of hydrogen, as much concentrated hydrochloric and phosphoric acids as was employed before, saturating it with peroxide of barium; by adding as much more acid, and cooling the solution as much as possible, the chloride of barium separates in crystals. We again add as much peroxide of barium to the fluid poured from the crystals, and repeat the operation as long as can be borne without too great a loss, from the decomposition of peroxide of hydrogen; we then separate the chloride of barium, by means of the sulphate of oxide of silver, and evaporate the solution under an air pump, over sulphuric acid; the water becomes then more volatile than peroxide of hydrogen.

Anhydrous peroxide of hydrogen is a colourless fluid, of the consistence of syrup, of the specific weight of 1·453: we have never been able to procure it in a solid form; it has a peculiarly nauseous taste and smell. At 77° F. decomposition commences, and at 257° it is very rapid. Dissolved in water, its decomposition commences at 145° F., but is complete at the boiling point of water.

On dissolving a known quantity in water, and boiling, we calculate, by weight, the quantity of oxygen gas that is given off, and find it amounts to as much as is contained in the water formed by decomposition; so that peroxide of hydrogen consists of one volume of hydrogen gas, and one volume of oxygen. It may be kept for some time in ice, but after a few months it is decomposed.

To many substances the peroxide of hydrogen gives off oxygen, we thus obtain a much higher degree of oxidation; as, for instance, peroxides of calcium and strontium, copper, or zinc. Litmus paper becomes blanched by it; the spot where it comes in contact with the skin, more particularly on the tongue, becomes equally white. This substance is the more important on account of the facts, it furnishes for the theory of chemical affinity. By adding to a diluted solution, finely powdered gold, platinum, silver, oxide of lead, peroxide of manganese, and many substances of this kind, a complete decomposition of the peroxide of hydrogen is effected; the substances remain unchanged; and a very small quantity of them is sufficient to decompose a large quantity of peroxide of hydrogen, into water and oxygen gas. If these substances are used in compact pieces, decomposition takes place slowly, but, in a finely divided state, much faster. Decomposition takes place when the fluid comes in contact with the substance itself; this proves, that where the decomposing substances come in contact with peroxide of hydrogen, a similar effect is produced as by decomposition from heat. We shall have numerous opportunities of mentioning instances, where, on the surface of various substances, chemical combinations and chemical decompositions are effected, without the substances themselves being at all changed. They only act through their surface: and in the same quantity, the operation is more powerful, the purer and the more finely divided they may be. Such substances are termed contact substances, and the process itself, chemical combination, or decomposition, by means of contact.

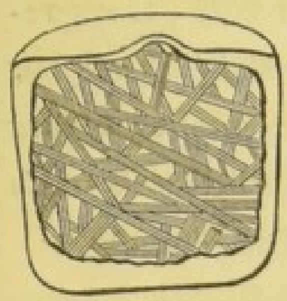
Acids have a different effect on peroxide of hydrogen; they render it more stable. By adding a very little sulphuric acid to a solution, which, by means of silver, is in full decomposition, it ceases immediately; but recommences if the sulphuric acid be saturated by a base. Salts do not equally produce decomposition of peroxide of hydrogen. Oxides of silver, gold, platinum, particularly metallic oxides, which give off oxygen by a slight elevation of temperature, do not only decompose peroxide of hydrogen, but give off their oxygen and become reduced to a metallic state. In these last, decomposition is unquestionably produced by the high temperature. If we allow peroxide of hydrogen to fall in drops on finely divided silver, gold, or platinum, it is decomposed with an explosion, and developement of a higher temperature, which is more than necessary to reduce the oxide of these metals; so that if drops of peroxide of hydrogen fall on oxide of silver, it is reduced by the heat produced from the decomposition.

If, therefore, in a fluid, a small portion of the peroxide of hydrogen is decomposed, by coming in contact with one of the above-mentioned metallic oxides, the temperature thereby produced will act on the metallic oxide with an energy, which is quite sufficient to reduce it; though it heats the greater part of the fluid, in which the peroxide of hydrogen is dissolved, to a degree scarcely perceptible by the thermometer.

SULPHUR.

Oxygen and hydrogen we are acquainted with only in a gaseous form, and only when we produce them artificially; some bodies, as, for instance, carbon, we know of only in a solid state; others, as iron, are both solid and fluid; whilst some assume all three forms, as sulphur, and phosphorus. These bodies are solid at the lowest temperature, fluid at a higher, and if the heat be carried to the highest point, they become gaseous. At a common temperature, sulphur is solid and brittle; heated above 280° F., it melts. Melted sulphur has the same relation to solid bodies that water has to ice; but there is a difference in the two bodies on passing to a solid state—the solid sulphur sinks under the melted, ice floats on the water; water dilates on becoming solid, sulphur, on the contrary, contracts, and so do all other bodies: water must, therefore, be considered an exception. If sulphur and water become solid, the two pass immediately from a fluid to a solid state; this is the case with most bodies, but not with all. Glass, iron, and many other minerals before they become fluid, are tough and viscid, and some remain in this state, even if the temperature is higher than 257° F. In glass these phenomena are best observed; the contrary, however, is the case with water, and the sudden transition into a fluid state is best remarked in sulphur. By allowing melted sulphur to cool in a vessel, after the temperature has reached 280° F., we remark that the parts of the fluid sulphur which become solid, shoot across the fluid mass, from single points of the vessel, like rays, and from these rays others also proceed. The parts of the fluid mass becoming solid, arrange themselves according to settled positions, alongside of each other, and form crystals. To be able to obtain these crystals singly, and to examine them, we make use of sulphur, melted and allowed to cool slowly; on the surface, after some time, an incrustation is formed, the fluid sulphur is found in the interior of the mass traversed by crystals. We procure these crystals in the best manner, by allowing a fluid mass of sulphur to cool in a large vessel; the incrustation formed from time to time

Fig. 28.



on the surface is broken, and the sulphur is allowed to flow out, after the vessel is upset. This figure (Fig. 28) represents the mass of sulphur treated in this manner, which has been sawn through the centre. By this method we can procure a great number of substances in crystals, and determine their form.

Another method of procuring crystallized bodies, consists in rendering solids, fluid, by means of a fluid body. Sugar and common salt are solid bodies; saturated with water, they are dissolved, forming a perfect fluid; if the water is evaporated, they again separate in a regular crystalline form. Thus water dissolves these and many other substances; some fluid bodies dissolve sulphur, and others, for instance, mercury, dissolve different metals.

Bisulphuret of carbon, which, as its name implies, consists of sulphur and carbon, dissolves sulphur; it is a volatile body, and evaporates rapidly, if allowed to stand in an open vessel. If sulphur is dissolved in bisulphuret of carbon, crystals of sulphur rapidly form on evaporation. Whilst, therefore, we render substances fluid, either through heat or by a fluid, we then procure them in regular forms; so too when bodies in a state of vapour become solid, we obtain them also in crystals. If the air is cooled down below 32°, the vapour which is suspended in it is separated, but no fluid is formed; there is no appearance of rain, but a solid body, namely snow; and it is known that snow has a regular form. This is the case with sulphur; if vapour of sulphur arising from evaporation of heated sulphur mixes with the air, and is allowed to cool below 280°, there remains no fluid, but a solid body. The crystals of sulphur are formed in volcanic countries, where the sulphur vapour proceeds from crevices in the ground, and sulphur crystals are also formed in the same manner in smelting houses.

Sulphur procured in these three methods has a very different appearance. Melted sulphur loses its transparency after some time, and breaks with a dull appearance. Volcanic sulphur, more particularly what is derived from nature, as well as what is crystallized from solution, is yellowish, transparent, and breaks in a scaly form, and is cleavable in certain directions. The form of sulphur derived from nature, or procured from solution, is composed of regular octagons P, (Fig. 29), following which, the crystals are at the same time cleavable; these sides are consequently called primitive. The side *r* (Fig. 30), is equally inclined towards the adjoining side P; the side *n* is equally inclined towards the anterior and posterior sides, and the angles which these sides form, are all parallel to each other. From this we observe, that knowing the inclination of the sides P towards each other, we can settle the inclination of the sides *n* and *r* towards the remaining sides; thus they are formed according to regular laws, in connection with the sides P. Those sides, *n*, *r*, *s*, whose inclination we can calculate from the inclination of the sides P, we term the secondary sides. Du-

Fig. 29.

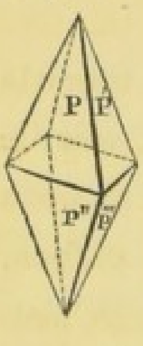
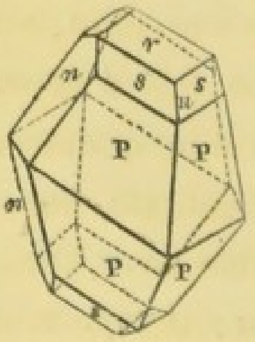


Fig. 30.

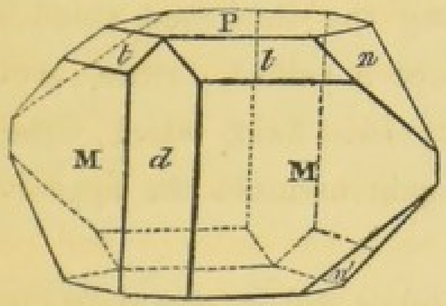


ring very long evaporation single crystals sometimes so group together, as to be connected with each other by their extremities, and have the appearance of a thread consisting of many crystals (Fig. 31). If we measure the angles of crystals with a reflective goniometer, an instrument which gives the greatest degree of correctness, we find that the inclination of the faces towards one another, in whatever part, and from whatever variety we have taken the sulphur, is always the same in good crystals.

Fig. 31.

The crystals of sulphur procured from fusion are at first yellowish, transparent, and clear, but lose this transparency after some time, and this is the state, in which we commonly find the sulphur of commerce. P and M (Fig. 32), are the primitive faces of this form; *t*, *n*, *d*, are secondary: according to the number, symmetry, and inclination of these faces towards each other, are these crystals distinguished from others. These experiments prove, that if a fluid body becomes solid, the parts of the same arrange themselves after a regular plan by the side of each other, and form crystals. A body formed by a peculiar power of matter, terminated by even planes, we call a crystal. These experiments prove besides, that according as different temperatures are found at the period of solidification, so the direction of the single parts may be different. Thus at a temperature about 280° F. sulphur may crystallize in one

Fig. 32.

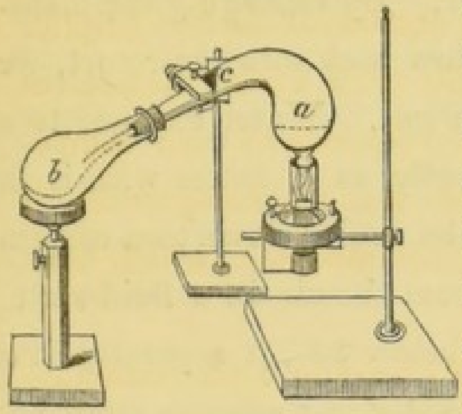


form, whilst at a lower temperature it assumes another. The rapid loss of transparency in crystals of melted sulphur arises from this cause, viz., single parts group themselves together into that form which corresponds to their temperature. Natural sulphur will also lose its transparency, if heated near 280° in a solution of common salt, which boils at 280°.

If sulphur be heated above 280°, we find a phenomenon, only known in the case of sulphur. Somewhat above 280° it is perfectly fluid, clear, and yellow as amber; from 390° it becomes thick and brown; and if heated above 480°, it becomes so viscid, that we may upset the vessel in which it is melted, without its flowing out. There is no contraction of the mass, as sulphur dilates continually from the melting to the boiling point. By pouring the thickened sulphur into cold water, we do not produce a yellow, brittle, crystalline mass, but a brown, soft, viscid fluid, which, after some days, becomes solid, and again assumes the appearance of common roll sulphur.

As this viscid and brown sulphur differs chemically in no one point from brittle sulphur, it therefore follows, that one and the same substance, as it is treated differently, may also have quite different properties. Heated to 970° F. sulphur boils, and in this respect it resembles water at 212°, as at this temperature it passes from a fluid to a gaseous form. The specific weight of sulphur is 6·654. Sulphur in passing from a fluid to a gaseous state, occupies about six hundred times more space: a small bit of sulphur is therefore sufficient to fill a vessel with vapour of sulphur.

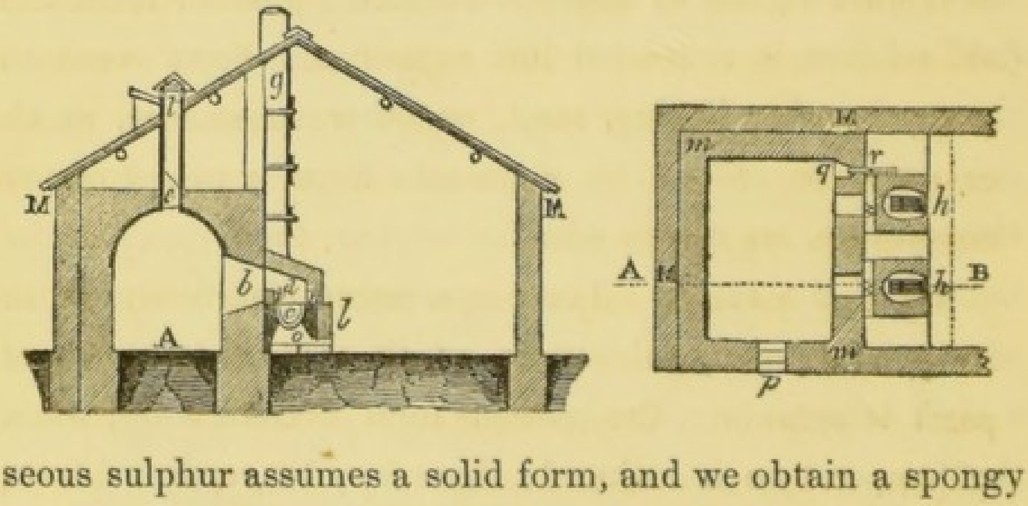
Fig. 33.



By heating sulphur in a retort, *a*, (Fig. 33,) with a spirit lamp to the boiling point, a very small portion is sufficient to fill the retort with sulphur vapour; by increasing the heat, more vapour is generated, which fills the retort, collects in its neck, *c*, as this part is not only not heated by the lamp, but is cooled by the surrounding air, and settles where the temperature is under 280°, as a fine powder, which is continually carried over in great quantities with the atmospheric air into the receiver. As soon, however, as the temperature in the neck of the retort is raised by the warm vapour continually coming over, the vapour condenses into fluid sulphur, which flows down to the under part of the neck of the retort. By continuing the heat till the whole quantity has by degrees assumed a gaseous form, the fluid sulphur is converted into vapour, and flows over into the receiver *b*. If clay, sand, or other substances, which can never be reduced to a gaseous form by means of any temperature, are mixed with the sulphur, they remain at the bottom of the retort. This experiment clearly shows in what manner many substances, which assume, by means of a high temperature, the gaseous form, become solid, when the temperature is reduced; these may be separated from such as do not become gaseous at any temperature, or at a much higher degree. This operation is termed distillation.

Oxygen, hydrogen, and azote, are colourless gases; sulphur vapour has a regular colour. By managing the distillation so that no sulphur can flow back into the retort, we see that it is filled with a brown gas. Water exposed to a free dry air evaporates very rapidly, as it mixes with it in the form of vapour. If this air be cooled down to a certain point, the vapour is separated from the air in a fluid state, as rain; if the air is cooled to below 32°, it separates in a solid form: and it appears that water in a gaseous state, occupies a much greater space, than as a solid, and is mixed with atmospheric air, not in large masses as ice, but in small foliated crystals, as snow. The relation snow bears to ice, is the same which the flowers of sulphur bear to common sulphur. The sulphur evaporates, when beginning to fuse, and unites with the warm atmospheric air, which surrounds it, as sulphur vapour; as soon as the air is cooled, the gaseous sulphur assumes a solid form, and we obtain a spongy yellow powder, consisting of very small crystals, which are termed flowers of sulphur. These are prepared in manufactories in the following manner (Fig. 34):—In an iron

Fig. 34.



cauldron *c* we place sulphur; this is heated at the bottom by means of charcoal, which burns in a grate *o*, and is surrounded by masonry work, so that the vaulted room A may be rendered very hot by fire, of which G is the chimney. The sulphur, which is continually heated, assumes by degrees a gaseous form, and becomes mixed with the air *d* which is found over the cauldron. This air on being warmed becomes much lighter than the air in the chamber, passes through the broad opening *b* into the chamber A, which is supplied with cold atmospheric air, so a continual current is kept up. The air mixed with sulphur vapour, as soon as it enters the chamber, becomes cooled by the air contained therein, and condenses to a fine crystallized powder, which is deposited on the floor of the chamber. In this manner a large quantity is changed into flowers of sulphur, which we remove from time to time. The air in the chamber ought never to be so hot as to melt the sulphur; the management of the fire should be carefully attended to, and the chamber should contain at least 2,000 cubic feet. From some circumstances the sulphur may ignite; we must open in this case the trap-door *e*, by which all danger arising from the combustion may be avoided.

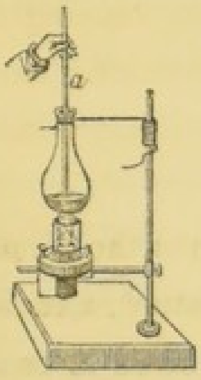
We may procure sulphur in a much more finely divided state, by dissolving in water one part of potassium with five parts of sulphur. This combination is effected by melting sulphur in excess with carbonate of potash, or in a concentrated solution of potash. By adding to such a solution, very diluted sulphuric acid, the potassium combines with the oxygen of the water, and the potash that is formed, with sulphuric acid, becoming sulphate of potash ; the hydrogen of the water unites with one part of sulphur, producing sulphuretted hydrogen which escapes as gas. The other four parts separate, forming so finely divided a powder, that at first it remains suspended in water. This powder is finely divided, for this reason ; whilst in solution, the single parts of sulphuret of potassium are separated from one another, by many parts of water, and can never again combine ; as the particles are insoluble in water.

Sulphur may be heated in atmospheric air up to the point of fusion without being ignited ; if it becomes hotter in contact with a heated body, ignition very readily takes place ; if the walls of the vessel in which it is fused, become very hot, it is ignited, and combining with oxygen forms a gaseous body, viz. sulphurous acid.

Besides this combination, there are also three others, all of which possess the properties of acids ; of these the highest degree of oxidation, is sulphuric acid, which we use combined with water, and which, on account of its great affinity for bases, surpasses most acids, and is of great importance.

Sulphur does not combine directly with hydrogen ; there are, however, two combinations of these bodies, which we procure through the decomposition of metallic sulphurets ; they are both acids. The combination of sulphur with many metals, takes place with disengagement of heat and light. By heating sulphur to fusion in a flask, so that the vapour fills the whole vessel, and by introducing a strip of rolled copper, the copper combines with the sulphur ; and

Fig. 35.



the combination becomes red hot, fuses, and forms a crystalline brittle substance—sulphuret of copper. It follows from this, that not only by combination of oxygen with simple substances, heat and light are evolved, but this phenomenon arises also from the chemical combinations of other bodies; future experiments will show, that by every chemical combination, heat, and (if it is carried far enough) light, are equally disengaged. As oxygen, so also sulphur, combines with other simple bodies, forming bases and acids; which, uniting with each other, produce salts. Arsenic, for instance, and oxygen, form arsenic acid; sodium and oxygen, soda: the acid and the base combine with each other, and form arseniate of soda. Arsenic and sulphur form an acid, sulphuret of arsenic; sodium and sulphur form a base, sulphuret of sodium; the acid and base combine to form a crystalline salt, soluble in water, the sulpho-arseniate of the sulphuret of sodium. Sulphur in its different degrees of combination, presents a similar relation, as oxygen; some highly oxidized bodies when heated, give off oxygen, as, for instance, peroxide of manganese; so too pyrites, a combination of sulphur and iron, when heated gives off sulphur, and a combination of less sulphur with iron remains. Pyrites is employed in some localities to furnish sulphur by heating the metal. The quantity of sulphur obtained in Europe is very considerable; it more particularly abounds in Sicily and Poland; in these countries it is found in tertiary hills, as native sulphur, (sulphur not combined chemically with any other body) mixed with various substances, from which it is separated by distillation. This pure sulphur is fused, and is poured into wooden moulds, in which it cools, and is what we meet with in commerce, under the name of stick sulphur.

SELENIUM.

Selenium may be procured as sulphur, in a solid or gaseous form; it is a solid at common temperature, and is perfectly fluid at a little above 212° F. If allowed to cool rapidly, its surface is clear, and has a metallic lustre; its cleavage, glassy and scaly: when cooled slowly, its surface uneven and dull: it breaks in fine and obscure grains. Although this appearance indicates a disposition to form crystals, still no one has, as yet, succeeded in obtaining crystals of selenium from fusion and slow cooling. All substances, which, as selenium, become viscid before they solidify, crystallize with difficulty. Somewhat above 212° selenium is fluid; at 212° it is half fluid; and under that degree, so soft, that it may be drawn out in threads as sealing-wax. Crystallization depends on the single parts of a body arranging themselves close to one another, according to a regular law; the more fluid the substances are, the more moveable the single particles; and the more readily they arrange themselves according to this settled rule—the thicker, or the more viscid a body is, the less moveable the particles are found to be. From solutions, as, for instance, a solution of selenium in concentrated sulphuric acid, we procure crystals, it is true, but they are with difficulty determinable.

If selenium be drawn out into thin threads, or if a drop of fluid selenium be compressed between two plates of glass, so that it forms a very thin layer, it is transparent, and becomes the colour of a ruby. Selenious acid, a degree of oxidation of selenium, is soluble in water, and is decomposed by sulphurous acid, to which it imparts oxygen, which combining, forms sulphuric acid; the selenium separates from the fluid as a beautiful red powder.

Selenium in a gaseous form, when cooled by the atmospheric air, also forms a finely-divided powder, which has the same relation to selenium, as flowers of sulphur to sulphur, and is as red as cinnabar. When heated, it forms a similarly finely divided powder, and the red colour appears more intense. Sulphur is twice as heavy as water, selenium four times. Selenium fuses at about 160° F., and the vapour which is then formed is yellow, somewhat darker than chlorine gas. Selenium is not inflammable at its fusing point; it becomes volatile when heated in the open air, and forms, as soon as the vapour is cooled by the atmosphere, red fumes consisting of solid selenium. It is ignited by any burning body, and burns with a blue flame, giving off a strong smell of horse-radish, owing to the formation of oxide of selenium. Besides this degree of oxidation, which is but little known, there are two others, selenious and selenic acids. Combined with hydrogen, selenium forms a gaseous body, which, as sulphuretted hydrogen, has the properties of an acid. Selenium and azote do not combine: no combination with carbon is yet discovered.

Selenium combines easily with chlorine, bromine, and iodine. It is found also in union with lead (as a mineral which is met with in the Hartz); from this we may obtain it, or from the residuum which collects in the leaden chambers, which are used for the preparation of sulphuric acid.

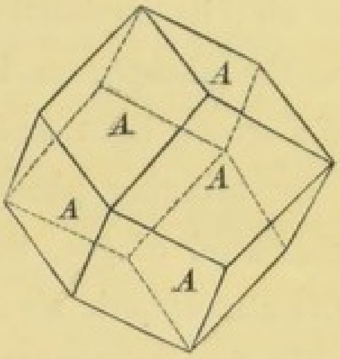
On account of many properties which selenium possesses as a simple body, it much resembles sulphur, as well as other metallic bodies. On account, however, of other characters with which it is endowed, it approaches so much metals properly so called, that it ought to be placed among the latter class. Selenium derives its name from σελήνη, the moon.

PHOSPHORUS.

Phosphorus, like sulphur and selenium, is either solid, fluid, or gaseous, according to difference of temperature. From 65° F. to 78° F. it is pliable as wax; at the freezing point and under, brittle and crystalline when broken. From a solution of sulphur and phosphorus, we procure phosphorus in large crystals, by mixing under water, two parts by weight of phosphorus, and one of sulphur, and allowing the fluid mass to cool.

The form of this crystal is a rhombic dodecahedron, a body terminated by twelve similar rhomboid faces, as A (Fig. 36). From oil of petroleum, purified by distillation, which we heat to the point of fusion, with more phosphorus than can be dissolved, we procure equally as well on cooling, phosphorus in crystals of the same form, as from chloride of phosphorus. From these experiments it follows, that oil of petroleum, as well as sulphuret or chloruret of phosphorus, dissolves more phosphorus at a high than a low temperature. Phosphorus is $1\frac{3}{4}$ times heavier than water; it is almost entirely colourless, with a slight approach to yellow. At 160° F. it fuses, and at 550° is converted into a colourless gas. The specific weight of phosphorus vapour is 4·326.

Fig. 36.



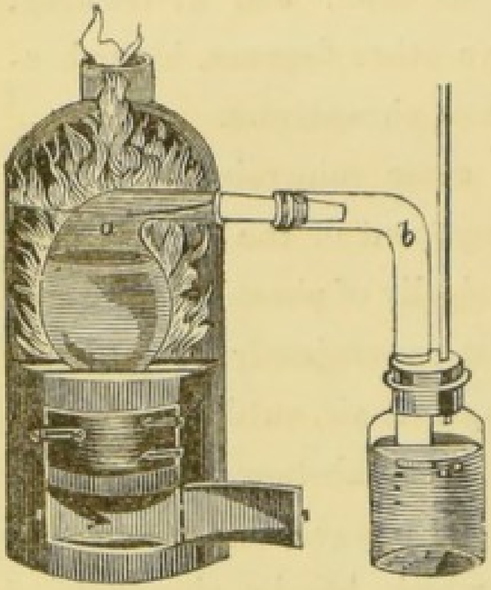
Phosphorus combines very readily with oxygen; heated to a temperature of 200° F. it begins to burn briskly, and when rubbed slightly, kindles immediately: it should be used with the greatest caution, as the wounds it produces by burning, are generally most dangerous. If we dry a piece of phosphorus with blotting paper, and hold it some moments in the air, we perceive by daylight that a small cloud surrounds it, and rises in the air; but in darkness, the phosphorus, as well as the cloud, appear in a flame. By writing with a piece of phosphorus on a dark ground, for instance, on black paper, the characters appear on fire in the dark: if they cease to throw out light after some time, they again commence, if we only pass the finger over them. If we perform this experiment, in atmospheric air confined in a vessel, the light after a time ceases; by allowing oxidized air to enter, it recommences. This ignition depends on the slow combination of phosphorus with the oxygen of the air; its combustion is therefore slow. In pure oxygen gas the phosphorus kindles, if heated to 82° F.; it gives off a strong light, and burns briskly.

By bringing phosphorus in contact with azote, or any other kind of gas, these gases kindle, if they are mixed with atmospheric air; in the same manner, as water unites in the form of vapour, with other kinds of gases, below the freezing point; so too, phosphorus as gas, mixes at a common temperature, with other species of gases, though in very slight quantities. By allowing atmospheric air to come in contact with a similar mixture, the gaseous phosphorus combines with the oxygen of the same, and thus ignition arises. In order that phosphorus should combine at a common temperature with oxygen, it appears necessary, that the oxygen gas should be in a state of rarefaction, as is the case with atmospheric air, in which it mixes with nitrogen gas. Thus phosphorus kindles of itself in rarefied air, under the bell of an air-pump, if it be sprinkled with rosin, or laid on cotton. For this experiment it is necessary that the rarefaction be made rapidly.

The ignition of phosphorus at a common temperature is interesting; as we thus see that some bodies, without being necessarily heated, can unite with each other; whilst others, for example, selenium or sulphur, cannot combine with oxygen, not even at the point of ebullition; others again, as iron, require a very strong heat. By the ignition of phosphorus, a lower degree of oxidation is produced, than if it burns with a stronger flame. This phenomenon is interesting, whilst it shows, that in proportion as the temperature is various, at which phosphorus combines with oxygen; so we procure two different degrees of oxidation, namely, in lighting phosphorus, phosphorous acid; and in burning, phosphoric. There are also two other degrees, hypophosphorous acid, and the red oxide of phosphorus.

Phosphorus is met with in some minerals, and most plants, and is an important component of the animal economy, as the bones consist principally of phosphate of lime; and from them we obtain it most conveniently. First, they are burnt in contact with atmospheric air, until they become quite white, from whence the animal substances, consisting of carbon, azote, hydrogen, and oxygen, are driven off. To three parts of burnt bones, which, besides phosphate of lime, consist also of carbonate of lime, we add thirty parts of water, and two parts of concentrated sulphuric acid. The sulphuric acid unites with the whole mass of calcareous matter, which was combined with carbonic acid, as well as with a part of the lime, which was combined with the phosphoric acid; the other part of the phosphate of lime contains, in consequence, a large quantity of phosphoric acid, and a bi-phosphate of lime is formed. The sulphate of lime remains as an insoluble sediment, as one part requires five hundred parts of water for solution. The superphosphate of lime dissolves readily in water, and, by filtration, is separated from the sulphate of lime. This solution becomes concentrated by evaporation, and at last is so thickened in the cast iron vessel, that it flows like syrup;

Fig. 37.



we then add as much carbon, as amounts to a fourth part of the bones, heating the mass, under continual agitation, till it acquires a slightly red heat. We then quickly place it in a stone retort *a* (Fig. 37), from whence comes off a tube, the extremity of which passes into a flask containing water, but only a few lines under its surface. The retort is placed in a drawing stove, and the fire is at first slowly kindled, but by degrees the heat is increased. The superphosphate of lime is so decomposed, that common phosphate of lime remains; consequently a part of the phosphoric acid is separated. The oxygen of this acid combines with carbon, forming carbonic acid, and oxide of carbon, which escape as gases; the phosphorus is given off as gas, which becomes condensed in the neck of the retort and copper tube; forming fluid phosphorus, which flows over, and is collected at the bottom of the flask. The tube only goes a line deep into the water of the jar, in order, that if by any accident the retort becomes cool, the water should not return into the heated retort. Should however such an accident occur, only so much water will rise, as corresponds with the height of two lines in the tube: should the atmospheric air only enter, some of the phosphorus will, it is true, burn, but the operation will not be impeded.

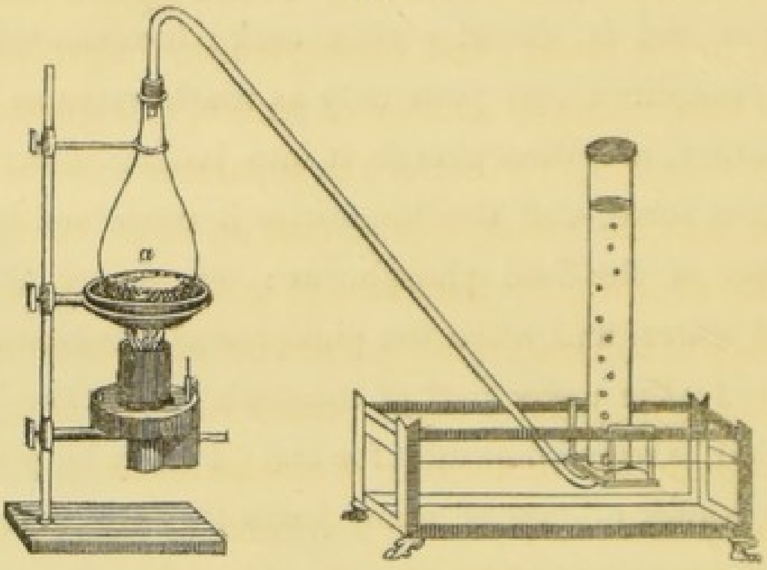
The phosphorus which we have obtained, we cut in small pieces, and place in a glass tube, as broad as a common thermometer-glass, having one end narrower than the other; the narrow end is closed with a cork; into the tube containing phosphorus, we pour only as much water as to prevent ignition, and then plunge it into boiling water. The phosphorus fuses, and the impurities it contained float on the surface of the fluid phosphorus: we plunge the tube into cold water, and when the phosphorus becomes solid, it is removed: the upper part of the stick, where the impurities settled, is rejected as unfit for use. It may be preserved in water: after a lapse of many years its exterior becomes white. Transparent phosphorus produces this white coating in the same manner as transparent sulphur produces the non-transparent sulphur in sticks. If the phosphorus has a red exterior, we can obtain it again perfectly clear, by heating it under water, to which a small portion of nitric acid is added.

Phosphorus signifies light-bearer, *φῶς*, *φέρω*.

Phosphorus and Hydrogen.

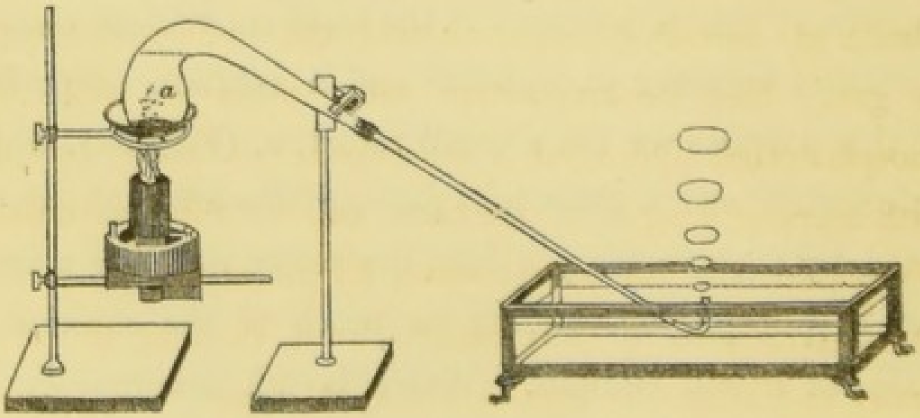
These two substances combine with each other, but in one proportion; this is procured in the most convenient manner by heating together phosphorus and a solution of potash. For this purpose we use a small retort, *a*, (Fig. 38), which is connected with a glass tube passing into a trough, and is heated by a spirit lamp. Into the retort we place a small piece of phosphorus, adding as much of the solution of potash as it will contain. Water is not decomposed by zinc alone; in order that this effect should take place, the affinity of the zinc for oxygen should be increased by the affinity of the additional sulphuric acid for the oxide of zinc; so also in this experiment phosphorus acts towards water in a similar manner.

Fig. 38.



Phosphorus alone does not decompose water, but the affinity of potash for hypophosphorous acid being added, then the decomposition takes place. The oxygen of the water oxidises one part of the phosphorus, forming hypophosphorous acid, which combines with the potash: another part of

Fig. 39.



the phosphorus combines with the hydrogen, and a spontaneously inflammable gas comes off, which rises in bubbles from the phosphorus. The first bubbles ignite in the air which is in the retort; and, consequently, if the retort is not entirely filled with the solution of potash, an explosion takes place so violent, as to shatter the apparatus: for this reason we must heat the retort slowly, that no large bubbles may form. By allowing the glass tube (Fig. 39) to pass just under the surface of the water, the bubbles inflame when they come in contact with the air, accompanied with a slight detonation. A beautiful round ring of smoke forms and rises in the atmosphere. By placing a cylinder of oxygen gas over the glass tube, the bubbles kindle with intense light in the oxygen. In performing this last experiment, we must take care to surround the cylinder with a small netting of iron wire, as it sometimes happens, that several bubbles pass over without igniting, and mix with the oxygen gas, till at last a similar bubble sets fire to the mixture; and a violent explosion is the consequence. If we boil a solution of hypophosphite of potash with an excess of potash, the water is decomposed; the oxygen combines with hypophosphorous acid, forming the highest degree of oxidation phosphorus admits of, namely phosphoric acid, the hydrogen escaping as gas. This decomposition takes place as well, while phosphoretted hydrogen is developed; so it may be mixed with more hydrogen at one time, and with less at another. We obtain it in the purest state, by mixing small sticks of phosphorus with a little slaked lime, heating them gradually in a retort by means of a spirit lamp.

We procure this combination equally as well by heating phosphorous or hypophosphorous acid. The acid, and the water which is combined with it, are decomposed, the acid gives off a part of its phosphorus, which combines with the hydrogen of the water, forming phosphoretted hydrogen, which is given off as a colourless gas; the oxygen of the water combines with the acid, and thus these two acids are converted into phosphoric acid, as well by giving off a part of the phosphorus, as by absorbing oxygen from the water. Phosphoretted hydrogen prepared in this manner does not inflame spontaneously; by allowing it to remain a short time, more particularly in contact with the atmospheric air, it ignites of itself; on the other hand, the inflammable gas loses this property of self-ignition, if kept long, though it be not decomposed. It is most probable that the above-mentioned property depends on a small quantity of phosphorus being present in the gas, which may be so inconsiderable that it cannot be detected by analysis.

Phosphorus, in the form of gas, may be mixed with hydrogen, or be mechanically suspended, as atoms in the air; and such mechanically mixed phosphorus can be in a more or less degree inflammable. Phosphoretted hydrogen gas, which has lost its inflammable properties, can recover them, by the addition of $\frac{1}{1000}$, or $\frac{1}{10,000}$ part of oxide of azote.

It is well known, that if hydrogen gas, at a low temperature comes in contact with phosphorus, it takes it up, and by allowing it to enter the air, it ignites, which evidently depends on the combustion of the vapour of phosphorus contained therein.

If phosphoretted hydrogen is collected over boiling water, it is perfectly colourless; it is however decomposed by common water, that has absorbed some atmospheric air. It has a very unpleasant odour, resembling stale fish. It is partly soluble in water, to which it communicates this odour.

The specific weight of phosphoretted hydrogen gas is found to be nearly 1·185; one vol., therefore, of phosphoretted hydrogen consists of $\frac{1}{4}$ vol. of the vapour of phosphorus, ($\frac{4·326}{4} = 1·0815$,) and $1\frac{1}{2}$ vol. of hydrogen gas ($0·0688 \times 1\frac{1}{2} = 1·032$). Even by a very accurate analysis, no difference has been found in the composition of this species of gas, whether it is of a self-combustible or incombustible nature. Phosphoretted hydrogen does not combine with bases; some metallic oxides and salts are decomposed by it, producing sometimes metallic phosphorets; at others, phosphoric acid, whence the metallic oxide is reduced to the metallic state, and water is formed. It unites with chloride of antimony, and also with hydriodic and hydrobromic acids, forming with the latter, very beautifully crystallizable combinations. By water each of these combinations is decomposed, and phosphoretted hydrogen is disengaged.

Phosphorus and Sulphur.

By fusing a piece of phosphorus in warm water, and adding sulphur in small parts, the two readily combine with each other. By taking equal parts, by weight, of each, the mass fuses at 43°. The combination of these two substances according to regular proportions is incontestable: this combination cannot be procured by fusion alone, as it dissolves phosphorus, as well as sulphur, which cannot be separated from the combination. By adding to this heated mass more sulphur, the sulphur crystallizes on cooling; by adding however phosphorus, the crystals of phosphorus separate at a lower temperature. By preserving the combination under water, it acquires the odour of sulphuretted hydrogen, and contains phosphorous acid. By boiling this combination with water, the sulphuretted hydrogen gas is given off, and sometimes an explosion takes place. This combination is more inflammable than phosphorus.

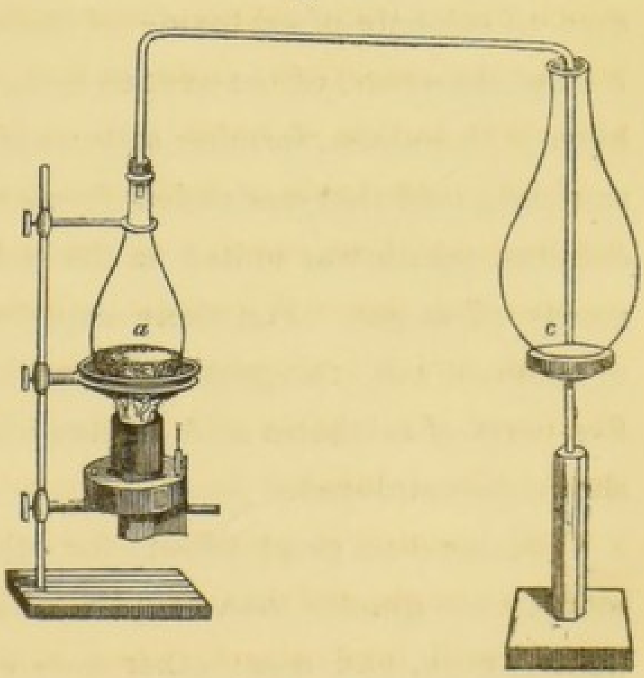
CHLORINE.

Chlorine is, at a common temperature, a gaseous body, which differs from oxygen, hydrogen, and nitrogen gases, which are colourless, from having a peculiar tint, from whence it derives its name, χλωρὸς, yellowish green.

If we inhale azote or hydrogen gas, life is extinguished, not because these species of gases are really deadly, but because the chemical process, which can arise only from oxygen, and is a necessary condition for the preservation of animal life, cannot take place. Chlorine, on the other hand, kills if inhaled in large quantities, as a poison; in a small quantity it produces a sensation of dryness in the nostrils, cough, and anxiety. These symptoms are easily transformed into catarrh, which is attended with pain in the head, and slight feverish attack. Chlorine gas is nearly $2\frac{1}{2}$ times heavier, than atmospheric air; its specific weight is 2·44. If chlorine be condensed so as to occupy only a fourth or fifth of its former space, it becomes fluid. Fluid chlorine is of a yellowish green colour, has a specific weight of 1·33, but up to this day has never been produced in a solid form at any temperature.

Chlorine gas is procured in small quantities in the easiest manner, by pouring hydrochloric acid on peroxide of manganese, submitting it to heat. Hydrochloric acid is the common name for a combination, dissolved in water, of chlorine and hydrogen. The whole quantity of oxygen of the peroxide of manganese, combines with the hydrogen of the acid; the manganese, however, can only combine with half of the chlorine thus set free, the other half escapes as gas. We use a spacious flask, heated by a sand bath (Fig. 40). The peroxide of manganese is first introduced in a fine powder, and the necessary acid at once, diluted with as much water, as will prevent fumes. In many experiments we collect chlorine over water; but it must be done rapidly, otherwise it

Fig. 40.



will be absorbed by water: one measure of water absorbs somewhat more than two measures of chlorine. Over mercury we cannot collect it, as it combines with chlorine at the common temperature of the atmospheric air. If we wish to fill a bottle, we conduct the tube by which the gas escapes to the very bottom of the flask *c*. The chlorine that is given off displaces the air, which is much lighter, from the flask, and the process is concluded when the chlorine, which is easily known by its colour, rises to the neck.

Chlorine is equally as well obtained from common salt, which consists of chlorine and sodium, which is a simple body, and belongs to the class of metals. With the common salt, peroxide of manganese is mixed, and is placed in a retort, on which sulphuric acid is poured. When the retort is gently heated, chlorine escapes as gas. Sulphuric acid and peroxide of manganese, when heated together, give off sulphate of protoxide of manganese, and oxygen: instead, however, of the oxygen coming off as a gas, it combines with sodium, forming soda; which, with a part of the sulphuric acid that was added, forms sulphate of soda. The chlorine, which was united to the sodium, is set free, and comes off as gas. For these experiments,—to three parts of common salt, two parts of peroxide of manganese, and five parts of sulphuric acid, diluted with four parts of water, should be employed.

Chlorine has great affinity for other simple bodies; for many, even greater than oxygen. Chlorine, if heated with potash, soda, and many other metallic oxides, decomposes these combinations, so that a metallic chloride is formed, and oxygen escapes as gas. This experiment may be easily performed in a globe, in which a metallic oxide is placed, and heated, through which we allow chlorine to pass, in the same manner as was employed for the reduction of oxide of copper by hydrogen gas. On the other hand, alumina is not decomposed by chlorine; as this metal has a greater affinity for oxygen.

Chlorine combines with many metals, without the aid of warmth, with disengagement of heat and light; thus a shower of sparks is formed, by dropping into a jar, filled with chlorine gas, finely pulverized antimony. Should there be two combinations of chlorine with the same body, the one that contains the least chlorine is called a chloruret, and that which contains the most, a chloride. Chlorine combines with oxygen in three different proportions.

With hydrogen, chlorine combines, but in one proportion, forming hydrochloric acid, a solution of which, in water, is known by the name of muriatic acid, and is of the highest importance to the chemist. By mixing one volume of chlorine gas, and one volume of hydrogen gas with each other, and igniting the mixture by means of a burning body, or an electric spark, the combination takes place with an explosion; and these form hydrochloric acid, with white fumes, if the gases are moist, or if water be present. By mixing these two gases in the dark, or in an artificial light, they do not combine; if this mixture takes place in daylight, the combination is slow; and if water be added, and an accurate proportion of each gas is taken, the gases disappear entirely after a little time, and the hydrochloric acid that was formed is immediately absorbed by the water. In sunshine this combination takes place with a violent explosion. This mixture is made in a small flask of perfectly white glass, and in a darkened room, covering the vessel with great care; by withdrawing the cover hastily, and placing it in the open air in such a direction that the rays of the sun may fall on it, the experiment is accomplished. The violet rays of the sun can alone affect the combination; by forming the mixture, therefore, in a green flask, no explosion takes place.

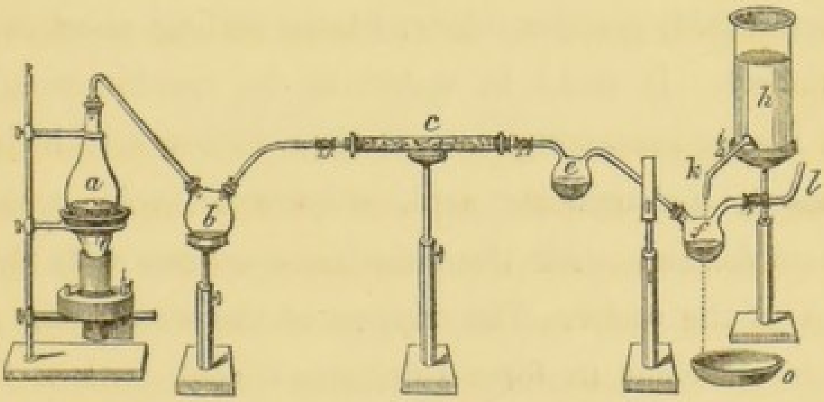
From its great affinity for hydrogen, chlorine decomposes very readily various organic substances. By placing in chlorine gas, a vegetable colour, for instance litmus, or paper coloured with litmus, the tint immediately disappears, and the paper becomes blanched. Colours are regular combinations of hydrogen, carbon, and oxygen, to which in some, as indigo, nitrogen is properly combined: if this chemical mixture changes, a new combination results, which is acted on in the same manner as the former by light.

The disagreeable odour proceeding from substances advanced in putrefaction, depends on the organic chemical combinations floating in the atmosphere; if a little chlorine is introduced into the air, the odour in a moment disappears, and the organic combination is decomposed. Organic substances, as they are suspended in the air, or in a state of solution as gases, carry infectious diseases from one individual to another; they are, however, present in such minute quantities, that we cannot present them to observation by any chemical means. It is, however, practicable to destroy them in the air, by means of chlorine; a proof that infectious diseases, even if no contact has actually taken place, may be spread through ponderable substances. Chlorine decomposes water; by exposing a solution of chlorine in water to the rays of the sun, oxygen is developed, till all the chlorine in solution has formed hydrochloric acid.

Chlorine and Sulphur.

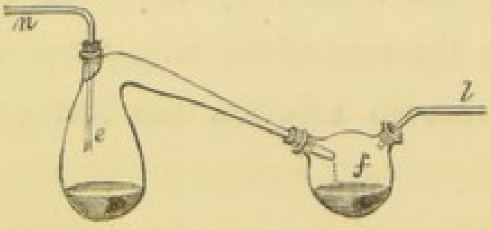
Small quantities of chloride of sulphur we can easily procure in the apparatus, which we use for decomposing, by chlorine, metallic combinations. Chlorine contains, particularly if heat be employed in its preparation, some hydrochloric acid and water; these are, for the most part, separated in the receiver, *b,* (Fig. 41,) the gas passes from thence through the tube, *c,* containing chloride of calcium, which absorbs all the water; so that it arrives, perfectly

Fig. 41.



anhydrous, in the globe, *e*, containing the substance which is to combine with the chlorine. If this is sulphur, it must be heated gently. Chlorine and sulphur combine together, and pass over into the globe, *f*, (Fig. 42). This is constantly kept cool by a stream of cold water dropping on it: this may be allowed to fall in a larger or smaller quantity, by opening, more or less, the cock, *i* (Fig. 41 :) the superfluous chlorine passes through the pipe, *l*, into the external air. Before commencing operations, it will be necessary to examine carefully, whether the apparatus closes tightly. In this manner more than an ounce of this combination may be procured very quickly. Should we wish to obtain large quantities of chloruret of sulphur, or similar combinations with chlorine, we must make use of an apparatus of larger dimensions.

Fig. 42.



Distilled chloruret of sulphur is a yellowish red fluid, of a disagreeable, peculiar odour, whose boiling point is 346° Fahrenheit. It sinks in water, as its specific weight is 1·687 ; after remaining a short time in contact, it is decomposed, hydrochloric acid, sulphurous acid, and sulphur are formed. All the chlorine combines with the hydrogen of the water. The oxygen of the water, that is set free, is sufficient to form sulphurous acid, with a fourth of the sulphur ; the other three-fourths are separated as solid sulphur. According to analysis, chloruret of sulphur consists of 100 parts of sulphur, and 110 parts chlorine.

The specific weight of the same, in a gaseous state, is 4·658; one volume of chloruret of sulphur vapour, consists of $\frac{1}{3}$d volume of sulphur vapour, ($\frac{6\cdot654}{3} = 2\cdot218$), and one volume of chlorine gas (2·44).

By allowing chlorine gas to pass over this chloruret for some time, we obtain a dull red combination, viz. chloride of sulphur, in which, with the same quantity of sulphur, twice as much chlorine is combined. By distilling in a stream of chlorine gas, it can be procured almost pure from the first combination. Its boiling point is 175°, its specific weight amounts to 1·620. The specific weight of this vapour is found to be near 3·549, therefore one volume contains $\frac{1}{6}$ volume of sulphur, and one volume of chlorine.

By dissolving sulphur in chloruret of sulphur, the temperature of the fluid sinks, as is the case with the solution of a salt in water. Chloruret of sulphur dissolves sulphur and selenium, in a greater proportion at a high temperature, than at a low. On cooling a warm solution, saturated with sulphur, we obtain beautiful crystals: selenium does not separate into crystals at all recognizable.

Chlorine and Selenium.

Selenium combines in two proportions with chlorine. This combination is produced in the same manner as that of sulphur; that containing the most chlorine, is solid and white, forming, when the water is decomposed, hydrochloric and selenious acids. The combination containing the least chlorine is brown and volatile, dissolving selenium.

Chlorine and Phosphorus.

These combine in two different proportions. We may procure them in the same manner as chloruret of sulphur, only phosphorus, which is carefully dried by means of blotting paper, is placed in the globe *e* (Fig. 41). In the commencement, the globe must be heated; the combination takes place, accompanied with evolution of heat and light. If we wish to obtain chloride of phosphorus with the greatest quantity of phosphorus, we heat the globe constantly, so that the chloride of phosphorus, when formed, passes over, and vapour of phosphorus is found in the globe; the operation must be interrupted, as soon as the phosphorus has disappeared.

If we wish to obtain chloride of phosphorus with excess of chlorine, we heat the globe now and then, so that chlorine be present in greater quantity; and the development of gas is continued till no more fluid chloride of phosphorus is found in the ball *e*, nor in the globe *f;* at last all is distilled over into the globe *f*.

The white crystalline combination we procure from an excess of chlorine, boils at about 365°; somewhat under this it is a fluid, so that the point at which it is a fluid, and that, at which it boils, are not far removed from each other. Warmed, it volatilizes without fusing, and soon settles on the cold parts of the receiver in a solid state. This operation, whereby we can procure it pure, is termed sublimation. The fluid combination contains phosphorus in solution, from whence it is separated by distillation; it is perfectly clear, very fluid, and sinks in water; its specific weight is 1·45. It boils at 205°. Both combinations are decomposed on coming into contact with water. The solid combination forms phosphoretted hydrogen and phosphoric acid, the fluid combination hydrochloric and phosphorous acids; if it contains phosphorus in solution, it is precipitated as a body, insoluble in water.

The specific weight of the gas of the fluid combination is 4·742; therefore one volume of this gaseous chloride of phosphorus consists of $\frac{1}{4}$ volume of phosphorus, ($\frac{4·326}{4}=$ 1·0815,) and $1\frac{1}{2}$ volume of chlorine ($2·44 \times 1\frac{1}{2}=3·66$). The specific weight of gas in the solid form, is nearly 4·788; one volume of this gas contains $\frac{1}{6}$ volume of vapour of phosphorus (0·721), and $1\frac{2}{3}$ of chlorine gas (4·076). By knowing how much chlorine and phosphorus are contained in the fluid or solid combination, we can, since the composition of water is known, easily ascertain the composition of phosphorous or phosphoric acid. The composition of phosphorous acid is calculated in this manner: by analysis, the fluid combination consists of 100 parts of phosphorus, and 338·49 of chlorine; one volume of chlorine combines with one volume of hydrogen, forming hydrochloric acid; and since two volumes of hydrogen combine with one of oxygen, forming water, so then, for each volume of chlorine, if the water is decomposed, half a measure of oxygen is separated. The specific weight of chlorine gas amounts, according to accurate calculations, to 2·44, that of oxygen gas to 1·1026; consequently the weight of a volume of chlorine gas, is to half a volume of oxygen gas, as 2·44 to 0·5513, or 1 to 0·22594. Thus 338·49 parts of chlorine, combining with the hydrogen of the water thus decomposed, sets free 76·4 parts of oxygen, which combining with 100 parts of phosphorus, that were united to chlorine, form phosphorous acid.

In the same manner the composition of the solid combination may also be ascertained, as we know that when moistened with water, it gives off hydrochloric and phosphoric acids. From analysis we have found, that 100 parts of phosphorus combine with 127·45 parts of oxygen, by weight; then 0·5513 is to 2·44, as 1 to 4·4265. In order, therefore, that 100 parts of phosphorus should combine with 127·45 parts of oxygen, it is necessary that they should combine with 564.1 (127·45 × 4·4265) parts of chlorine. From this example, we see how easily we can ascertain from the combination of oxygen, the combination also of chlorine, or one from the other reciprocally; according to the calculation of the composition of the body by weight, whichever is considered the most correct; so that at one time one plan, and at another the other, may be followed, according as we can most readily arrive at the exact combination of chlorine or oxygen.

This case occurs to all the metallic oxides, which, coming in contact with hydrochloric acid, give off metallic chlorides and water, as well as to all combinations of chlorine, which give off hydrochloric acid, and a degree of oxidation of the body, with which chlorine unites.

Thus, with such a combination of chlorine, the degree of oxidation also corresponds. In chlorides of phosphorus, the fluid combinations correspond with phosphorous, and the solid with phosphoric acid. A combination of chlorine, corresponding with the lowest degree of oxidation, of phosphorus does not appear to exist; for if phosphorus is brought in contact with fluid chloride of phosphorus, the higher the temperature is, so much the more is dissolved; on cooling, almost all the phosphorus crystallizes.

Chlorine and Water.

By filling a flask with chlorine gas, and pouring a little water on it, and allowing it to cool to the freezing point; or conducting chlorine gas into water at the freezing point, the chlorine combines with water, forming a crystalline mass, which is separated from the water that is present by means of thick blotting paper. This mass is placed in a bent tube, which is closed at both ends; it is then heated to 40°: the combination is decomposed into chlorine gas and water; if the chlorine can escape free. The crystals are of a pale yellow colour, and very volatile, so that they sublime from one part of the tube to another, which is cooler, as is the case with camphor. They contain only 28 per cent. of chlorine.

By plunging one end of the tube *a*, (Fig. 44,) in which the crystals are situated, into warm water, from 104° to 106°, they disappear, and there form two fluid layers; the upper one appears to be only a solution saturated with chlorine in water, and the under one fluid chlorine, which separates as a dark oleaginous body. If the other end, *b*, is cooled, the chlorine is condensed.

Fig. 43.

By cooling the tube to 80° Fahrenheit, then the chlorine and water combine again with each other, and the same crystals result. This substance offers one of the most remarkable examples of a simple body combining with a compound one; before a similar combination of bromine with water was discovered, it was the only example of the combination of a simple body with water.

BROMINE.

Bromine is fluid at a common temperature; from $-8°$ to $-13°$ Fahrenheit, it is solid, and forms a crystalline leafy mass. A drop of bromine mixes with the air contained in a flask, as quickly as gas: the colour of bromine is a brown red. Fluid bromine, in thin layers or small drops, is of a hyacinth red (red with a disposition to yellow) colour; this, in large quantities, is so intense, that it appears opaque and black.

Fluid bromine is about three times heavier than water; its specific weight in a gaseous form is ascertained accurately to be 5·3933. Bromine, as chlorine, is a poison, and has a peculiar unpleasant odour, as the name, which has been given the body, "Βρῶμος," signifies an unpleasant odour.

With regard to its affinity for bodies, bromine resembles chlorine, and also produces similar phenomena. As chlorine, bromine also decomposes many metallic oxides at a high temperature, as potash, soda, and others, inasmuch as it combines with the metal and expels the oxygen.

Magnesia and alumina are not affected; but with antimony and tin, it combines, producing an evolution of light. For oxygen, bromine has but a slight affinity; with hydrogen it combines, it is true, directly, but only with difficulty. By light of the sun, the combination is not effected; by means of a heated wire, these two gases unite, but only at that point where the wire is plunged into the mixture.

Indirectly, this combination may be prepared in different ways. With regard to colouring matters, bromine exerts the same influence as chlorine; organic dying matters are decomposed by it. Bromine combines directly with chlorine; so also with sulphur, phosphorus, and selenium. These combinations are quite analogous to those of chlorine with the same bodies, only the affinity of bromine is weaker. By distillation we can procure no regular combination of bromine with sulphur. Bromine combines, as chlorine, with water at 32° Fahrenheit, forming a red crystallizable combination, which remains unchanged at 66°; but, at a higher temperature, it separates into bromine and water: it contains 28 per cent. of bromine.

IODINE.

At common temperature, iodine is a solid body, which is easily obtained in crystals, by allowing it to sublime slowly, or by fusing and cooling; or by exposing a solution of hydriodic acid to the atmosphere. Water dissolves iodine but sparingly; it cannot take up more than $\frac{1}{7000}$ part; if, however, certain salts, for instance, sulphate of ammonia, hydrochlorate of ammonia, or hydriodic acid be dissolved in water, considerably more can be taken up. By exposing to the air a solution of hydriodic acid in water, the oxygen of the air gradually combines with the hydrogen of the hydriodic acid, and iodine remains in the solution, which it deeply stains. If by degrees, all the hydriodic acid be decomposed, the iodine, in a state of solution, separates from the fluid in large and beautiful crystals. The specific weight of solid iodine is 4·947. At 273° Fahrenheit iodine fuses; at 428° to 440° it boils, forming a beautifully coloured gas; from the colour of which it derives its name, *τὸ ἴον*, signifying violet, with an inclination to purple red.

The specific weight of this vapour, calculated accurately, amounts to 8·7011; it is the heaviest of all known gases. At a common temperature, iodine exposed to the open air evaporates gradually. The smell of iodine is very similar to that of chlorine. Iodine, dissolved in water, does not blanch vegetable colours. It does not produce so destructive an effect on organic substances as chlorine; with many it even combines, for instance, gum, starch, and sugar. It colours the skin brown; the stain, however, soon passes off: paper, linen, and wood are also coloured brown, but here the mark is permanent. The combination with starch is a beautiful purple or violet colour; and if much iodine is present, such a deep colour arises, that it appears blue:

dissolved in potash, and precipitated by an acid it has a blue tint; and from this we can discover from one to two millionth part of iodine, in a fluid, which must be rendered acid by nitric acid, to decompose the combination of iodine contained therein.

Iodine has but a very slight affinity for oxygen.

Iodine and sulphur fuse together at a gentle heat; if heated more intensely, iodine comes off as gas, mixed with sulphur vapour; the sulphur settles. Iodine and phosphorus combine if fused with each other, heat being evolved: the melted mass is decomposed, if moistened with water; so that the hydrogen of the water combines with the iodine, and the oxygen with the phosphorus. In an excess of iodine, it separates, dissolved in hydriodic acid; and, in proportion as more phosphorus is taken up, phosphoric or phosphorous acids are obtained, and phosphorus, which separates.

By pouring into a flask filled with chlorine gas, small quantities of iodine, a brown body forms, which, combining with a larger proportion of chlorine, becomes converted into a solid crystallizable mass. In excess of iodine we obtain a brown combination: this combination, if saturated with chlorine, becomes colourless; if, however, it contains chlorine in solution, it is rendered yellowish. This combination is probably dissolved in water, without being decomposed. By decomposing such a solution with potash, a large quantity of iodine is precipitated each time; by decomposing water, chlorine and an unknown degree of oxidation of iodine must be held in solution. Iodine is a violent poison; in small doses, it is administered in bronchocele.

Bromine is found combined with magnesium in sea-water, and mineral springs; and iodine with sodium, in various plants which grow on the sea-shore.

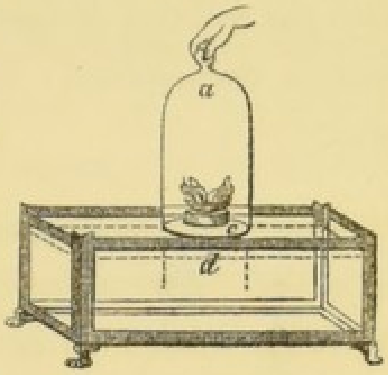
FLUORINE.

Persons have succeeded in separating fluorine from fluoret of silver, by means of chlorine; but the affinity of fluorine for other substances is so great, that, as soon as it is set free, it combines with the ingredients of the vessel itself. By placing fluoret of silver in a glass, and allowing chlorine to pass over it, so that the fluorine is set free, it combines immediately with silicium, which, combining with oxygen, forms silica, which is a component of glass, and the oxygen is set free. If this operation takes place in platinum vessels, fluoret of platinum is formed. Fluorine has a most remarkable affinity for most bodies. Combinations of fluorine with oxygen, chlorine, iodine, bromine, carbon, and azote have not yet been discovered.

NITROGEN, OR AZOTE.

In the experiments on combustion in oxygen gas, the result was, that the atmosphere contained oxygen, as well as another gas which cannot support combustion, and cannot combine directly with any combustible bodies. The preparation of this gas is very easy, by allowing some inflammable body, confined in atmospheric air, to combine with oxygen gas of the air. On a cork, *c*, (Fig. 44,) which floats on water in a large trough, we place a thin shell of porcelain. Into this shell a little alcohol is poured, which we kindle with a bit of ignited phosphorus; and over it place a bell-glass, *a*; the burning body is quickly extinguished, and the water rises in the inside of the bell.

Fig. 44.

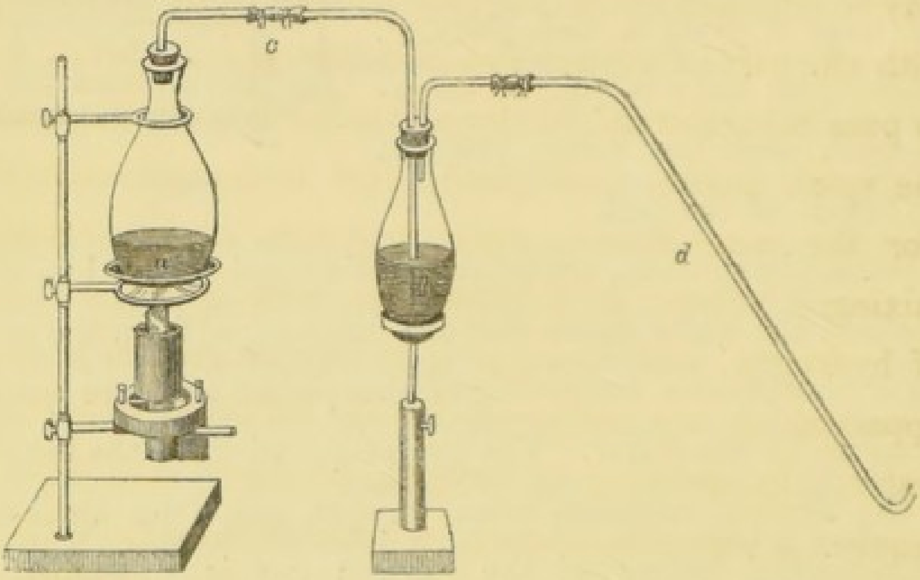


From phosphorus, azote gas is obtained purer than from alcohol; the white fumes that are disengaged from the burning of phosphorus, consisting of phosphoric acid, are quickly taken up by the water. The gas prepared from the burning of the alcohol contains some oxygen gas, (the alcohol is extinguished before all the oxygen gas is consumed) as well as carbonic acid, which is also ormed by the combustion of alcohol. To procure perfectly pure azote gas, we use a solution of ammonia in water.

Ammonia consists of azote and hydrogen. By adding to this combination, chlorine, a simple gaseous body, the chlorine combines with the hydrogen of the ammonia, forming hydrochloric acid, which combining with a portion of the ammonia, forms a salt, hydrochlorate of ammonia, or, if we choose to call the combination by its common name, sal ammoniac.

The azote of the ammonia, assumes, on the contrary, a gaseous form, and is disengaged with continual effervescence. In the flask, *a*, we place peroxide of manganese, upon which hydrochloric acid is poured. The gaseous chlorine that is given off passes through the glass tube, *c*, into the solution of ammonia, which is found in the flask, *b*, and is decomposed: the azote gas escapes through the waste pipe, *d*.

Fig. 45.



If the fluid is concentrated, that is to say, if there is much ammonia present, the chlorine acts in a violent manner, decomposing the ammonia with slight explosions and evolution of heat; this, however, may be prevented by the addition of a slight quantity of water. These explosions are, nevertheless, unattended with danger.

Nitrogen gas does not present any very characteristic properties: it is somewhat lighter than atmospheric air, free from colour, odour, and taste. Burning bodies are in a moment extinguished in it, as azote cannot combine directly with them. Animals die therein, not because these gases are noxious, but because air containing oxygen is a necessary condition for supporting animal life.

A mixture of azote and oxygen cannot combine through simple combustion, or by similar means, as employed in a mixture of hydrogen and oxygen, though azote and oxygen have affinity for each other; as there are four different combinations of these two substances. One of these is nitric acid, containing the greatest quantity of oxygen; it may be obtained by mixing four parts of moist nitrogen gas, with one part of oxygen gas, and allowing an electric spark to pass several hundred times through it. At the moment the spark passes, some nitric acid is formed each time. For the same reason, nitric acid may be generated, by mixing 1 volume of nitrogen gas, with 13 or 14 volumes of hydrogen, and igniting it in oxygen gas, in a similar apparatus as was employed for the artificial production of water. In speaking of oxygen, we have seen how iron requires a high temperature, in order to combine with oxygen; once kindled, the remaining iron, from the combustion of the iron itself, becomes gradually, as the combustion itself advances, heated to that temperature, which is necessary for its combustion. Nitrogen requires also a high temperature to be able to combine with oxygen: by the act of combination, a little heat only is evolved; so that, from the combination, the nearest parts of the nitrogen are not sufficiently heated, that its combination with oxygen might succeed. Mixed with hydrogen, the combustion of hydrogen produces the temperature which nitrogen requires for its combination with oxygen; besides, too, the water assists, with which nitric acid can combine. Nitrogen combines with oxygen in four different proportions: protoxide of nitrogen, oxide of nitrogen, nitrous and nitric acids.

With hydrogen, nitrogen forms ammonia, a strong base, and a problematically metallic substance, which cannot be found in an isolated state. Combined with carbon, it forms a very important body, cyanogen, which is found in most vegetable and in some animal substances. We are only acquainted with two combinations into which nitrogen enters with metals, namely, potassium and sodium. A combination of sulphur with nitrogen has been announced; the crystals of which are procured, if chloride of sulphur, in a solution of ammonia, be dropped into alcohol.

Phosphorus and Nitrogen.

By allowing fluid chloride of phosphorus, which is kept cool, to pass over dry ammoniacal gas, it is absorbed, and we obtain a whitish body, completely soluble in water, containing neutral phosphite of ammonia, and hydrochlorate of ammonia.

By heating this white body, sal ammoniac is given off, the chlorine combining with hydrogen of the ammonia; by heating hydrogen, phosphorus and ammonia escape; by continuing the heat till no further development of sal ammonia is observable, we then procure a loose white powder. It does not fuse at a strong red heat, nor volatilize; it is insoluble in water; and in almost all acids, as well as in alkalies; heated with the solid hydrates of which it gives off ammonia and phosphoric acid. It is not changed by hydrochloric acid; sulphuric acid does not dissolve it; concentrated sulphuric acid oxidizes it, producing phosphoric acid. Hydrogen, passing over this heated substance, decomposes it, without leaving a trace of water: heated with oxide of copper, it is completely decomposed, without water forming. In this decomposition is observed, neither chlorine, oxygen, hydrogen, phosphorus, nor nitrogen.

By chemical analysis, in which phosphorus is calculated in the same manner as phosphoric acid, this body consists of 52·56 parts of phosphorus, and 47·44 parts of nitrogen, or of $\frac{1}{2}$ of a volume of vapour of phosphorus, and 2 volumes of nitrogen gas. This substance is equally as well obtained by using, instead of chloride, bromide of phosphorus. By allowing the solid chloride of phosphorus to absorb ammonia, and pouring water on the resulting product, sal ammoniac is dissolved, and a white residue, which is obtained pure by boiling with a diluted solution of potash, remains: it is a combination of phosphoret of nitrogen and water. By allowing dry ammoniacal gas to pass over chloride of phosphorus, and pouring water on the mass that is obtained in a retort, a volatile body passes over with the water, which settles in the receiver in a crystalline form. These crystals are easily soluble in ether, and are again formed by evaporation. At 255° they fuse, and, if heated more intensely, they volatilize. From a solution of potash, nitric acid, sulphuric and hydrochloric acids, they undergo no change; conducted over hot iron, they give off nitrogen gas, chloride and phosphoret of iron; this substance consists of nitrogen, chlorine, and phosphorus.

Chlorine and Azote.

By filling a small bell glass with a solution of sal ammoniac, or any other ammoniacal salt, and placing it in a saucer containing the same solution, and allowing chlorine gas to enter the bell, the chlorine gas is absorbed, and the fluid appears of a yellow colour. On the surface of the fluid, oleaginous drops form, which soon sink to the bottom. The formation of this oleaginous body is much accelerated, if the fluid be raised to 95°. 100°; besides, it is advantageous that the solution should not be entirely saturated with sal ammoniac in water; that is to say, that there should not be dissolved as much sal ammoniac as it could possibly take up.

Sal ammoniac consists of hydrochloric acid and ammonia, which is composed of nitrogen and hydrogen. A part of the chlorine, which passes into the fluid, combines with the hydrogen of the ammonia, forming hydrochloric acid; the other part combines with the azote that was set free, forming the oleaginous body, which, as it is but slightly soluble in water, soon separates from the fluid, collects in drops, and sinks to the bottom, from being heavier than water. Its specific weight is 1·653.

The chloride of azote is an oleaginous fluid of a yellow orange colour, which, at 190°, distils over unchanged; at

240° it boils briskly, at 257° it explodes with a violent noise, and, at the moment of explosion, it becomes decomposed into azote and chlorine, and it appears that 1 volume of nitrogen and 3 of chlorine are formed. A fluid body, by this decomposition, becomes gaseous, and occupies about five hundred times more space. We can give a proof of the powerful effects of this rapid expansion, by placing a tea-cup on a loose bit of wood, and, in the cup, a drop of chloride of nitrogen, covered with a little water, and bringing into contact with it, a stick dipped in oil of olives or a heated piece of iron wire, a violent explosion takes place, the cup is shattered to pieces, and the fluid is thrown over.

On account of these violent effects, each experiment on chloride of nitrogen is accompanied with danger, which is much increased by the decomposition being occasioned by the most inconsiderable circumstances. When brought in contact with sulphur, carbon, metals, alcohol, resin, sugar, wax, and fat, it does not explode; with olive oil, turpentine, caoutchouc, on the contrary, it explodes, and, most violently of all, with phosphorus.

As this combination is only of importance in a scientific point of view, and all that deserves observation can be well understood without experiment, it would, therefore, be absurd to incur any risk with so dangerous a body.

Its discoverer, M. Dulong, had his hand dreadfully mutilated, and his eye dangerously injured by an explosion, whilst performing an experiment on its properties.

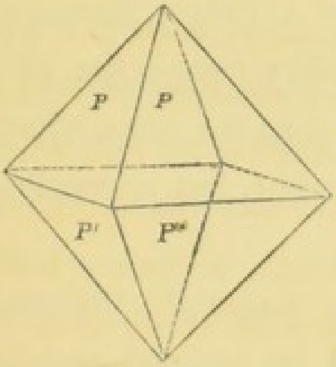
Iodine and Nitrogen.

By boiling a mixture of hydrochloric acid and nitric acid with an excess of iodine, a part of the oxygen of the nitric acid combines with the hydrogen of the hydrochloric acid, the chlorine of which combines with the hydrogen of the iodine, forming a brown solution, in which chloride of iodine is suspended. By adding to this solution, ammonia, so that chlorine combines with the hydrogen of the ammonia, and iodine with azote, a brown body falls to the bottom, which has the external appearance of a thick black powder. This combination is as dangerous as chloride of nitrogen; if we employ very small quantities of iodine, for instance, a grain, the combination is a solid body, which injures the eyes from its colour, but is prepared without danger. We must immediately filter the sediment whilst it is yet moist, dividing it into very small particles, and then the filtering machine should be broken. When dry, it explodes with the slightest touch, sometimes even of itself. This method is more easy and less dangerous than by pouring iodine on ammonia; one part of the ammonia is decomposed, and hydriodate of ammonia and iodide of nitrogen are produced.

CARBON.

Nature presents us with carbon, in its greatest purity, in the shape of the diamond, which is discovered in Golkonda, Vesapour, and the Brazils. It is seldom found in the octohedral form, with plane faces, (an octohedral body is terminated by eight similar, even-sided faces, (Fig.46); it usually has a great number of curved faces, which are the secondary faces of an octohedron; it is, however, always cleaveable, according to the face of the octohedron, and has a peculiar and remarkable lustre. The surface of a raw diamond is commonly rough. A diamond is perfectly colourless, if pure; sometimes it is found of a clear brown, yellowish tint, rose, green, or blue. These colours depend, doubtless, on foreign bodies. Its specific weight is 3·5 to 3·55. It scratches all known bodies; it is, therefore, the hardest substance that exists.

Fig. 46.



The hardness of a body we calculate by the relative proportion it bears to another; for this purpose, we select certain substances, which have a peculiar property for such trials. Carbonate of lime (calcareous spar) is, for instance, scratched by fluor spar, fluor spar by quartz, quartz by diamond; the hardness of these bodies, is, therefore, given according to proportions: glass is scratched by quartz, glass scratches fluor spar; glass is, consequently, harder than fluor spar, and softer than quartz.

More intermediate degrees might be given, than between these three bodies; but the hardness is sufficiently determined, though it is impossible to give it in numbers. We cannot say that one substance is a regular number of times harder than another; the hardness of a body cannot be given, as we calculate its heaviness, by its specific weight. The diamond does not only scratch, but it also cuts glass; a scratching body operates as a saw, and a cutting body, as a hatchet. Cutting glass by means of a rough diamond, depends on this reason, namely, secondary faces; the surface of a rough diamond is crooked, so that the edge, which is formed by two faces, is not a straight, but a crooked line.

If, therefore, we cut glass with a diamond, the two faces, forming the crooked line, should be inclined equally against the plate of glass, and, accordingly, we draw a line with the edge, which these two inclined faces form; on whichever part of the line a slight pressure is made, the glass splits, according to the direction of this line.

Polished diamonds, such as we generally find them, do not divide glass whilst the angles form straight lines; if they are cut with crooked edges, they readily divide glass. The ruby, quartz, and other substances, which are harder than glass, if they are cut with crooked edges, in a similar manner as a diamond, would cut glass equally as well as it; they, however, often wear out, from not being so hard as a diamond.

The diamond, as well as carbon in any other form, does not fuse at any temperature that can be produced: no access of air must be allowed. We can, however, render a diamond hot, if wrapped in powder of carbon, or in a vacuum; or in those gases which contain no oxygen, until the highest degree of heat be attained, without its being fused.

Persons have fancied they have fused the points of carbon, which have been used as the conductors of electric fluid, and therefore heated to a very high degree; but it was only the ashes of the carbon, which have been fused on the surface of the points.

The infusibility of carbon is the reason that it has so varied an appearance, when procured from organic substances containing it. Coals and wood contain carbon, oxygen, and hydrogen; by heat, these two last substances combine partly with each other, and partly with carbon, giving off volatile productions: the residue is almost entirely pure charcoal. Coals which do not soften by heat, (or cake, as it is called,) produce a thick, heavy kind of charcoal, differing much in appearance from the light and porous carbon from coals which become soft and swell up, giving off different gases. That kind of charcoal we procure free from gaseous ingredients, from coals, is termed coke.

Wood neither fuses nor becomes soft; the charcoal remains in the form of wood, as a porous mass, which depends on the volatile parts being expelled by heat. Hard wood leaves a heavy solid charcoal; from soft wood it is of a lighter and looser texture. Charcoal, if heated intensely, changes its properties, becomes hard like horn, heavy and thick, and with difficulty inflammable; this is also the case with coke, which has been used in furnaces, and exposed to the great heat required for smelting iron.

Animal substances fuse entirely, when heated; the gases are given off, which cause the ebullition of the mass, leaving, from the consequent decomposition, a very porous charcoal.

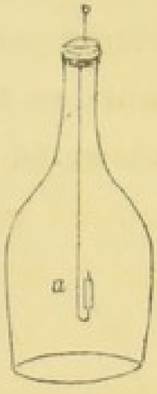
If we were in a situation to be able to dissolve carbon, to fuse or sublime it, we should be enabled, by one of these methods to produce it in the form of crystals, and most probably fabricate diamonds.

In science, this experiment, up to the present day, appears to have no further interest, than a similar one, by which, from a solution of sulphur in various fluids, we can procure crystals of sulphur, perfectly resembling those we find in nature.

Still, however, there is a means of dissolving charcoal, namely, cast iron in a state of fusion; by bringing this in contact with an excess of charcoal, the latter becomes dissolved, and separates, on cooling, from the fluid iron, in beautiful and foliated crystals. This crystallized charcoal is termed graphite or plumbago; it is perfectly opaque, soft to the touch, has a metallic lustre, and its specific weight is about 2·5. It is the same substance as discovered in primitive soils, and those parts of the earth which were once fluid at a higher temperature. The purest kind is found in Borrowdale in Cumberland, and pencils are formed from it.

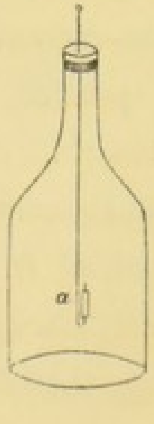
Besides this substance, there is found also a carbonaceous body in nature, nearly in a state of purity, which burns without flame or smell, and is known by the name of anthracite, which resembles common coal. Two bodies, differing so entirely in external properties, as the diamond and graphite, may, however, be very similar in chemical relation, as we have already observed, in the instance of sulphur, which, heated above 390° and plunged into cold water, forms a brown pliable mass, very unlike the brittle yellow sulphur, which is procured on slow cooling.

Fig. 47.



On burning charcoal in atmospheric air, it entirely disappears, leaving but a few ashes, consisting of foreign bodies mixed with it. In oxygen this combustion proceeds more rapidly. By placing a piece of charcoal at the end of a wire, in a state of ignition, into a flask (Fig. 47), it burns briskly, and surrounds itself with a small flame. It arises when the oxygen and charcoal come in contact; the lowest degree of oxidation of the charcoal, oxide of carbon gas, is formed, which, combining with the additional oxygen gas in excess, forms carbonic acid. The charcoal disappears, and the gases in the flask remain perfectly colourless. The light kinds of coal burn as charcoal in the open air; the combustion of more compact coal, as the heavy coke, can only take place by the assistance of bellows or some other means. Neither graphite nor diamond burn in atmospheric air; in oxygen gas they are entirely consumed without any residue. To consume a diamond in oxygen, a flask must be filled with the gas, and the diamond must be affixed to a piece of wire; it is first heated in a stream of oxygen by means of a spirit-lamp, and is then plunged into the flask (Fig. 48): it burns immediately and dis-

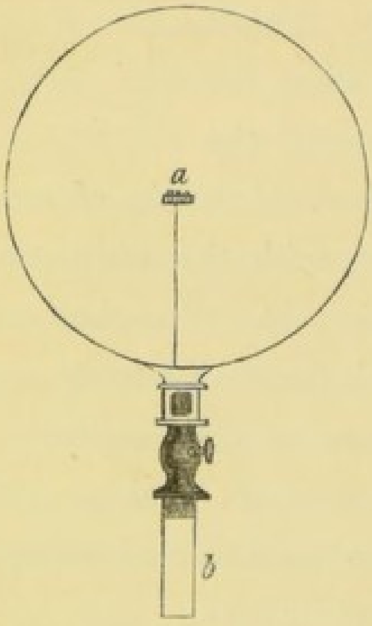
Fig. 48.



appears entirely. By pouring lime water into the flask, we obtain a white precipitate, which is carbonate of lime; the carbonic acid being formed by a combination of oxygen with the diamond.

As carbon combines with oxygen, forming a gaseous body, a question may be asked, whether the oxygen, combining with the carbon, occupies more or less space, or whether it remains the same? This question may be easily answered by means of an experiment. In a glass globe, (Fig. 49), several diamonds are introduced by an iron wire, which supports a small basket of platinum wire, *a*, and the air is exhausted from the globe which is filled with oxygen. The diamond is kindled by means of a burning glass, and it continues burning; when extinguished, the globe is cooled, and the extremity, *b*, is plunged into mercury, and the cock is turned; if the oxygen gas has contracted, since it has combined with the carbon, the mercury mounts into the pipe and globe; but if it has expanded, then the mercury is pressed down into the trough. Neither of these cases, however, does occur. It consequently follows, that the carbonic acid, which is formed from the combination of oxygen with carbon, exactly occupies the same space as oxygen itself. By knowing, therefore, the specific weight of carbonic acid, we have

Fig. 49.



only to deduct the specific weight of oxygen, to determine how much carbon has united with the oxygen.

Specific weight of carbonic acid, . . .	1·5245
,, ,, Oxygen gas, . . .	1·1026
Carbon .	0·4219

Therefore, 0·4219 : 1·1026 : : 100 : 261·34.
Or, . . . 1·5245 : 1·1026 : : 100 : 72·325.

100 parts of carbon, by weight, combine, therefore, with 261·34 parts of oxygen, by weight, to form carbonic acid, and 100 parts of carbonic acid contain 72·325 of oxygen, and 27·675 carbon.

From the consideration of the component parts of various carboniferous substances, it is very convenient to be able to give the carbon in a gaseous form, according to volume; as carbon is never rendered fluid at any temperature, so its weight is only hypothetically determined. The carbon in carbonic acid may be combined with one or two volumes of oxygen gas.

We are led to a right hypothesis in this manner, only by the proportions of two substances, both gaseous, which combine in one gaseous body.

We find, that if one volume of one gas combine with one volume of another, no contraction takes place; in binoxide of nitrogen, one volume of oxygen gas combines with one volume of nitrogen gas, forming two volumes of binoxide of nitrogen. One volume of chlorine gas and one volume of hydrogen gas, give off two volumes of hydrochloric acid gas. In protoxide of nitrogen, one volume of nitrogen gas and $\frac{1}{2}$ volume of oxygen gas so combine as to form one volume of protoxide of nitrogen; and one volume of hydrogen gas with $\frac{1}{2}$ volume of oxygen, gives off one volume of vapour of water.

One volume of oxygen gas combines with carbon, forming a volume of carbonic acid, and one volume of oxide of carbon gas, with $\frac{1}{2}$ volume of oxygen, forming one volume of carbonic acid; in one volume, therefore, of oxide of carbon gas, there is contained $\frac{1}{2}$ volume of oxygen gas. Carbonic acid has, therefore, an analogous relation to protoxide of nitrogen gas, and vapour of water, and carbonic oxide gas to binoxide of nitrogen gas; consequently one volume of carbonic acid contains $\frac{1}{2}$ of a volume, and one volume of the oxide of carbon gas also contains $\frac{1}{2}$ volume of vapour of carbon; therefore, the specific weight of this vapour amounts to 0·8438.

Besides carbonic acid and oxide of carbon gas, there are three other combinations of carbon with oxygen; oxalic acid, which is procured from different plants, in which it is generated by organic processes, or from oxidation of organic substances, and the other two are mellitic and croconic acids.

Charcoal surpasses, in its affinity for oxygen, at a high temperature, all other known bodies, and, as it is infusible, can be easily separated from it by combustion; and as its combinations with oxygen escape as gases, it has the property, above all other substances, of reducing metallic oxides, that is, of removing the oxygen from them, and of leaving the metal endowed with its peculiar characters. Charcoal combines with sulphur, chlorine, iodine, and bromine, with nitrogen and some metals. Its combinations with hydrogen, those of hydrogen and nitrogen; and such again with hydrogen, oxygen, and nitrogen, which form the principal ingredients of animals and plants, are of peculiar importance, and very numerous.

Charcoal has two very interesting properties, namely, the power of separating various organic substances from solutions, so as to render coloured fluids perfectly clear, and of condensing gaseous bodies, as a piece of charcoal, plunged in carbonic acid, absorbs 35 times more than its volume amounts to. These two properties are most conspicuous in charcoal, as being a most porous body, though they may be found in other substances, they offer an easy method of presenting a clear idea of the proportions, which solid, fluid, and gaseous bodies bear to each other.

CARBON AND HYDROGEN, COMBINATIONS OF CARBURETTED HYDROGEN.

The combinations of carbon, hydrogen, and oxygen, which partly fall under our observations, already formed in the animal and vegetable worlds, and partly produced by the chemical changes these combinations undergo, are found to be exceedingly numerous.

By mixing these substances with an excess of oxide of copper, or allowing them, either in a gaseous or very fluid state, to pass through a heated tube, filled with oxide of copper, the oxygen which combines with the carbon, forms carbonic acid, and, with the hydrogen, water.

If we join to the tube, containing oxide of copper, a pipe filled with chloride of calcium, and with this a tube containing a solution of potash, the carbonic acid becomes condensed in this, and the water in the other. From the additional weight of these tubes, we are enabled to calculate the quantity of water formed, and of the carbonic acid; and from these the quantity of hydrogen and carbon contained in the substance; and deducting this from the weight of the substance employed, we arrive at the volume of oxygen. If nitrogen be present, we connect to the tube, containing the solution of potash, a pipe, which passes under a bell glass, graduated according to a regular scale, in which the nitrogen is collected that is given off.

By this analysis we discover how much nitrogen, hydrogen, carbon, and oxygen a body contains, though not in the proportion they combine with each other; thus if, instead of oxide of copper, we examine aqueous nitrate of ammonia, we find only the weight of the component elements, though not what part of the nitrogen combines partly with oxygen in forming nitric acid, partly with hydrogen, producing ammonia; and the superfluous part of the hydrogen and oxygen that remains unite, forming water.

It is discovered by analysis, in what manner we may expel the ammonia by means of a stronger base, and the nitric acid, by means of a stronger acid, and also by synthesis, in which case, by adding nitric acid to ammonia, we form this combination. In the combinations which have been as yet treated, we can very seldom discover the means by which the elements combine with each other: they are partly united in such a peculiar manner, that neither the acid nor the base can be separated; partly, too, the combinations, which unite with each other, are easily decomposed either by means of high temperature, or of some powerful affinity, so that, before the base separates from the acid, both the base and acid are decomposed. The instance of benzin may tend to illustrate this opinion; it is a combination of similar volumes of hydrogen gas, and vapour of carbon, which are so intimately combined, that they cannot be set free. It is, as far as its combinations, of essential importance, in a scientific point of view, as it explains the method, by which many substances are composed and prepared, which are of the highest consequence both for common life and for the improvement of science, as sugar, alcohol.

BENZIN.

1 vol. of vapour of benzin = 3 vol. of vapour of carbon + 3 of hydrogen gas.

By mixing benzoic acid with a strong base in excess, sufficient to saturate a double quantity of benzoic acid (for instance, 1 part of benzoic acid with 3 parts of slaked lime) and submitting to distillation, water passes over at first, then a thin oily fluid, which floats on the surface of the water. By heating the mixture slowly, the residue in the retort is rendered perfectly colourless, and, when dissolved in an acid, not a trace is left, carbonic acid alone being formed. The solution in acid is colourless, giving off, when distilled, no gas; the benzoic acid is converted into carbonic acid and an oily fluid. The oleaginous fluid can be entirely separated from water, by means of decanting, agitating a little with potash, and distilling. By allowing potassium to be some time in contact with this fluid, or by distilling them together, the surface of the potassium still retains its metallic lustre, the fluid, therefore, contains no oxygen. As this fluid is derived from benzoic acid, the name benzin has been given to express such combinations as it forms. This substance can be procured equally as well in the preparation of gas from oil, mixed with other combinations of carbon and hydrogen, as well as in distilling with an excess of base, those substances which contain benzoic acid, and in whose decomposition benzoic acid is formed.

Benzin is clear, colourless, and of a peculiar pleasant ethereal smell; its specific weight is 0·85, and it boils at 210°. Placed in ice, it becomes solid, forming a crystallized mass, which becomes fluid at 48°, is easily soluble in alcohol and ether, but slightly in water, though quite sufficient to be able to impregnate strongly the water with its smell. Sulphuric acid of the specific weight of 1·85 does not dissolve it, nor produce any alteration, though they may be distilled together; this is the case too, with hydrochloric and many other strong acids. Benzin analysed by means of oxide of copper, consists of similar volumes of the vapour of carbon and hydrogen.

100 parts contain 92·46 carbon.
7·54 hydrogen.

The specific weight of the vapour of benzin is 2.77.

Thus, according to analysis, in 2·77 parts of benzin 0.209 ($\frac{2{\cdot}77 \times 7{\cdot}54}{100}$) of hydrogen, and 2·56 ($\frac{2{\cdot}77 \times 92{\cdot}46}{100}$) of carbon are contained.

$$\left.\begin{array}{l}\text{Therefore 1 vol. of vap.}\\ \text{of benzin} = (2{\cdot}7378)\end{array}\right\} = \left\{\begin{array}{l}3 \text{ vol. of vap. of carbon} = 3 \times 0{\cdot}8437 = 2{\cdot}5311\\ 3 \text{ ——— hydrogen} = 3 \times 0{\cdot}0688 = 0{\cdot}2064\end{array}\right.$$

Benzin forms the following combinations, important for the theory of chemistry.

1. *Sulpho-Benzide.*

By adding benzin to sulphuric acid, freed from water, we obtain, without a decomposition of benzin in the least degree succeeding, consequently no trace of sulphurous acid is perceived; a viscid liquid, perfectly soluble in water: from which, if decomposed by a large quantity of water, a crystallizable substance separates, amounting to five or six per cent. of the benzin that was employed: this is sparingly soluble in water, and may be purified, by solution in water, from all the acid present; but to procure it quite pure we dissolve it in ether, filter the solution, and allow it to crystallize.

This combination, which is soluble in ether and alcohol, is procured in determinable crystals. It is changed into a transparent colourless fluid by fusion at 255°, and boils at a heat between the boiling point of mercury, and that of sulphur; it is free from colour and smell. In alkalies it is insoluble, in acids soluble, from whence it is precipitated by water. Heated with sulphuric acid it combines, forming a peculiar acid, which combines with barytes, and forms a soluble salt; it undergoes no change from other acids. Mixed and heated with nitre, or with chlorate of potash, it may be distilled without decomposition; agitated in hot fusing nitre, or in chlorate of potash, which is heated so strongly that it is decomposed, it undergoes decomposition attended by an explosion. Chlorine and bromine produce no effect on it at a common temperature; by heating the substance till it begins to boil, it is decomposed both by chlorine and bromine, and forms chloride of benzin.

The quantity of carbon and hydrogen is calculated by being burnt with oxide of copper; the quantity of sulphur by the decomposition of the combination by means of chlorine.

100 parts therefore contain 66·42 carbon = 12 vols.
4·52 hydrogen = 10
14·57 sulphur = $\frac{1}{3}$
14·49 oxygen = 2

2. *Nitro-Benzide.*

Nitric acid, when pure and concentrated, acts so little on benzin, that we can distil them, without undergoing any change; heated, on the other hand, with fuming nitric acid, great action takes place with development of heat; for this reason, benzin should be added in very small quantities to the heated acid. The combination that takes place is entirely soluble in warm nitric acid, without undergoing any change; it separates, however, partly on cooling, and settles, from being lighter than nitric acid on the surface of the fluid. If the acid be diluted with water, the combination sinks from being heavier than the water. On washing in water, and by distilling, it may be found perfectly pure. It forms a somewhat yellowish coloured fluid of a very sweet taste, and peculiar smell, between that of the oil of bitter almonds, and that of oil of cinnamon. At 66° its specific weight is 1·209, and at 500° it boils and distils over unchanged. At 39° it is found in a solid state, and acicular crystals traverse the whole fluid mass. Heated with diluted sulphuric acid, if the temperature is high enough, it distils over unchanged; heated with concentrated sulphuric acid, it becomes decomposed, with a development of sulphurous acid, and the colour of the fluid becomes darker. Chlorine and bromine, if conducted through the fluid, produce no effect; if chlorine is conducted with the vapour of the substance through a heated tube, decomposition takes place, and hydrochloric acid is formed. Heated with potassium it detonates so violently, that the vessels are broken. A watery solution of potash operates but slightly on it. Potash dissolved in alcohol is not decomposed at the common temperature, but boiled with it the solution becomes entirely red.

It is almost insoluble in water, but soluble in alcohol and ether in every proportion; in concentrated acids, for instance, nitric and sulphuric acids, it is easily soluble; at a high temperature more than at a low. Its composition has been calculated by combustion, by means of oxide of copper.

100 parts, therefore, consist of—

58·92 carbon = 12 volumes of vapour of carbon.
40·08 hydrogen = 10 . . . . of hydrogen gas.
11·47 nitrogen = 2 . . . . of nitrogen gas.
25·69 oxygen = 4 . . . . of oxygen gas.

The specific weight of the gas of nitro-benzide amounts to 4·194.

1 vol. of nitro-benzide vapour {
3 vol. of vap. of carbon = 2·5314
2½ . . . . hydrogen gas = 0·1720
½ . . . . nitrogen gas = 0·388
1 . . . . oxygen gas = 1·1026
4·1940

Sulpho-benzide, and nitro-benzide, are thus formed, inasmuch as nitric and sulphuric acids produce a neutral combination with benzin; and from this combination two volumes of hydrogen, and one volume of oxygen, are given off in the form of water.

3. *Azoto-Benzide.*

If nitro-benzide is distilled with lime, but a very inconsiderable portion of it is decomposed: a watery solution of potash produces very little effect. By dissolving potash in alcohol, and adding to it a solution of nitro-benzide in alcohol, when heated a strong action is set up; there forms a salt of potash, free from nitric acid, and a combination upon which an excess of potash can produce no further effect. By submitting the red solution to distillation, there passes over a red substance, which forms large crystals on cooling; these we lay on blotting paper to absorb the moisture, and then dissolve in ether: large well-formed crystals are produced on evaporation. This substance is easily soluble in ether and alcohol; and on evaporating it remains in large crystals. Boiling water dissolves it but sparingly—only sufficient to render it somewhat coloured; and, on cooling, the solution becomes turbid. It is slightly soluble in ammonia, in a concentrated solution of potash, and in concentrated hydrochromic acid: in concentrated nitric and sulphuric acids it is, on the contrary, very soluble, and is precipitated when the solution is diluted with water. By heating the solution in sulphuric acid, a decomposition takes place, carbon is deposited, and sulphurous acid escapes. With potash, however concentrated the solution may be, it may be distilled without decomposition; and the same effect is also observed with lime. At 175° it fuses, at 466° ebullition takes place, and it distils over without being decomposed. The vapour conducted through a red-hot tube is decomposed without inflaming or detonating, as is the case with those combinations which we obtain from the action of nitric acid on benzin and napthaline, which furnish three different combinations, and which contain azote and oxygen.

This substance contains in 100 parts—

Carbon = 79·30 = 12 vol.
Hydrogen = 5·30 = 10
Azote = 15·40 = 2

In comparing the composition of this body with that of nitro-benzide, 4 volumes of benzin vapour (=12 volumes of vapour of carbon, and 12 volumes of hydrogen gas), combine with 2 volumes of protoxide of nitrogen, (= 2 volumes of nitrogen, and 1 volume of oxygen gas), and from the combination are 1 volume of oxygen gas, and 2 volumes of hydrogen gas separated as water; it is, therefore, nitro-benzide deprived of its oxygen.

4. *Carbo-Benzide.*

This combination is procured by distilling benzoate of lime. First, benzin passes over, then water, and lastly, a substance, which contains napthaline in solution, which separates from the fluid on cooling. By exposing it for some time to a temperature of—13°, the fluid separates in two layers: the upper one has the appearance of pure carbo-benzide. By boiling beyond 590°, it is colourless, is not taken up by nitric acid and potash, though decomposed by chlorine, a crystalline body and hydrochloric acid being formed.

This substance consists in 100 parts—

Of 85·96 carbon = 13 volumes.
5·39 hydrogen = 10
8·65 oxygen = 1

5. *Benzinsulphuric Acid.*

This acid is easily procured by exposing benzin to common fuming oil of vitriol in a flask, agitating it so long as any is taken up, and allowing the flask to cool from time to time; as a development of heat takes place during the combination. The acid is dissolved in water, whereby sulpho-benzide is separated. By saturating the acid with carbonate of barytes, the filtered solution is precipitated by sulphate of oxide of copper, and benzinsulphate of barytes is obtained in crystalline incrustations. The salt of copper is evaporated till it commences crystallizing, when it is found in beautiful large masses. Benzinsulphates of oxide of zinc, protoxide of iron, oxide of silver, potash, soda, ammonia, and several other salts are found in crystals. The salt of copper may be decomposed by sulphuretted hydrogen; the acid, evaporated to the consistence of syrup, forms a crystalline sediment; on being heated more intensely it is decomposed.

Benzinsulphates support a considerable temperature without being decomposed; the benzinsulphate of oxide of copper may be heated to 480°, without its solution in water being rendered turbid by salt of barytes. The composition of this acid, and its salts, is ascertained by means of the analysis of the salt of copper; in which the quantity of oxide of copper is known by its being precipitated by potash; of carbon and hydrogen, by combustion with oxide of copper, as well as the quantity of sulphur, so that one part of the salt is heated and mixes with twenty parts of carbonate, and ten parts of nitrate of soda; and the sulphuric acid becomes united with the barytes. This salt consists in 100 parts of—

38·57 carbon = 12 volumes.
2·62 hydrogen = 10
16·94 sulphur = $\frac{2}{3}$
21·03 oxygen = 5

$$20{\cdot}84 \text{ oxide of copper} = \left\{ \begin{array}{l} 16{\cdot}63 \text{ copper.} \\ 4{\cdot}21 \text{ oxygen} \end{array} \right. = 1 \text{ vol.}$$

The acid consists, therefore, of benzin (12 volumes of vapour of carbon, and 12 volumes of hydrogen gas) and sulphuric acid ($\frac{2}{3}$ of a volume of vapour of sulphur, and 6 volumes of oxygen gas), from which combination 2 volumes of hydrogen, and 1 volume of oxygen gas separate as water.

6. *Benzincarbonic Acid. Benzoic Acid.*

Benzoic acid, which is found in commerce, is obtained from the gum benzoin. It is soluble in 200 parts of cold, and 30 parts of warm water: by allowing the hot solution to cool, it forms a mass of thin acicular crystals. Nitric acid produces no effect on benzoic acid; by digesting with nitric acid, which decomposes foreign bodies, and recrystallizing, the acid may be easily found in a state of purity. It is obtained in large crystals, by evaporating in the air neutral benzoate of ammonia.

At 300° benzoic acid fuses as fat, and on cooling forms a radiant mass; it boils at 528°, distils over unchanged, and settles on the cool part of the vessel, in fine, flexible, acicular crystals. This acid is colourless, possesses a peculiar smell, and a mild acid taste; it undergoes no change from the air, and does not chemically combine with water. Distilled benzoic acid, by analysis, consists of 14 volumes of vapour of carbon, 12 volumes of hydrogen gas, 4 volumes of oxygen gas.

It has but a feeble affinity for bases. The salt of silver is found in crystalline foliated masses, by precipitating neutral benzoate of ammonia with nitrate of oxide of silver;

but the salt of potash is found, by adding to a solution of potash in anhydrous alcohol, benzoic acid. The oxygen of the acid has the same relation to that of the base in benzoates as 4 : 1. Combined with oxide of copper or silver, one volume of oxygen and two volumes of hydrogen separate as water, as is the case with benzinsulphates: thus carbonic acid has the same relation to this acid, as sulphuric acid has to benzinsulphuric acid.

The specific weight of gaseous benzoic acid is found to be 4·26.

$$\begin{array}{l} 1 \text{ vol. of benzoic acid vapour} \\ \quad (4{\cdot}2623) = \end{array} \begin{cases} 1 \text{ vol. of benzin gas} \;.\;.\;. = 2{\cdot}7378 \\ 1 \text{ vol. of carbonic acid gas} = 1{\cdot}5245 \end{cases}$$

7. *Sulphobenzoic Acid.*

Concentrated nitric acid, sulphuric acid of the specific weight of 1·85, and various other concentrated acids, easily dissolve benzoic acid, which, if diluted with water, separates more copiously from the solution. By adding, on the contrary, benzoic acid to anhydrous sulphuric acid, it then combines, with development of heat, producing a viscid transparent mass, as sulphuric acid of 1·85 specific weight, and a peculiar combination is formed. By adding benzoic acid in excess, when the viscid mass is dissolved, benzoicacid separates, saturated with carbonate of barytes; the new acid remains in solution. By adding to the filtered solution hydrochloric acid, a combination of barytes with the acid forms beautiful crystals from the fluid, which, as it is more easily soluble in warm than cold water, (one part requiring 20 of water for its solution,) may be obtained pure, on crystals again being formed. These crystals have an acid action, and undergo no change from the air; treated with fuming nitric acid or other oxidizing substances, by which alcoho-sulphates are decomposed, the sulphuric acid is not set free, as might have been expected; and therefore the benzoates and benzoic acid are not oxidized. 100 parts of this acid consist—

$$28·29 \text{ barytes} \begin{cases} 25·33 \text{ barium} \\ \ \ 2·96 \text{ oxygen} = 1 \text{ vol. of oxygen gas.} \end{cases}$$

29·64 sulphuric acid = $\frac{2}{3}$ vol. of vapour of sulphur + 6 vol. of oxygen.
31·33 carbon = 14 vapour of carbon.
1·84 hydrogen = 10 hydrogen gas.
8·87 oxygen = 3 oxygen gas.

By a careful precipitation of barytes from the solution, we can easily procure a pure solution of the acid: it may be boiled, evaporated, and heated to 370°, or even higher, without decomposition. This hot acid becomes hardened into a crystalline mass on cooling; exposed to a moist atmosphere, it attracts water, and becomes completely deliquescent. The acid may unite with these bases in two proportions: the second combination with barytes is obtained by saturating the above-mentioned combination with carbonate of barytes. It is easily soluble in water, and has a neutral action; if a concentrated solution of it is evaporated in the air we obtain crystals, whose form it is very difficult to determine, and which undergo no change when exposed to the air. This salt contains, in the same quantity of acid, double as much base, as a salt of an acid action.

The affinity of sulphobenzoic acid for bases is so strong that it decomposes nitrate of barytes, and chloride of barium, consequently nitric acid and hydrochloric acid are set free, and an acid salt is formed. This acid, both on account of its strong affinity, as well as the number of its salts has an equal rank with the most important vegetable acid, for instance, tartaric acid.

8. *Oil of Bitter Almonds.*

From the bitter almond a volatile and a fatty oil is procured; the fatty part is separated by pressure, and the volatile part is obtained by heating the residue with water, and distilling in a common flask. The fluid that passes over forms two layers; the under one is a volatile oil, that is heavier than water; the raw oil is agitated with lime, and a salt of protoxide of iron, which is made into a paste with water, in order to absorb the hydrocyanic and benzoic acids that are contained in the oil; and is then distilled; the oil is then separated from the fluid that has passed over, and is heated to its boiling point.

The pure oil is colourless, very fluid, and of a peculiar odour, producing a burning sensation on the tongue, but on the system no effect different from other volatile oils. It has a specific weight of 1·043, and boils at 428°. On free exposure to air, or in oxygen gas, it becomes converted into benzoic acid, as only oxygen is absorbed, and no other body formed: in the light of the sun this oxidation proceeds very rapidly. Brought in contact with anhydrous alcohol it undergoes no change; by adding, however, water, then its decomposition takes place on being heated, and a benzoate is formed. By placing the oil in a solution of potash in absolute alcohol, a benzoate is equally formed ; hydrogen is not disengaged. By mixing together in alcohol a solution of oil and ammonia, the combination of ammonia quickly separates in the form of crystals, which are easily soluble in alcohol ; by diluting, however, the solution, and allowing it to remain some time, crystals separate, which are with difficulty soluble in alcohol. By conducting chlorine into a mixture of water and this oil, the water is decomposed, and benzoic and hydrochloric acids are formed.

This oil is soluble in nitric and sulphuric acids, without undergoing any change.

The oil of bitter almonds consists of—

79·43 of vapour of carbon = 12 volumes.
5·60 of hydrogen gas = 14
14·97 of oxygen gas = 2

or of 4 volumes of vapour of benzin = (12 of vapour of carbon, and 12 volumes of hydrogen gas,) and 4 volumes of carbonic oxide gas = (2 of vapour of carbon, and 2 volumes of oxygen gas).

Hence it follows, that if oil of bitter almonds is changed by oxidation to benzoic acid, 2 volumes of oxygen are added to the oil; or 2 volumes of carbonic oxide gas of the oil combine with 2 volumes of oxygen gas, forming 4 volumes of carbonic acid gas ; consequently, 14·97 parts of oxygen to 100 of oil are allowed by weight. Persons have attempted, but without success, to transform benzoic acid, by withdrawing the oxygen, into oil of bitter almonds.

The following interesting combinations are annexed to the oil of bitter almonds.

A. *Chloride of Benzule.*

By conducting chlorine through oil of bitter almonds hydrochloric acid is disengaged, until the fluid assumes a yellow tint, and then the action of chlorine ceases; if some of the chlorine in excess be absorbed by the fluid it may easily be expelled by boiling. The chloride of benzule is colourless, has a specific weight of 1·196; plunged in water, it sinks, and boiled with it, it is entirely decomposed into hydrochloric and benzoic acids, no other body being formed. With solutions of alkalies, it yields chlorides and benzoates. It consists of—

14	volumes of vapour of	carbon
10	ditto	hydrogen gas.
2	ditto	oxygen gas.
2	ditto	chlorine.

B. *Bromide of Benzule.*

By an addition of bromide to the oil, the same decomposition takes place as in the action of chlorine. Bromide of benzule is a soft, foliated mass; when slightly heated it fuses. It is soluble in ether and alcohol without being decomposed: it can only be obtained in crystals by evaporation. Moistened with water it is slowly decomposed; and if boiled with it for some time, it separates, without any other change taking place, into hydrobromic and benzoic acids.

C. *Iodide of Benzule.*

This substance is generated, by distilling iodide of potassium with chloride of benzule, in the form of a brown fluid, which crystallizes on cooling.

D. *Sulphuret of Benzule.*

This substance is procured as a yellow oil, which crystallizes on cooling, by mixing and distilling chloride of benzule with sulphuret of lead, reduced to powder. Boiled in water it is not decomposed, but in a solution of potash it is very slowly resolved into benzoate of potash and sulphuret of potassium.

E. *Cyanuret of Benzule.*

This is obtained by distilling cyanuret of mercury with chloride of benzule, as an oily fluid of a yellow colour, in which cyanuret of mercury remains. In contact with water, but more rapidly if boiled with water, it yields hydrocyanic and benzoic acids.

F. *Amygdalo-sulphuric Acid*

Is procured by allowing anhydrous sulphuric acid to act on the oil of bitter almonds.

9. *Benzoine.*

Benzoine is obtained as a solid body, by allowing a saturated oil of bitter almonds, to which some potash is added, to remain several days, in acicular crystals, which have an external yellow appearance; by dissolving in alcohol, boiling with charcoal, and recrystallizing, it is found pure, and of a white exterior. It has neither smell nor taste, it fuses at

300°, and on cooling it concretes into a crystalline mass; and if greater heat be applied, it boils and distils over unchanged. In cold water it is not at all soluble, in boiling water it is partially so, but in alcohol and ether in large quantities.

It is neither decomposed by hot concentrated nitric acid, nor by a heated solution of potash. It is soluble in sulphuric acid, accompanied with a blue tint; by heating the solution, decomposition takes place. This combination is decomposed by bromine, as was the oil of bitter almonds, but it forms a combination quite different from bromide of benzule, which, boiled with a solution of potash, yields bromide of potassium; the acid, however, which forms at the same moment, is by no means benzoic acid. Fused with hydrate of potash, hydrogen is given off, and benzoic acid is formed. Though benzoine, both on account of its properties as well as its affinity for other substances, is entirely different from oil of bitter almonds, nevertheless it is found to be composed quite in a similar manner.

By allowing chlorine to pass over fusing benzoine, hydrochloric acid is disengaged. The combination that remains may be dissolved in alcohol, and obtained, on cooling the heated solution, pure, and in well-formed crystals; it is free from taste and smell, fusing at about 235°. It consists of 14 volumes of vapour of carbon, 10 volumes of hydrogen gas, and 2 volumes of oxygen gas, thus chlorine has withdrawn 2 volumes of hydrogen gas from the benzoine: chlorine is not contained therein. We consider it, therefore, as composed analogously to sulphobenzide; it consists, therefore, of a combination of benzin (12 volumes of vapour of carbon, and 12 volumes of hydrogen gas) with oxalic acid, (2 volumes of vapour of carbon, and 3 of oxygen gas,) from which combination 2 volumes of vapour of water (two volumes of hydrogen gas, and one volume of oxygen) are separated: and it has been proposed to assign to it the name of oxalo-benzide.

By boiling this substance in a solution of potash in alcohol, decomposition ensues; benzoic acid is formed, as well as another substance, which is not oil of bitter almonds, which requires further investigation.

10. *Chloride of Benzin.*

This substance is obtained by pouring benzin into a large flask, and whilst the sun shines, conducting chlorine through it. The chlorine is immediately absorbed with evolution of heat, and the formation of white vapours; after some time chloride of benzin, which is soluble in benzin, separates in crystals from the benzin; and by continuing the operation longer, the benzin is all converted into chloride of benzin. The chloride is insoluble in water, slightly so in alcohol, and somewhat more in ether; by allowing the fluid mass to cool, the temperature sinks below 312° before it commences to be solid. This chloride consists of equal volumes of carbon, hydrogen, and chlorine, or of one volume of vapour of benzin, and three of chlorine.

11. *Chloride of Benzide.*

This substance is procured in small quantity, during the formation of the chloride of benzin, from whence it is easily separated, by dissolving it in ether; and chloride of benzin forms crystals; but in large quantities on being submitted to distillation. It is also easily obtained by mixing hydrate of barytes, or lime in excess, and submitting to distillation; water and a metallic chloride are formed, and chloride of benzide passes over. Distilled with barytes, or lime, the chloride of benzide is no longer decomposed. It is a colourless, oleaginous fluid, of the specific weight of 1·457, at 48°. In water it is insoluble; but it is easily dissolved in alcohol, ether, and benzin. It undergoes no change from acids and alkalies, or, at least, as little as from bromine and chlorine: it enters into ebullition at 504°.

The quantity of carbon and hydrogen in chloride of benzide is calculated by combustion with oxide of copper; otherwise, the chloride of benzin would be completely decomposed, if heated with hydrate of barytes, into chloride of benzide, water, and chloride of barium; no other products are formed. The specific weight of vapour of chloride of benzide is 6·37. According to this analysis

1 vol. of chloride of benzide = 6·2946	3 vol. of vapour of carbon	=	2·5314
	1½ ditto ditto hydrogen gas	=	0·1032
	1½ ditto ditto chlorine gas	=	3·66

12. *Bromide of Benzin and Benzide.*

Bromine exerts the same action on benzin as chlorine. It may be dissolved in benzin at a common temperature, and without the influence of the sun; and may be separated, for the most part, unchanged by distillation. If the light of the sun operates on it, a solid combination is gradually formed, which is soluble in alcohol and ether, though much less so than chloride of benzin; in water it is insoluble.

The oil of fennel and anise yield, beside oil of bitter almonds, by being oxidized by nitric acid, benzoic acid; it is also found in the resin of benzoin, in vanille, and in many vegetable substances, ready formed. In what manner it is however generated in these bodies has never yet been ascertained, though the subject is very interesting.

Oil of Cinnamon.

Pure oil of cinnamon consists of 18 volumes of vapour of carbon, 16 of hydrogen gas, and 2 volumes of oxygen gas: it quickly absorbs oxygen. The crystallized acid which is then formed consists of 18 volumes of vapour of carbon, 16 of hydrogen gas, and 4 of oxygen gas. In combining with bases, it gives off 2 volumes of vapour of water: the oxygen of the base is to that of the acid as 1 to 3. The oil of cinnamon is compared to that of bitter almonds, as far as relates to the composition; then there would be a combination in oil of cinnamon consisting of 4 volumes of carbon, and 4 volumes of hydrogen, whilst in oil of almonds the carburetted hydrogen consists of 3 volumes of vapour of carbon, and 3 volumes of hydrogen.

Oil of cinnamon combines, when moistened with cold nitric acid, forming a crystalline combination (=18 volumes of vapour of carbon, 16 of hydrogen gas, 2 oxygen, + 2 nitrogen, 5 oxygen gas + 2 volumes of hydrogen gas, 1 volume oxygen gas) so also with hydrochloric acid (= 18 volumes of vapour of carbon, 16 hydrogen gas, 2 volumes of oxygen + 2 volumes of chlorine, 2 volumes of hydrogen gas:) and as oil of bitter almonds, combines forming with ammonia a solid substance. If this oil be heated with nitric acid, we procure benzoic acid, from whence the oil undergoes general decomposition.

Chlorine, bromine, and iodine, have, in combining with other substances, such a similar action, that in preparing one combination with one of these substances, we can also imagine, with tolerable accuracy, the same combination with the other two. Next to these bodies stands, in this light, cyanogen, then sulphur, and oxygen ; so that in the combinations which they enter, one volume of chlorine, bromine, iodine, and cyanogen gas, corresponds with half a volume of oxygen gas, and one-third of a volume of sulphur vapour.

These substances either combine with simple bodies, for instance, with metals, in these proportions ; or with compound bodies, for instance, with different combinations of carbon and hydrogen ; with benzin, but more particularly with etherine. It is highly probable that these combinations may unite with other substances ; thus, hydrocyanic acid combines with various metallic cyanurets, for instance, with cyanuret of iron ; and the metallic cyanurets, for instance, cyanuret of lead, which is produced by a metal being added in place of the hydrogen of the hydrocyanic acid, combine with the metallic cyanurets, which were formerly united with hydrocyanic acid.

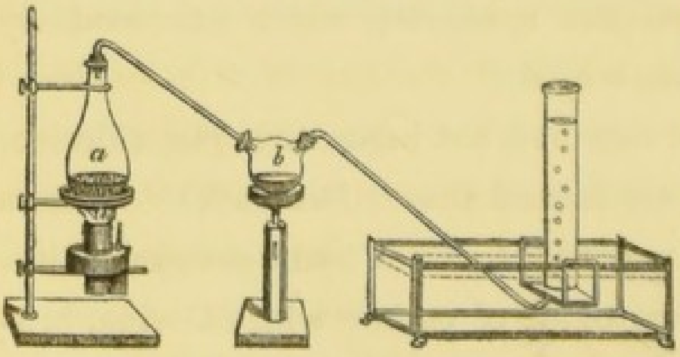
From this point of view, it is not improbable that chloride, bromide of benzule are formed thus. Benzin (12 volumes of vapour of carbon, and 12 volumes of hydrogen gas) unites with a combination of oxide of carbon with chlorine, bromine, (2 volumes of vapour of carbon, 2 volumes of oxygen gas, 4 volumes of chlorine gas,) and, from this combination, 2 volumes of chlorine and 2 volumes of hydrogen separate as hydrochloric acid, in a similar manner, as from combinations of oxygen, 2 volumes of vapour of water are separated.

II.—ETHERINE—OLEFIANT GAS.

1 vol. of etherine vap. = 1 vol. of vapour of carbon + 2 vol. of hydrogen gas.

By adding 1 part of anhydrous alcohol to 4 parts of concentrated sulphuric acid, and heating the mixture to 480°, one part of the alcohol is resolved into water, and a peculiar combination, which unites with chlorine, forming a body resembling oil, and has been termed olefiant gas; and as it is one of the ingredients of the different varieties of ether, is also named etherine. The other portion of the alcohol is so decomposed, that hydrogen partly combines with the oxygen of the same, partly with a portion of the oxygen of the sulphuric acid, forming water, whilst carbon is separated, and sulphurous acid is produced.

Fig. 50.

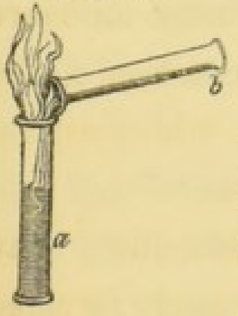


Etherine may be easily studied in its preparation in a flask, *a*, (Fig. 50,) heated by means of a spirit lamp. In the receiver, *b*, during the development of carburetted hydrogen, water is continually condensing, in which an oleaginous body, oil of wine, sinks to the bottom.

In the cylinder the gas is collected, already deprived of sulphuric acid from having passed through the water, which is able to dissolve a large quantity. As the carburetted hydrogen and water are at the same time given off, so it is not the affinity alone of the sulphuric acid for water, which occasions the decomposition of alcohol, but the sulphuric acid produces, through contact only, the decomposition of alcohol into carburetted hydrogen and water.

Smaller quantities of this gas can be procured in this manner, over a spirit lamp and collected in the cylinder; but for large quantities we must employ a stove and gasometer. By admission of air, this gas burns with a very bright flame when ignited.

Fig. 51.



Having collected this gas in a glass cylinder (Fig. 51.), after having ignited the gas, we must pour water into the cylinder to drive the gas out. On the subject of combustion, it will be shown at greater length, that the brilliant power of what is commonly called gas light, depends in a great degree on the quantity which it contains of this species of gas. Conducted through red-hot tubes, this gas is decomposed into carbon, which is deposited, and into hydrogen gas: an electric spark produces the same decomposition. 1 volume of carburetted hydrogen yields 1 volume of carbon, which is deposited, and 2 volumes of hydrogen gas.

By mixing 2 volumes of chlorine gas, and 1 volume of carburetted hydrogen gas, and igniting the mixture quickly, then chlorine and hydrogen combine with each other, and carbon is given off in the form of a thick smoke. By mixing 3 volumes of oxygen gas, with 1 volume of this gas, allowing the mixture to burn, then we find 2 volumes of carbonic acid, and fluid water. For this experiment a peculiar apparatus must be employed, for if the mixture be ignited at once, the explosion which takes place is so violent, that the strongest vessels are broken. The cylinder, in which the explosion takes place, should be covered with cloths. To produce an explosion, it is necessary that one volume of this gas, and 15 volumes of air should be employed. From these decompositions it follows, that this carburetted hydrogen gas contains 1 volume of vapour of carbon, whose weight is 0·8438, and 2 volumes of hydrogen gas, whose weight is 0·1376 ($2 \times 0·0688$), condensed to one volume, and the specific weight of the same amounts to 0·9814. From direct weighing, this gas has been found to be 0·9852.

During the decomposition of alcohol into water and carburetted hydrogen, by means of sulphuric acid, there condenses in the receiver, with the vapour of water, an oleaginous body, called oil of wine, which is most easily obtained by pouring 2½ parts of sulphuric acid on one part of anhydrous alcohol.

It is equally as well procured by submitting to distillation sulphovinates dried, as much as possible; for instance, sulphovinate of barytes or lime. It is purified, by washing in water, from sulphuric and sulphurous acids, alcohol, and ether: placed under an air pump, near a saucer containing sulphuric acid, the last impurities present, as well as water, are evaporated. It is slightly soluble in water, but more so in alcohol and ether; it has a peculiar smell and flavour, resembling that of peppermint.

Its specific weight is 1·133, and consists of

Carbon	33·67	=	8 volumes.
Hydrogen . . .	5·68	=	18
Oxygen	5·50	=	1
Sulphuric acid . .	55·15	=	4

If potassium brought in contact with purified oil of wine. at a common temperature, undergoes no decomposition, it is a proof that no water is contained therein. By adding one more volume of oxygen, and 2 volumes of hydrogen to the substance, combined with sulphuric acid, then we have the composition of ether. As we cannot isolate this combination, nor prepare it combined with other acids, it is even yet difficult to form a proper idea of the composition of oil of wine. It has been considered as a double combination of sulphate of ether with sulphate of carburetted hydrogen; which opinion, the combinations of ether with other oxacids, as acetic ether, and those of carburetted hydrogen with hydracids, for instance, hydrochloric ether, more particularly tend to confirm.

This combination, when distilled, is decomposed, so that it passes over in the shape of olefiant gas, and vapour of water.

Moistened with water, oil of wine is decomposed, and very rapidly too, if heated, into sulphovinic and an oleaginous fluid, which collects on the surface of the water: the same effect also takes place, if a base is allowed to act on it; then only a sulphovinate is formed. This decomposition may give rise to a supposition, and very justly so, that the heavy oil of wine is but a solution of the oleaginous fluid in sulphovinic acid.

The oleaginous fluid is set aside for some days in a very cold spot, then the crystals separate. The fluid is then filtered, and the crystals remain; they should be compressed between paper, till completely dry. The solid combination has no taste; when heated, however, it has a smell similar to that of oil of wine: it fuses at 280°, and distils at 615°, without undergoing any change. It is not soluble in water, slightly so in alcohol, but more so in ether, from which it may be procured in beautiful crystals: it has a specific weight of 0·980.

The fluid combination has a peculiar aromatic odour, and its specific weight is 0·921. It is transparent, and colourless, distils at 560°, and at —45° it becomes solid.

These two substances contain, in 100 parts,

Carbon . . . . . 85·71=1 volume,
Hydrogen . . . . 14.29=2 volumes:

their composition is exactly the same as that of etherine in a gaseous form.

From decomposition of alcohol we obtain etherine and water; from the operation of acids on alcohol, ether and combinations of etherine; and from oxidizing alcohol, acetic acid. Alcohol itself is procured from various kinds of sugar, and one species, from starch. By comparing the composition of these substances together, we can point out etherine in all; and we shall find it very simply composed: in some cases we can prepare one or the other combination from this or that substance. Sulphuric acid and alcohol, or sulphuric acid and ether, yield sulphovinic acid, from whence we can procure ether or alcohol at pleasure.

Nevertheless, we cannot procure alcohol or ether by means of etherine, nor sugar or starch by means of alcohol, not even so little as we procured from benzin in benzoic acid. The same reasons that induced us to assume benzin in benzoic acid, and in other combinations of benzin, make it probable, that etherine is contained in these combinations, which bears the same relation, as benzin in the corresponding ones. Etherine, however, cannot be separated from many combinations, for instance, from varieties of sugar, as it is more easily decomposed than benzin. Etherine consequently combines in two proportions with water, forming ether and alcohol; in varieties of sugar it combines with carbonic acid and water.

1. *Alcohol.*

1 vol. of alcohol vapour = 1 vol. of etherine vap. + 1 vol. of vapour of water.

The intoxicating property of wine, brandy, beer, and several other liquors, depends on a chemical substance, which is separated by distillation from water and other substances which are usually found in these liquors. This substance is termed alcohol. By distilling strong beer in a retort, until a tenth part of the fluid has passed over, and adding to the fluid a dry salt, for instance, carbonate of potash, which is soluble in water, but not in alcohol, it therefore attracts water from alcohol, which contained it, and two fluids are formed, of which the upper one, consequently the lightest, is alcohol, and the under one is water, containing the salt in solution that was employed. In this manner we can prove the presence of alcohol, and determine its quantity. How alcohol results from the process of fermentation, and is brought to the degree of purity it is met with in commerce, will be hereafter described. It may be purchased in such purity, that it contains but 10 per cent. of water. This water may be abstracted, by merely adding a substance with which water chemically combines. Chloride of calcium is best adapted for this purpose, previously heated to its fusing point, to expel all the water it contains.

The chloride of calcium is reduced to a rough powder, and is moistened with an equal quantity of aqueous alcohol, containing 90 per cent. anhydrous alcohol. Both substances are allowed to operate for some time on each other: the distillation is effected in a flask furnished with a cooling apparatus, or, for larger quantities, in a retort connected with a receiver: only half of the alcohol should be distilled. Anhydrous alcohol has a specific weight of 0·7947 at 66°; should, however, the alcohol, that has passed over, be heavier than this, it should be again submitted to the operation of chloride of calcium. Greater quantities

may be conveniently obtained by pouring the most concentrated alcohol of commerce upon unslaked lime in a flask; the lime, combining with the water of the alcohol, becomes slaked, the heat arising from this operation is sufficient to render the alcohol anhydrous; this variety of alcohol is commonly termed absolute alcohol: it is colourless, and more limpid than water: under moderate pressure of the atmosphere, it boils at 176°. The specific weight of gaseous alcohol is found to be 1·6133; and at a temperature of $-100°$, it does not assume a solid form. According to analysis, 100 parts contain 52·65 carbon,
12·90 hydrogen,
34·45 oxygen.

From this the specific weight of the vapour of alcohol, and its composition, can be calculated in volumes.

$$\begin{array}{r}\text{1 vol. of vapour of}\\ \text{alcohol}=1{\cdot}6015\end{array}\left\{\begin{array}{lll}\text{1 vol. of vap. of carbon} & = & 0{\cdot}8438\\ 3\text{ ——— hydrogen gas} & =3\times0{\cdot}0688= & 0{\cdot}2064\\ \tfrac{1}{2}\text{ ——— oxygen gas} & =\dfrac{1{\cdot}1026}{2}= & 0{\cdot}5513\end{array}\right.$$

Exposed to the air, alcohol absorbs water; if mixed with water the temperature rises, and the fluids are condensed. It follows, therefore, that between the alcohol and water attraction takes place; but whether this attraction depends on chemical affinity, or on a solution of the two fluids, one with another, has not as yet been accurately made out. Water and alcohol can combine with each other in every proportion. Brandy is such a solution; its value depends on the quantity of alcohol it contains. As alcohol is lighter than water, so can we calculate from the specific weight of the fluid the quantity of alcohol contained. In consequence of the condensation alcohol mixing with water undergoes, and also the expansion which takes place in the alcohol and water from warmth, the calculation of the quantity of alcohol in brandy, from its specific weight, is involved in much difficulty.

Alcohol combines in a similar manner as water with various substances, more particularly with salts; for instance, chloride of calcium, and nitrate of lime. Many substances, insoluble in water, are soluble in alcohol; for instance, gums; whilst others, soluble in water, are not so in alcohol. For this reason alcohol is a powerful agent for separating substances from foreign ingredients, which are thus found in a state of purity and crystalline form. Alcohol presents much interest to our notice from its affinity for other substances; for instance, for oxygen of the air, from whence results acetic acid at a low temperature, or carbonic acid and water are formed from its combustion; for its affinity for acids, whereby the various species of ether are generated; for its affinity for chlorine, from whence several peculiar combinations are produced.

2. ETHER.

1 volume of vapour of ether = 2 volumes of etherine, and 1 volume of vapour of water.

Ether is colourless, very limpid at a common temperature, of peculiar odour and taste; at 59° its specific weight is 0·724, at —38° it begins to produce foliated crystals, at —69° it forms a solid, pliable, crystalline mass, and under moderate atmospheric pressure boils at 112°. The specific weight of the vapour of ether is found to be 2·586; and from accurate analysis

100 parts contain 65·31 carbon
13·33 hydrogen
21·36 oxygen.

Composition by volumes:—

$$\text{1 vol. of vapour of ether} = 2{\cdot}586 = \begin{cases} \text{2 vol. of vap. of carbon} = 2\times 0{\cdot}8438 = 1{\cdot}6876 \\ \text{5 —— hydrogen gas} = 5\times 0{\cdot}0688 = 0{\cdot}3440 \\ \tfrac{1}{2}\text{ —— oxygen gas} = \dfrac{1{\cdot}1026}{2} = 0{\cdot}5513 \\ \hline \qquad\qquad\qquad\qquad\qquad\qquad 2{\cdot}5829 \end{cases}$$

Direct observation also agrees with this calculation, as far as could possibly be expected.

Ether is formed from the decomposition of alcohol by various acids. In comparing the composition of ether with that of alcohol, we have 1 volume of vapour of ether, by taking away 1 volume of hydrogen gas, and $\frac{1}{2}$ volume of oxygen, (consequently 1 volume of vapour of water) from 2 volumes of alcohol.

$$\left.\begin{array}{l}\text{2 vol. of alco-}\\ \text{hol vapour}\end{array}\right\} = \left\{\begin{array}{l}\text{2 vol. vap. of carbon, 6 vol. hydrogen gas, 1 vol.}\\ \text{oxygen gas.}\end{array}\right.$$

—1 vol. of hydrogen $\frac{1}{2}$ vol. oxygen

1 vol. ether vap. = 2 vol. vap. carb. 5 vol. hydrogen gas, $\frac{1}{2}$ vol. oxygen.
2 vol. of vap. alcohol = 2 × 1·6015 = 3·2030
1 vol. of hydrogen gas = 0 0688 — $\frac{1}{2}$ vol. oxygen gas $\frac{1{\cdot}1026}{2}$. = 0 6201
1 vol. of vapour of ether . . . . = 2 5829

Or,

2 vol. of vap. of alcohol = 2 vol. etherine gas + 2 vol. of vapour of water . . . . = 2 × 1·6015 = 3·2030
—1 vap. of water . . = 0 6201

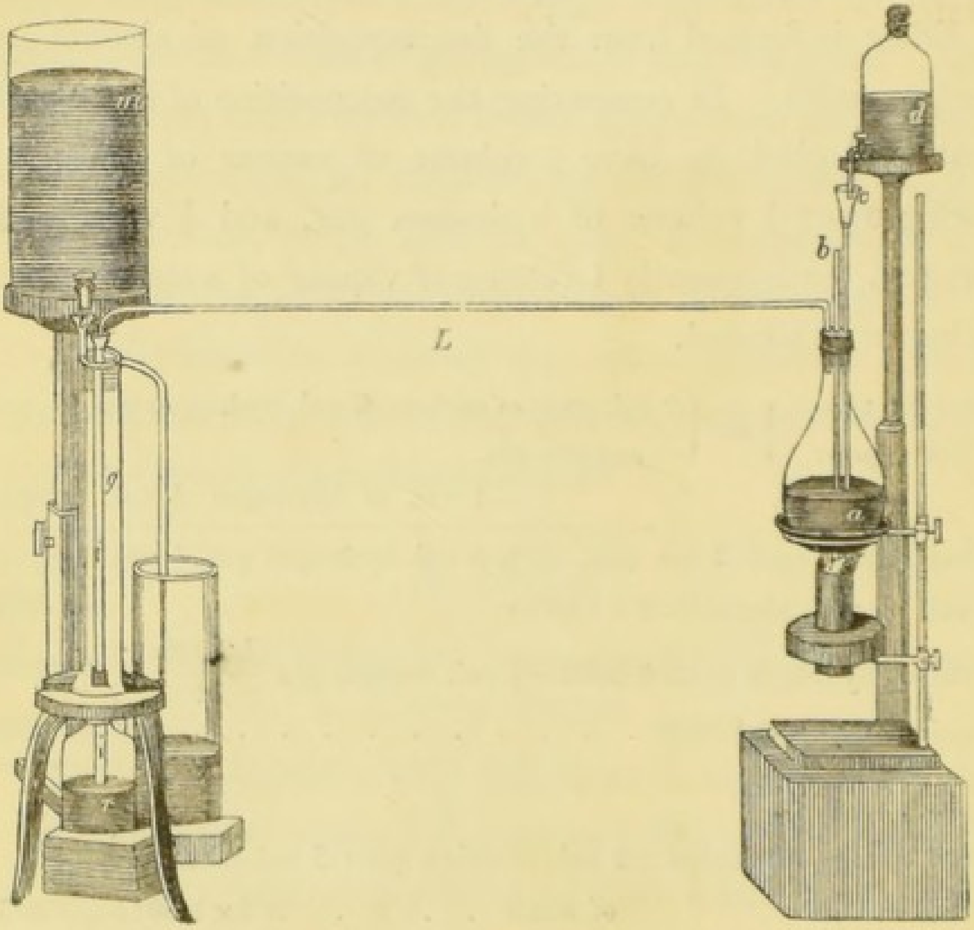
1 vol. of vap. of ether = 2 vol. of etherine vap. + 1 vap. of water = 2·5829

100 parts of alcohol yield 80·64 parts of ether, and 19·36 water.

The decomposition of alcohol into ether and water is not only important, because ether is generated, but offers also an example of a very peculiar chemical decomposition, which can be easily observed in this substance, and which takes place in the formation of many other important bodies.

The apparatus for the formation of ether consists of a flask, *a* (Fig. 52), furnished with a funnel, *c*, to admit alcohol, which drops into the vessel, *d*, in a continual stream; *b*, is a thermometer, and *l*, is a waste pipe for the escape of such vola-

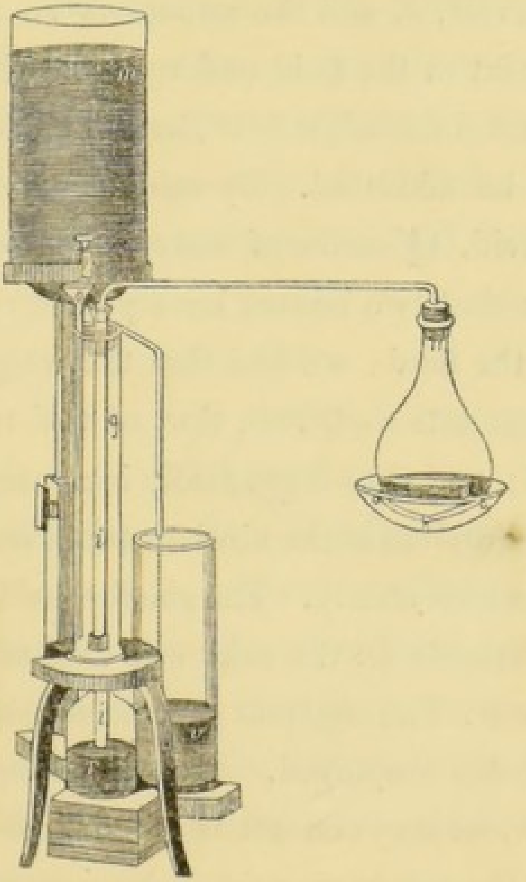
Fig. 52.



tile substances as are given off. The end that passes into the flask should be broken obliquely, in order that what condenses in the perpendicular part might drop back into the flask, and not pass over with the vapour; the other end of the tube passes through a wide cylinder, *g*, through the bottom into a flask, *r*, where it collects. This cylinder is filled with water from above, which falls in drops, and the stream may be regulated accordingly. The substances which pass over, either ether or bisulphuret of carbon, undergo no loss, as they are immediately condensed by the coldness of the water, which drops from the vessel, *m*, in a constant stream.

Fig. 53.

Fig. 54.



In order to purify volatile substances by distillation—for instance, raw ether—we pour into the flask, *o*, (which is placed in a saucer filled with water), resting on an iron triangle, in order that it might not come in contact with the saucer, lest a shock should take place; anhydrous alcohol, and then diluted sulphuric acid. To 100 parts of sulphuric acid, containing already 18·5 parts of water, we add 20 parts more, or a little more than it previously held; and for 100 parts of concentrated sulphuric acid 50 parts of anhydrous alcohol are allowed.

The fluid is then heated till it reaches 340°, and we remark, by observing the lines on the retort, the height of the fluid. The alcohol is now allowed to flow gradually from the reservoir, *d*, and the stream is so regulated that the boiling point of the fluid undergoes no change, as when the temperature sinks below 340°, less alcohol; but if it rises, more should be admitted. By calculating, from 6 ounces of sulphuric acid, 1½ ounce of water, and 2 ounces of alcohol, each time that two ounces have passed over, the specific weight of the fluid; we find that the weight of the first two ounces amounts to 0·780, that of the two succeeding ones is 0·788; and thus it gradually increases till it reaches 0·798 which it arrives at the ninth or tenth ounce; and soon after this it remains steady. The small specific weight of the first ounces depends on the sulphuric acid taking up somewhat more water. The constant specific weight is very nearly that of the alcohol employed. By conducting the operation in this manner, we may convert as much alcohol into ether as we please, as the sulphuric acid undergoes no change, and only as much escapes as evaporates with the vapour of ether, or becomes decomposed by foreign ingredients which are mixed with the alcohol.

The fluid that passes over consists of two layers, of which the upper one is ether, containing some alcohol and water in solution; and the under one is water holding suspended some alcohol and ether; its weight amounts to exactly as much as that of the alcohol employed, if care be taken, to prevent any evaporation.

By pouring the fluid that has passed over into a retort, and submitting it in a water-bath to distillation, till the temperature may rise to 212°; we then find an aqueous alcohol, whose quantity of alcohol is estimated from its specific weight. By adding a small quantity of water to absorb the alcohol from ether, to the ether that has passed over, whose weight we have calculated, we then distil again, and calculate the quantity of alcohol of the remaining fluid. According to analysis the fluid that passes over consists of—

65 ether.
18 alcohol.
17 water.

If alcohol is allowed to flow rapidly at once, the vapour of the alcohol passes over, without coming in contact with the sulphuric acid, and, on the other hand, by allowing less alcohol to drop than passes over, it is decomposed by the alcohol contained in the fluid; thus, in the first case, the fluid that passes over contains more alcohol, and in the second, more ether.

In comparing the results obtained from analysis with calculations on the decomposition of alcohol, then 15·4 parts of water must be assigned to 65 parts of ether : a more accurate correspondence must not be expected, as the loss of some ether cannot be prevented, and analysis itself can only give a proximate result. Good wholesale manufacturers adhere to the same proportion : in diluted alcohol the quantity of the watery layer is naturally much larger.

By taking 6 ounces of concentrated sulphuric acid, and 6 ounces of anhydrous alcohol, which must be added gradually, the first two ounces of raw ether that pass over have a specific weight of 0·768; and this weight is not reached, till the sulphuric acid has taken up the quantity of water mentioned. By taking, however, three ounces of sulphuric acid, and two ounces of water, and allowing alcohol to be dropped in, then the two first ounces consist of aqueous spirit of wine of 0·926, which contains scarcely a trace of ether; the following ounces have a specific weight of 0.885. The specific weight decreases until the water of the sulphuric acid is reduced to a given quantity, and the portion that has passed over has the specific weight of alcohol. By adding water to a mixture of concentrated sulphuric acid and alcohol, then alcohol distils over as long as any is present in the solution. By an excess of water all the alcohol is separated from the sulphuric acid; and by an excess of alcohol so much water, till the sulphuric acid contains twice as much water as in a concentrated state. By adding to concentrated sulphuric acid anhydrous alcohol in excess, anhydrous alcohol first distils over. As soon as the temperature reaches 315° the first traces of ether are perceptible: the greatest quantity of ether is formed between 348° and 370°; at 390° a decomposition of sulphuric acid takes place, although ether still continues to pass over up to 480°. If 6 ounces of sulphuric acid, and alcohol in excess be employed, the quantity of ether which passes over between 380° and 480° scarcely amounts to $\frac{1}{4}$of an ounce.

Persons have attempted to explain the formation of ether, by supposing that the sulphuric acid, from its affinity for water, absorbs from the alcohol half of its water. From the experiment previously described, it results that water continually passes over with ether, and it is evident that the sulphuric acid would combine in preference with water to combining with the water contained in the alcohol, which was retained through chemical affinity, and entering into a combination, which almost at a same temperature is destroyed. Besides alcohol is not converted into ether by means of other substances, for instance, potash or soda, which have a greater affinity for water, than the diluted sulphuric acid that is employed. The concentrated solution of soda and potash in alcohol may be heated to 345°, till it reaches the point at which ether is usually formed; the fluid however which passes over contains no trace of ether. A high temperature does not convert alcohol into ether, an experiment which can be easily performed, by conducting the vapour of alcohol through a tube gradually raised to a red heat. By mixing sulphuric acid, even after adding to it as much more water as it contained, with anhydrous alcohol, a part of the sulphuric acid combines with alcohol, forming sulphovinic acid. The crystalline combination of this acid with potash is so composed, that the sulphuric acid amounts to double as much as is necessary for the saturation of the salt; and to 6 volumes of oxygen gas in the sulphuric acid, 1 volume of oxygen gas, 10 volumes of hydrogen gas, and 4 volumes of vapour of carbon are assigned. We have still to remark during the formation of this acid, that by employing anhydrous alcohol or ether, the whole of the sulphuric is never changed into sulphovinic acid: thus an excess of sulphuric acid is a necessary condition for the formation of this acid.

It is difficult to determine in what light we ought to consider sulphovinic acid; whether as a combination of alcohol and sulphuric acid, from whence half the water is separated, or as a combination of ether and sulphuric acid: against this latter acceptation, the existence of an acid, procured by allowing anhydrous sulphuric acid to operate on alcohol or ether, whose salts are as exactly composed as if they contained ether, is plainly demonstrative.

Sulphovinic acid presents the same internal combination of ingredients as a similar acid, which sulphuric acid forms, for instance, benzinsulphuric acid; so that it is not decomposed by a solution of potash. Dissolved and boiled in a quantity of water, it is decomposed into alcohol and sulphuric acid. By submitting to distillation an aqueous salt with excess of base, we procure oil of wine and alcohol; this decomposition takes place not only at 347°, but also at 400°. If sulphovinic acid is decomposed by the presence of an acid, for instance, concentrated sulphuric acid in excess, ether is formed. In the usual distillation of ether, persons have not yet succeeded in entirely excluding the formation of some sulphovinic acid. In the formation of ether by means of phosphoric and other acids, similar combinations to sulphovinic acid are formed, and we might fancy ourselves capable of proving the formation of ether by these means, viz. the alcohol combines with the sulphuric acid as soon as it drops into the fluid, forming sulphovinic acid, which must be considered as composed from ether and sulphuric acid, and water separates, and this acid, as soon as it reaches a temperature of 345°, is decomposed into sulphuric acid and ether, which passes over. There yet remains a formation of ether, (in which an acid similar to sulphovinic acid plays no part,) which is produced by conducting fluoret of boron through anhydrous alcohol, from whence the fluid is distilled. It is, therefore, very probable that in a similar manner, as may be inferred more determinately in acetic acid, sulphuric acid and other acids act as contact substances, by means of which alcohol between 348° and 370° is resolved into ether and water. If sulphovinic acid plays a part in the preparation of ether, an acid is, therefore, necessary as a contact substance; provided at the same temperature, and under the same circumstances, as much water is present as is required to form alcohol, and the contact substance is a base, alcohol is always produced.

In proportion as the preparation of ether is undertaken in larger quantities, the apparatus should also be increased. To procure ether in manufactories, a cylinder of lead, about 1½ foot high, and the same in diameter, is best adapted for the purpose. This cylinder, fitted above and below with an iron cover, is placed in a cauldron of copper. In an adjoining chamber a barrel of alcohol is placed; from this barrel a leaden tube passes through the wall; another tube serves for the purpose of carrying off the vapour that escapes from the ether, which passes through the wall into an adjoining room, where it is cooled: this precaution is necessary to avoid all danger of fire. The ether that passes over is washed with water, and shaken with lime; then the fluid is again distilled, and the ether is thus rendered pure. The fluid that remains, and which was the water employed, is distilled; what passes over, becomes again of use. By means of this apparatus 300 pounds of ether may be conveniently procured in a day. From a pound of alcohol of 90 per cent. we obtain, on an average, 10 ounces, and from 100 parts of anhydrous alcohol in the same proportion 69 pounds of ether are produced.

Ether is very inflammable, and burns with a brilliant flame, which deposits on cold bodies soot. It easily evaporates when exposed to the air, as it is very volatile, and mixes with it, as ether vapour. By bringing such a mixture in contact with a burning body, a violent explosion takes place, as the carbon and hydrogen of the vapour of ether combine with the oxygen of the air. As frequent accidents often arise from these detonations, we should be very cautious in its use. To preserve ether in its purity, it should be placed in well-closed bottles, otherwise it partly evaporates, and it partly abstracts oxygen from the air, forming acetic acid.

Ether dissolves water slightly, and is soluble in 9 parts of water; by adding more ether, it floats on the surface of the solution.

Alcohol and ether combine in every proportion: the celebrated drops of Hoffman consist of 1 part ether of 0·76, and 3 parts of alcohol of 0·83. Ether dissolves many substances, insoluble in water and alcohol, as caoutchouc. We may make use of ether as alcohol, for separating many chemical combinations.

A. *Nitrous Ether.*

This ether is procured in the most convenient manner by pouring one part by volume of anhydrous alcohol, or $1\frac{1}{10}$ part of alcohol of 90 per cent., $\frac{1}{3}$ part of water, and $\frac{2}{3}$ part of fuming nitric acid, into a long thin cylinder. These three substances are found in three very evident layers, separated from each other; by allowing the cylinder to remain in a cold spot the acid is dissolved, as well as alcohol, in a layer of water; they act on each other, and produce nitrous ether; as it is lighter than water, it ascends, so that fresh alcohol can be continually added to the nitric acid. After a week or two the operation ceases, and two layers are found, the upper of which is ether. This operation may be accelerated by careful agitation, still it is attended with danger; if too much nitric acid and alcohol come in contact so violent an action is produced, that the fluid is thrown out of the vessels.

To avoid this violent action, another plan is adopted, but less lucrative, of distilling either alcohol, sulphuric acid, and fused nitre, or diluted nitric acid with alcohol. If we wish to prepare large quantities, several cylinders should be used: these should be closed with a cork, as the ether is very volatile. The ether is separated from the acid solution, by means of a filtering machine; it is then agitated with a diluted solution of potash in water, till litmus paper is no longer rendered red. The nitrous ether, when distilled over with care at a low temperature, is procured colourless, of the specific weight of 0·886 at 40°; of a peculiar sweet pricking taste, smells like apples, and boils at 80°. It consists of 2 volumes of azote gas, 3 volumes of oxygen gas (nitrous acid), and 1 volume of oxygen gas, 4 volumes of vapour of carbon, and 10 volumes of hydrogen gas; or 2 volumes of vapour of water, and 4 volumes of etherine vapour (2 volumes of vapour of ether).

The specific weight of gaseous nitrous ether is 2·627: 1 volume of this vapour contains therefore $\frac{1}{2}$ volume of ether vapour. From exposure to air, it becomes more acid, particularly if water or potash be present, by which an acid is formed, containing carbon, hydrogen, and oxygen. A solution of nitrous ether, which is prepared for the purpose, in which 8 parts of anhydrous alcohol are added to 1 part nitrous ether, is employed as a medical remedy.

B. *Oxalic Ether.*

Oxalic ether is prepared in the purest and most convenient manner, by distilling till the fluid reaches 348°, 1 part of oxalic acid (which is allowed to remain in a warm place, by which it loses $\frac{2}{3}$ of its water), and 6 parts of anhydrous alcohol in a retort; then as much alcohol is again added, and the fluid is distilled till it reaches 392°. What remains in the retort, consisting for the most part of oxalic ether, is agitated with water, which dissolves the free oxalic acid. The ether, which is but sparingly soluble in water, is agitated several times with water, till there remains but little oxalic acid to be taken up; this is removed by oxide of lead, and the ether is distilled. The fluid which is given off after 480°, is pure oxalic ether: two parts of oxalic acid give off 1 part ether.

Oxalic ether is an oleaginous, colourless fluid, of an aromatic smell, and a pleasant bitterish taste: its specific weight is 1·093. It is little soluble in water, but in alcohol, in all proportions. It consists of

$$\left.\begin{array}{r}\text{4 vols. oxygen gas,}\\ \text{10 vols. hydrogen gas,}\\ \text{6 vols. vap. of carbon,}\end{array}\right\} = \left\{\begin{array}{l}\text{2 vols. vap. of carbon, 3 vols. oxygen gas,}\\ \qquad = \text{oxalic acid.}\\ \text{4 vols. vap. of carbon, 10 vols. hydrogen,}\\ \qquad \text{1 vol. oxygen} = \text{ether.}\end{array}\right.$$

Its specific weight in a gaseous form is 5·078; consequently 1 volume of ether vapour is contained in 1 volume of oxalic ether vapour. Brought in contact with a solution of potash in water, it separates into oxalic acid, which combines with the potash, and into alcohol; if the water is gradually withdrawn from the air, then oxalic ether separates in crystals, most probably the first hydrate. By adding to the solution of oxalic ether in alcohol, only half as much of a solution of potash in alcohol, as is necessary for the decomposition of ether, a peculiar acid, ethero-oxalic acid, combines with the potash. On adding a solution of ammonia, two combinations form, namely, etheroxamide and oxamide.

C. *Acetic Ether.*

By distilling equal parts of anhydrous alcohol and acetic acid, concentrated as much as possible, and pouring back from time to time what has passed over, acetic ether is procured: it is more quickly prepared by adding 10 to 15 per cent. of sulphuric acid. It is however most conveniently prepared, by distilling 10 parts of anhydrous acetate of soda, or 20 parts of anhydrous acetate of oxide of lead, with 7 parts of sulphuric acid and 8 parts of alcohol. The fluid that has passed over is mixed with carbonate of soda, till it no longer retains an acid action: the fluid that floats on the watery solution, is poured on pieces of chloride of calcium; and this process is repeated till the chloride is no longer moistened; it is then distilled.

Acetic ether consists of 8 volumes of vapour of carbon, 16 volumes of hydrogen gas, and 4 volumes of oxygen; or of 4 volumes of vapour of carbon, 3 volumes of oxygen gas, 6 volumes of hydrogen (acetic acid); or of 4 volumes of vapour of carbon, 10 volumes of hydrogen gas, and 1 volume of oxygen gas = (4 volumes of etherine vapour, 2 volumes of vapour of water [ether]). Its specific weight in the form of gas, is 3·0634, one volume therefore contains $\frac{1}{2}$ volume of ether vapour. Digested in a solution of potash, it is completely separated into acetic acid and alcohol. Heated with sulphuric acid, it forms sulphuric ether; with hydrochloric acid, hydrochloric ether; with nitric acid, nitrous ether. It does not become acid from exposure to the air. By pouring acetic ether on chloride of calcium, it combines, forming a crystalline mass, from which, by the addition of a small quantity of water, acetic ether again separates. It is a colourless fluid, of specific weight of 0·89, and of a pleasant acid ethereal smell; its boiling point is 205°, and it is soluble in 7 parts of water. It is employed as a medical remedy.

D. *Formic Ether.*

By distilling equal parts of anhydrous alcohol, and concentrated formic acid, and reducing the fluid that passes over to half, formic ether separates, if a diluted solution of potash be added to what has passed over, to remove the acid: if allowed to stand some time with chloride of calcium, all the water is taken up. This ether is colourless; it smells and tastes like peach kernels. Its specific weight is 0·916, and its boiling point 156°. It is soluble in 9 parts of water, and in all proportions with alcohol, as acetic acid. A solution of it in water separates after some time into alcohol and formic acid; it is similarly composed as acetic ether; the specific weight of this ether in a gaseous form is 2·57: it contains $\frac{1}{2}$ volume of ether vapour.

E. *Citric Ether.*

By distilling 1 part citric acid with 8 parts of anhydrous alcohol, till the temperature reaches 437°, and repeating the operation till the temperature reaches 460°, and adding water to the residuum, citric ether is precipitated; by agitating with water, in which some ammonia is dissolved, it may be freed from the acid that is present.

Citric ether is heavier than water; it cannot be distilled without decomposition; is free from smell; is little soluble in water, but in alcohol in all proportions. It is decomposed by a solution of potash and yields alcohol, as other varieties of ether. In a similar manner as citric ether, malic ether (malic acid and alcohol), is prepared; though it has been so little analysed, that it cannot be depended on. Tartaric ether (tartaric acid and alcohol), has been examined even less; its existence has not yet been fully ascertained.

F. *Benzoic Ether.*

By distilling 4 parts of anhydrous alcohol, 2 parts of benzoic acid, and 1 part of concentrated hydrochloric acid, till the temperature reaches 437°, returning the fluid that has passed over, and distilling till it arrives at the same temperature; and by repeating the operation several times, we obtain the ether pure, if the residue is agitated with water, and the ether which was poured off is heated with oxide of lead at 502°. It passes over colourless and limpid, of a peculiar smell and pricking taste; its specific weight is 1·05. It is insoluble in cold water, in warm slightly; but in alcohol, in every proportion. Brought in contact with a solution of potash, it is decomposed after some time into alcohol and benzoic acid, which combines with the potash. It is not decomposed by fuming nitric acid. This ether consists of 18 volumes of vapour of carbon, 20 volumes of hydrogen gas, and 4 volumes of oxygen; or of 14 volumes of vapour of carbon, 12 volumes of hydrogen gas, 4 volumes of oxygen (benzoic acid), and of 4 volumes of vapour of carbon, 10 volumes of hydrogen, 1 volume of oxygen (ether), from which combination 2 volumes of vapour of water are separated. The specific weight of this gas in a gaseous form is 5·24; 1 volume of which contains in consequence ½ volume of vapour of ether.

G. *Succinic Ether.*

This ether is obtained in the same manner as benzoic ether, by employing instead of benzoic, succinic acid; and it is formed by distilling alcohol with succinic acid. Its boiling point is 515°; its specific weight is 1·036. It consists of 8 volumes of vapour of carbon, 14 volumes of hydrogen gas, 4 volumes of oxygen; or of 4 volumes of vapour of carbon, 4 volumes of hydrogen, 3 volumes of oxygen gas. (Succinic acid,) and 4 volumes of vapour of carbon, 10 volumes of hydrogen, 4 volumes of oxygen gas (ether).

The specific weight of this vapour is found to be 6·2: a volume therefore contains ½ volume of vapour of ether.

H. *Muriatic Ether.*

1 vol. of vapour of muriatic ether = 1 vol. of hydrochloric acid gas + 1 vol. of etherine vapour.

For the preparation of this ether, which has been termed light hydrochloric ether, to distinguish it from another combination, the same apparatus is employed as for the preparation of ether; by mixing either equal quantities of concentrated muriatic acid and anhydrous alcohol; or by conducting into cold alcohol, hydrochloric acid gas, as long as any is absorbed, and pouring this mixture into a retort, over a sand-bath. From the retort a pipe passes, connected with the cooling apparatus. The fluid is distilled at a gentle heat. Alcohol, and the acid which passes over with the ether, are dissolved by the water at a temperature of 112°, and the ether is disengaged; at 66° it may be collected under a bell-glass in a gaseous state over water. The cooling apparatus must be filled with snow or ice. The ether should be washed with a diluted solution of potash, till it loses its acid action; and is then carefully cooled.

Light muriatic ether is colourless, of an acrid taste, and spicy smell; it boils at 57°: its specific weight is 0·84. It is soluble in 50 parts of water, and in every proportion in alcohol. It must be preserved in well-closed bottles. It is slowly decomposed by alkalies, a metallic chloride and alcohol being formed; conducted through moderately heated tubes, it is resolved into equal quantities of etherine gas and hydrochloric acid gas. The same composition we reach through other methods of decomposition. Its specific weight amounts to 2·236 = (1 volume of etherine vapour = 0·984, and 1 volume of hydrochloric acid gas = 1·256).

I. *Hydrobromic Ether.*

This ether is procured by adding 1 part of phosphorus, by weight, to 40 parts of alcohol of 0·84, and 7 to 8 parts of bromine; there forms phosphoret of bromine, which is resolved into phosphorous acid and hydrobromic acid, which combines during distillation with the etherine of the alcohol. By water the alcohol is separated, and the acid by a weak solution of alkali. This ether is very volatile, heavier than water, colourless, of ethereal odour, and soluble in every proportion in alcohol; it may be preserved undecomposed under water.

K. *Hydriodic Ether.*

Hydriodic ether is procured by moistening 5 parts of iodide of phosphorus with 2 parts of alcohol of 0·841, and distilling at a gentle heat. This ether is separated by water; it is colourless and of ethereal odour. Its specific weight is 1·92; and it boils at 176°. It is only inconsiderably decomposed by alkalies; and when exposed to the air it becomes reddened. The specific weight of this vapour is 5·4; 1 volume therefore contains 1 volume of etherine and 1 volume of hydriodic acid.

L. *Hydrosulphuric Ether.*

By rubbing together sulphuret of potassium and oxalic ether, agitating the mixture, that is distilled over, with potash to remove the oxalic ether that is present, and distilling over chloride of calcium, an ethereal fluid is obtained, which smells like assafœtida: in water it is only slightly, but in alcohol and ether, soluble in every proportion: this is hydrosulphuric ether. By distilling sulphovinate of barytes with hydrosulphate of sulphuret of barium, there forms a combination of hydrosulphuret with this ether, which has the same relation to hydrosulphuric ether, as etheroxalic acid has to oxalic ether.

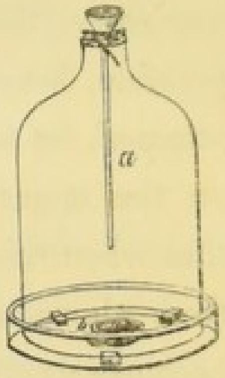
M. *Hydrocyanic Ether.*

By distilling sulphovinate of barytes with cyanuret of potassium, a colourless ethereal fluid is obtained, which smells like garlic; it is poisonous; slightly soluble in water, but in alcohol, in every proportion; its boiling point is 216°, and its specific weight is 0·787 : 1 volume of this ether, in a gaseous form, consists of 1 volume hydrocyanogen gas, and 1 volume of etherine vapour.

3. Acetic Acid.

This is by far the most important of all the acids we are acquainted with. It is found ready formed in the sap of different plants, and more particularly trees. It is produced from the distillation of the greater part of non-volatile organic combinations, during their passage through moderately heated tubes, and consequently, from the incomplete combustion of organic substances. It is also obtained from the oxidation of alcohol; on which depends the usual method of preparing this acid; namely, by bringing into contact with the oxygen of the air, spirituous liquors, such as brandy, beer, &c. Diluted in water, this acid constitutes common vinegar, which is used either to give an agreeable taste to certain articles of food, or to preserve meats from putrefaction. Pure alcohol, in a concentrated, or diluted state, when exposed to the atmosphere, does not combine with the oxygen of the air. A contact substance must therefore be employed, whose operation takes place in a manner particularly advantageous to the study of this class of phenomena, and is very useful in this variety of combination. As a contact substance we use porous platinum, or what is called a fermenting body. Finely powdered platinum is obtained by throwing down a solution of chloride of platinum, by sulphuretted hydrogen, and the sulphuret of platinum is exposed to the air, whence the sulphur becomes oxidized. If the precipitate be washed, the platinum remains perfectly pure which is placed in a small saucer, *b* (Fig. 55). In the mouth of a bell glass, a funnel is placed, whose lower end is drawn to a thin point, that the alcohol which is poured in, may drop very slowly; the glass is placed on supports, that the atmospheric air may be admitted. The acetic acid, which is continually forming, flows down the walls of the bell-glass, and may be collected. From experiments performed in a confined vessel, it is found that the alcohol is principally converted into acetic, without forming carbonic acid. This experiment may be thus accomplished, by pouring on the bottom of a broad saucer, a thin layer of alcohol, and placing in several watch glasses, very finely powdered platinum, moistened with alcohol, and over this a bell glass is placed. By the requisite exposure to the air, in a few days the alcohol is principally converted into acetic acid. The same gradual oxidation, effected by platinum, is also produced by means of some fermenting substance, only it takes place at a still lower temperature, from 100° to 120°. The most active fermenting substances are such as contain vegetable albumen; for instance, the expressed juice of beet-root, of potatoes (helianthus tuberosus), or a solution of raw sugar, weak beer, and many other combinations containing nitrogen, may be employed

Fig. 55.



for the same purpose. If the process of fermentation has once commenced, acetic acid is a powerful means of promoting it. Alcohol itself ought not to be employed in a concentrated state, 1 part must be diluted with 8 to 9 parts of water. As the preparation of acetic acid consists in oxidizing alcohol by means of atmospheric air, it is necessary, therefore, to bring as many contact points as possible, between the alcohol and air. This end is best attained, by filling a vessel with chippings of wood; and on the upper side of the tub several holes are bored, so that when the alcohol with the fermenting principle, drops from above, it gradually mixes with the chips, and thus becomes oxidized. A spill-hole is bored through the walls of the barrel, by which a continual supply of fresh air is kept up.

If acetic acid combines with a base, for instance, oxide of lead, and the aqueous solution be distilled over heat, with a necessary quantity of sulphuric acid, acetic acid is procured in its most concentrated form: it becomes solid at a temperature of 66°.

The crystals consist of 4 volumes of vapour of carbon, 8 volumes of hydrogen gas $+ 4$ volumes of oxygen gas.

It is not improbable that the same case occurs to acetic acid, combining with bases, as to benzinsulphuric and benzoic acids; viz., that 1 volume of oxygen gas, and 2 volumes of hydrogen separate from the combination as water; therefore this crystallized acid would be that peculiar acid which consists of 4 volumes of etherine vapour, and 4 volumes of oxygen gas. In the oxidation of alcohol, 1 volume of etherine vapour combines with the oxygen of the air, the hydrogen of which is disengaged.

The oxidation of alcohol by means of porous platinum, is a most beautiful instance of contact substances; as, by means of the same quantity of platinum, we may unite any portion of alcohol and oxygen at pleasure, without the metal suffering the slightest change, or entering into any other combination.

M. *Oxidized Ether.*

This ether is formed by oxidizing alcohol and ether by various methods. It is most conveniently obtained by submitting to distillation, 1 part of spirit of wine of 80 per cent., 1½ parts of peroxide of manganese, 1½ parts of sulphuric acid, and 1 part of water. A roomy flask, *a*, (Fig. 55), is used for this purpose, which is placed in a water-bath, and connected with a cooling apparatus. At first the mass boils up, but by pouring into the bath some cold water, the ebullition proceeds very tranquilly. This operation is continued as long as any fluid passes over; it is then poured into a flask, with about double as much chloride of calcium; and allowed to stand, and is again distilled, till half of the fluid has passed over: to this, ether, saturated with ammonia, is gradually added. This oxidized ether, combined with ammonia, separates in crystals.

Fig. 55.

This combination is dissolved in an equal quantity of water in a flask, by adding 1½ parts of sulphuric acid, diluted with 2 parts of water, and distilling in a water-bath. The portion that passes over is agitated in a flask, to which chloride of calcium is introduced; and this is again distilled. As the pure substance boils at 79°, the heat in the water-bath should not rise above 99°; whilst ice must be placed in the cooling apparatus. Oxidized ether is colourless, of a peculiar odour, similar to what is observed in burning spirits of wine. In water, ether, and alcohol it is soluble in every proportion, and is very inflammable.

Brought in contact with a moist atmospheric air, or in co-operation with finely divided platinum, it is quickly oxidized into acetic acid. Chlorine and bromine soon decompose it, forming bromic or hydrobromic acid; nitric acid oxidizes it, producing acetic acid; by sulphuric acid, it is first rendered brown and then black.

The specific weight of gaseous oxidized ether amounts to 1·53; and its composition is calculated thus:

$$1 \text{ vol. oxidized ether vap.} = \left\{ \begin{array}{l} \left. \begin{array}{l} 1 \text{ vol. vap. carbon} \\ 1 \text{ vol. hydrogen gas,} \end{array} \right\} 1 \text{ vol. etherine vap.} \\ \tfrac{1}{2} \text{ vol. oxygen gas.} \end{array} \right.$$

We may consider oxidized ether, as an oxide of etherine, which is formed by alcohol giving off its quantity of water, and assuming instead, oxygen. It is produced by dropping ether on metals, heated to 595°; for instance, upon fusing bismuth; if alcohol is heated by means of a burning platinum wire or porous platinum; if the flame of a spirit lamp is extinguished, and the wick still is kindled; or if 1 part of spirit of wine of 80 per cent., is diluted with 2 parts of water, and saturated with chlorine under careful cooling, then only hydrochloric acid and oxidized ether are formed.

It is besides obtained by submitting to distillation spirit of wine with common nitric acid; or if ether be allowed to pass through, in a gaseous state, a glass tube filled with rough pieces of glass, there result oxidized ether, etherine and inflammable fire-damp, which, as it contains twice as much hydrogen as etherine does, may be formed, by the hydrogen of one part of the water of the ether uniting with one part of the etherine, whilst the oxygen of the other part of the water combines with the other part of the etherine, producing oxidized ether.

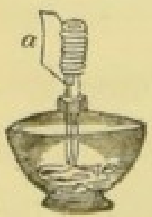
A combination of ammonia and oxidized ether is found in beautiful crystals, by mixing a concentrated solution of it in alcohol with ether, in which it is very slightly soluble. At 257° it distils over unchanged; it is decomposed by acids, however weak, for instance, acetic acid, as a salt of ammonia is formed, and oxidized ether set free.

This combination consists of equal parts of ammonia ($1\frac{1}{2}$ volume of hydrogen gas $+\frac{1}{2}$ volume of azote gas) and oxidized ether (1 volume of vapour of carbon $+ 2$ volumes of hydrogen gas $+\frac{1}{2}$ volume of oxygen gas).

Besides oxidized ether, by the action of diluted sulphuric acid and peroxide of manganese on alcohol, which through the gradual giving off a part of the oxygen of the peroxide to the alcohol, is a slower process of oxidizing the alcohol, which, no doubt, may be produced by means of many other substances; carbonic acid, formic acid, formic ether, acetic acid, and ether may be generated in a similar manner. By heating gradually to the boiling point, oxidized ether with oxide of silver and water, the metallic silver separates, and settles on the walls of the vessel as a metallic case, without the development of gas taking place. A salt of silver is contained in the solution, which cannot be evaporated without the reduction of oxide of silver. By adding a solution of barytes to a solution of the salt of silver, the oxide of silver separates; by boiling a solution of this salt with the oxide of silver, the oxide of silver becomes reduced, and the acid of the salt completely changed into acetic acid. From the calculation of the silver that is separated, it appears that the silver most probably contains an acid, consisting of 4 volumes of vapour of carbon, 8 volumes of hydrogen gas, and 3 volumes of oxygen; and the oxygen of the base has the same proportion to that of the acid, as 1 : 3.

This acid has the same relation as ether acid, which is obtained by suspending over the wick of a lamp, filled with ether, a thin platinum wick, *a*, which has been heated to redness, by igniting the ether; and the flame is then extinguished; at a low temperature, the combustion of ether is conducted here, in a similar manner as that of hydrogen, by means of spongy platinum. The acid thus formed, may be collected by placing over the lamp, a retort, the bottom of which is broken, and has been denominated lampic acid.

Fig. 56.



N. *Acetal.*

By saturating with chalk, the fluid obtained from oxidizing alcohol by means of spongy platinum, by distilling it and pouring it on chloride of calcium, an ethereal fluid is given off, consisting of acetic ether, oxidized ether and acetal. By distilling this fluid, the oxidized ether passes over first; and lastly, a fluid which boils at 246° to 249°; it is with difficulty separated from the acetic ether it is mixed with; and therefore it is impossible to determine with accuracy what the composition of this substance may be.

By heating a solution in water, of oxidized ether with a solution of potash, it soon becomes turbid, and on its surface, a red brown mass separates, (the resin of tinctura kalina,) which may be drawn out in threads. It is equally as well formed by exposing to the air a solution of acetal and potash in alcohol. From the origin of this substance from oxidized ether, we may also infer it is present in nitrous ether, and heavy hydrochloric ether. It is formed too as well by exposing to the air a solution of potash in alcohol, (tinctura kalina,) from whence it derives its brown colour. Precipitated from solution by sulphuric acid, it is no longer soluble. The name resin is not a proper term for this body.

4. *Pyroacetic Spirit.*

By submitting to distillation dry acetate of barytes, a watery fluid passes over, from which, if powdered chloride of calcium be added, to absorb the water, a peculiar, volatile, colourless combination is procured, which boils at 156°, and its specific gravity amounts to 0·7921.

Acetate of barytes =	6 hydrogen gas,	4 carb. 3 oxygen + barytes.
− Carbonate of barytes =		1 carb. 2 —— + barytes.
	6 hydrogen gas, 3 carbon : 1 oxygen.	

By conducting the distillation at a slowly increasing heat from the acetic acid, only carbonic acid and pyroacetic spirit are the results; the quicker the temperature rises, the more pyroacetic spirit is destroyed: carbon remains, and empyreumatic oil renders the spirit impure. The fluid is found composed in the proportion corresponding to the analysis. From the specific gravity of the vapour, it follows that

1 vol. of vap. of pyroacetic spirit	3 vols. hydrogen gas	$3 \times 0{\cdot}0688 = 0{\cdot}2064$.
	1½ vol. vap. of carbon	$1\frac{1}{2} \times 0{\cdot}8438 = 1{\cdot}2657$.
	½ vol. oxygen gas	$\frac{1{\cdot}1026}{2} = 0{\cdot}5513$.
		2·0234.

Or,

1 vol. vap. pyroacetic spirit = 1½ vol. etherine vap. + ½ vol. oxygen gas.

This spirit mixes in every proportion with water, alcohol, and ether. Exposed to the air, it undergoes no change; it forms no acetic acid, is easily kindled, and burns with a brilliant flame. It suffers no change from alkalies. It mixes with sulphuric acid with development of heat; distilled with it, it produces no ether. This solution in sulphuric acid yields, if saturated with carbonate of barytes, a soluble salt of barytes, (as was the case with alcohol,) which, however, is quite distinct from sulphovinate of barytes.

Acetic acid, oxidized ether, and pyroacetic spirit, may be considered from their composition as oxides of etherine.

4vols. etherine vap. + 4 oxygen gas = crystallized acetic acid.
4 —— + 2 —— = oxidized ether.
3 —— + 1 —— = pyroacetic spirit.

It is as yet too early to change the names of these combinations to correspond with this composition.

5. SUGAR.

The sweet flavour of many plants and animal substances depends on peculiar chemical combinations, which can for the most part, be isolated in a state of purity, and which, on account of their extent, as well as use in life, are of the highest importance. These combinations differ from each other, both in composition and chemical relation. The sugar of the cane, of syrup, of grapes, and milk, are the most important; besides which, we have the sugar of oil, of liquorice, mushrooms, and manna; of which the last two crystallise remarkably well. The first mentioned varieties serve as ingredients of our daily provisions, and particularly deserve our attention, from undergoing chemical change during the preparation of fermented liquors. The sugar of the cane is found ready formed in the sap of many plants; and in proportion as it is the preponderating ingredient, and as some foreign substances are mixed with it, so is it obtained in a more or less crystallized state from the evaporated sap. It is commonly prepared from the juice of the sugar cane; the sap of the maple contains 5 per cent. of the sugar of the cane, and that of beet-root, 4 to 5 per cent. It is met with in commerce quite pure, and in large crystals, which are obtained, after a slow process, under the name of candy; or in small crystals, which are procured from agitating a solution of sugar, as it begins to concrete, and is known by the name of refined sugar. It is easily soluble in water, and is entirely insoluble in anhydrous alcohol.

Syrup is found ready formed in the sugar cane and different plants, and from it, the syrup commonly met with in commerce is derived. It is easily soluble in water, and on being dried, forms a solid mass, without any appearance of crystals. In alcohol it is also easily soluble, but it cannot be obtained from a solution of it in a crystalline shape. By boiling a concentrated solution of sugar at a high temperature for a length of time, the sugar of the cane is converted into syrup without anything escaping but water, which served for its solution, and without the addition of any substance; so that the composition of syrup differs only from that of the sugar of the cane, as it gives off hydrogen and oxygen, or on the other hand, takes up oxygen and hydrogen as water.

The sugar of grapes is formed in grapes, and separates from them when dried (as raisins), in the form of white, crystalline masses; it is found also in figs, plums, cherries, apricots, pears, and various other fruits: it abounds in honey (the granular residue of honey being this sugar), and diabetic urine, from which, in combination with chloride of sodium, it separates in crystals. Sugar of milk may be transformed into this sugar, by boiling 100 parts of sugar of milk with 400 parts of water, and 2 parts of sulphuric acid during three hours. Starch too may also be converted into sugar of grapes, by boiling 100 parts of pure starch with 400 parts of water, and 1 part sulphuric acid during 36 to 40 hours; or with 400 parts water and 10 parts of sulphuric acid for seven to eight hours. The evaporated water should be constantly replenished by fresh; 100 parts of starch yield 107 parts of sugar of grapes.

Sugar of the cane, and of starch, is composed in the same manner as that of milk and of grapes.

	Sugar of Cane.	Anhydrous Starch.	Sugar of Milk.	Sugar of Grapes.
Carbon	44·78=12 vol.	44·00=12 vol.	45·45=12vol.	37·37=12 vol.
Hydrogen	6·40=22 —	6·64=20 —	6·06=24 —	6·78=28 —
Oxygen	48·82=11 —	49·43=10 —	48·49=12 —	56·51=14 —

In these four substances, oxygen and hydrogen are found exactly in the same proportions as in water. The change of sugar of milk and starch into sugar of grapes, depends on this reason; namely, that with both a new quantity of water combines, or rather, oxygen and hydrogen; and in this combination the sulphuric acid acts as in the preparation of ether; or as porous platinum, or a fermenting medium in the preparation of vinegar: the acid undergoes, however, no change.

Sugar of milk, of the cane, and of grapes can be easily procured in crystals. The sugar of the cane combines with bases; for instance, with oxide of lead, it gives off 2 volumes of hydrogen gas and 1 volume of oxygen gas. By dissolving in a concentrated solution of sugar, chloride of sodium, the chloride of sodium first separates in crystals, and then a combination of chloride of sodium and sugar: in this combination 4 volumes of hydrogen and 2 of oxygen gas are separated. The sugar of the cane, combined with oxide of lead, may be considered as a combination of 8 volumes of carbonic acid gas, and 4 volumes of ether vapour (therefore from 4 volumes of vapour of carbon, 8 volumes of oxygen gas=4 volumes of carbonic acid gas,) (and 2 volumes of oxygen gas, 20 volumes of hydrogen gas, 8 volumes of vapour of carbon=4 volumes of ether vapour,) and sugar of milk, as a combination of equal parts of vapour of alcohol and carbonic acid gas.

The sugar of grapes, combined to the chloride of sodium, would be thus composed, and in the crystallized form would contain 4 volumes of vapour of water in addition. In the same manner, by agitating 100 parts of starch with 40 parts of cold water, to which 20 parts of warm are added, and allowing it to stand seven or eight hours in conjunction with gluten from 145° to 190°, starch becomes converted into sugar of grapes. This transformation presents us with the theory for the preparation of beer, brandy, and other spirituous liquors and substances which contain starch. The sugar of grapes is with more difficulty soluble than that of the cane; it is easily soluble in boiling alcohol: it separates, however, on cooling, as a concentrated watery fluid.

The alcohol which our fermented liquors contain, is procured by one of these three varieties of sugar; of which syrup is most easy, sugar of the cane somewhat slower, and the sugar of the grape is the slowest to go into fermentation. This process does not take place in any combination in a state of purity; a slight addition of some fermenting substance, for which purpose yeast or some other article may be chosen, produces the same effect. By dissolving 100 parts of pure sugar in 1000 parts of water, and adding some yeast, which, deducting water and foreign substances, need not exceed 1½ parts; the sugar is then resolved into alcohol and carbonic acid.

The chemical decomposition takes place in the same manner, as in similar processes, by means of a contact substance of a fermenting medium. As the employed substances consist of carbon, oxygen, and hydrogen, in that proportion which is found in water; when a given quantity of carbonic acid is disengaged, a corresponding formation of alcohol is produced.

1 v. alcoh. vap.	=1 v. carb. :	3 v. hydrogen gas,	½ v. oxygen	=1·6015
2 v. carb. acid gas	=½ ——	——	1 ——	=1·5245
	1½ v. carb.	3 hydrogen gas,	1½ vol. oxygen.	

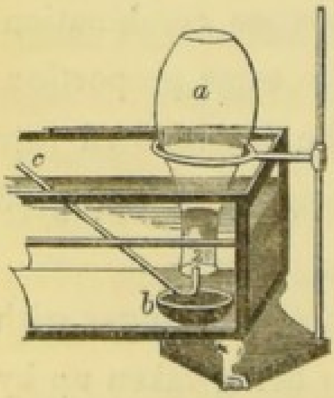
100 parts of carbon, yield by weight, 126·5 of alcohol, containing 66⅔ of carbon, and 120·5 carbonic acid; of which 33⅓ are carbon. Every carboniferous combination, containing hydrogen and oxygen, in the same proportion, as in the formation of water, can also be decomposed into alcohol and carbonic acid, by either taking up or giving off water.

In comparing the composition of varieties of sugar with these results, we find that, besides water being taken up by sugar of the cane, the sugar of the grape, as was the case when in combination with chloride of sodium, is decomposed into carbonic acid and alcohol; carbonic acid and alcohol are formed, and, at the same time, hydrogen and oxygen combine with each other, producing water. It is often of consequence, for practical use, to be able to ascertain, from the composition of substances which are submitted to fermentation, the quantity of alcohol which can be generated under the most favourable cases. In 100 parts of potatoes, by weight, there are often 20 parts of starch, and in these, 8·8 carbon are contained. In transforming this starch into sugar, and this again into alcohol and carbonic acid; we can obtain after a complete decomposition from the starch contained in 100 parts of potatoes, generally 12·2 of alcohol; but we must remember that there is also contained in potatoes, gum, which is converted into sugar and alcohol. The profit on the wholesale article nearly corresponds with this calculation.

6. CHLORINE, BROMINE, IODINE, AND ETHERINE.

A. *Chloride of Etherine.*

Fig. 57.



Chlorine gas combines both in the dark, as well in access of air, with etherine vapour, forming an oleaginous, limpid, colourless body, which is easily obtained, by either allowing chlorine to enter a flask, *a*, (Fig. 57), filled with hydrochloric acid, and inverted in water, or by introducing at the same moment, chlorine and etherine into a balloon.

To purify etherine from other substances, particularly ether, it should be conducted through pure concentrated sulphuric acid, and then through a solution of potash. The chloride of etherine is then distilled alternately over sulphuric acid and potash, until no black appearance arises. It has a pleasant ethereal smell, and a specific gravity of 1·256: it boils at 215°: after combustion with oxide of copper, by which carbon and hydrogen are formed, and after calculating the quantity of chlorine, when conducted over lime, by which chloride of calcium is formed, in which the quantity of chlorine is ascertained, by solution in water, by being rendered neutral, and precipitated by oxide of nitrate of silver; it is found that

$$\begin{array}{c}\text{1 volume of chloride of etherine} \\ \text{vapour } (3{\cdot}4214) \;=\end{array} \left\{\begin{array}{l}\text{1 volume of chlorine} \qquad = 2{\cdot}44 \\ 1 \text{ ———— etherine vap.} = 0{\cdot}9814\end{array}\right.$$

B. *Bromide of Etherine.*

Bromide can be more conveniently obtained than chloride of etherine, by filling with etherine, which has passed through sulphuric acid, and a solution of potash, a gasometer, and connecting to it a tube, which leads to a capacious flask in which bromine is placed. Etherine and bromine then combine; and this operation takes place very rapidly. Bromine of etherine, is procured pure by distilling it with sulphuric acid and potash, repeated several times, till the sulphuric acid no longer assumes a black colour. It is a colourless, ethereal-smelling fluid of the specific weight of 2·164; it boils at 322°, and becomes a solid mass at 27°. Its composition is made up as that of chloride of etherine.

$$\text{1 volume of bromine of etherine vapour (6·37)} = \begin{cases} \text{1 bromine vap.} & = 5·39 \\ \text{1 etherine vap.} & = 0.98 \end{cases}$$

C. *Iodide of Etherine.*

This is formed as bromide of etherine. The retort in which it is placed must be heated to 144°. Crystals, which are formed, and are iodide of etherine, are washed with an aqueous solution of ammonia. By exposing iodine with etherine to the light of the sun, iodide of etherine is equally formed. It fuses at 195°. Dissolved in ether it is, after slow evaporation, obtained in crystals of a yellowish colour. Carefully heated, iodide of etherine sublimes; but when heated too rapidly it is decomposed. The specific gravity of gaseous iodide of etherine has not yet been discovered. This substance consists of equal parts of iodine vapour and etherine vapour.

D. *Chloretheride.*

This combination is obtained by distilling together 3 pounds of water, to which two ounces of alcohol have been added, with 1 pound of chloride of lime, in a very capacious flask; the chloride of lime, consisting of a mixture of lime, chloride of calcium, and chloride of lime, produces the decomposition of alcohol. The combination is as well procured by conducting chlorine into a solution of potash and alcohol, or distilling pyroacetic spirit with chloride of lime. Chloretheride is a colourless fluid, its boiling point 167°, and specific weight is 1·480.

$$1 \text{ vol. of chloretheride vap.}(=4{\cdot}1138=)\left\{\begin{array}{ll} \frac{1}{2} \text{ vap. of carbon} & =0{\cdot}4219 \\ \frac{1}{2} \text{ hydrogen gas} & =0{\cdot}0344 \\ 1\frac{1}{2} \text{ chlorine} & =3{\cdot}6565 \end{array}\right.$$

Two volumes of chlorine vapour combine therefore, with half a volume of etherine vapour of the alcohol; and from this combination half a volume of chlorine gas, and half a volume of hydrogen gas have separated. By boiling this body with potash it is decomposed into formic and hydrochloric acids; the water therefore, becomes decomposed, its hydrogen combines with chlorine, and its oxygen unites with carbon and hydrogen.

E. *Brometheride.*

By distilling bromide of lime with alcohol or pyroacetic spirit, we obtain a fluid, which is rendered pure by sulphuric acid, and then distilled: it is heavier than sulphuric acid, and consists of ½ volume of carbon, ½ volume of hydrogen, and 1½ of bromine.

F. *Iodetheride.*

By adding a solution of potash in alcohol to a concentrated solution of iodine in alcohol under continual agitation, until the solution of iodine has lost its brown colour; we obtain a clear solution, from which, by adding a quantity of water, a yellow body, iodetheride is precipitated; the solution when evaporated yields only ioduret of potassium. This substance is insoluble in water, but soluble in alcohol and ether; slowly evaporated, the solution yields large yellow crystals. Heated to 304° it is decomposed into iodine and carbon; at 255° it sublimes. It has an excessively unpleasant smell; its specific weight in a gaseous form cannot be ascertained; it consists of $\frac{1}{2}$ volume of vapour of carbon, $\frac{1}{2}$ of hydrogen gas, $1\frac{1}{2}$ of iodine vapour.

G. *Chloral.*

The action of chlorine on alcohol may be most conveniently observed by employing a long wide tube, *a*, (Fig. 58.) at the end of which a narrow pipe *b* is fixed to allow the chlorine to enter; and the other end is furnished with a pipe, to collect the gas that is given off. By this operation several products are obtained, according as the alcohol which is employed is either anhydrous, or contains water. Chloral is obtained in larger quantities, and in shorter time, if chlorine be allowed to pass into an empty flask, and through a tube (Fig. 59.) containing chloride of calcium into a retort, *n*, where alcohol is placed; the flask is furnished with a safety tube, *a*, *b*, which prevents the alcohol that was passed from falling back in the retort: the flask should be kept cool as long as the action of the chlorine continues. The hydrochloric acid that is set free is conducted

Fig. 58.

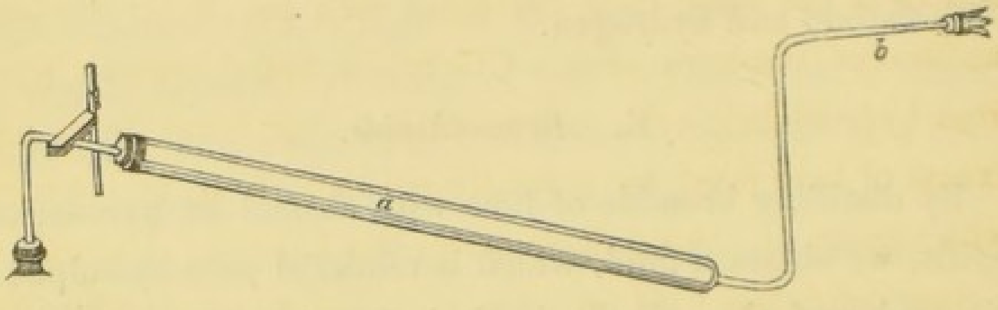
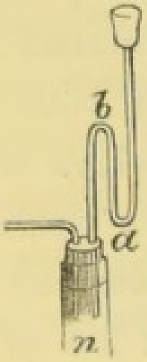


Fig. 59.



by a waste pipe into a chimney; in this manner 8 ounces of alcohol can be easily decomposed in a day.

The fluid of the consistence of syrup obtained at the end of the operation, and which forms, if it absorbs water, a white crystalline mass, contains besides chloral, alcohol, and hydrochloric acid: this is mixed with three times as much sulphuric acid, and distilled. The fluid that passes over is again distilled, and heated to 243°. At this temperature hydrochloric acid is disengaged, and the alcohol at the same time combines with the water, by the medium of sulphuric acid. Chloral is found entirely free from hydrochloric acid, when distilled over burnt lime; an excess of lime must be carefully avoided, as it, in contact with vapour of chloral decomposes the chloral. Chloral is a clear colourless fluid of the specific weight of 1·502, boils at 242°, and distils over unchanged; it has a peculiar smell, provocative of tears from the eyes; it is almost tasteless, is soluble in water in a large quantity, but without decomposition. Analysed in the same manner as chloride of etherine, it is found—

$$1\text{ vol. of chloral vap.}(=5{\cdot}0)=\begin{cases}1\text{ volume of vap. of carbon} & =0{\cdot}8438\\ \tfrac{1}{2}\text{ ——— hydrogen gas} & =0{\cdot}0344\end{cases}$$

$$\text{Or}\quad\begin{cases}\tfrac{1}{2}\text{ ——— oxygen gas} & =0{\cdot}5513\\ 1\tfrac{1}{2}\text{ ——— chlorine gas} & =3{\cdot}66\end{cases}$$

$$\overline{\quad 5{\cdot}09 \quad}$$

It may be considered that 1 volume of chloral vapour is composed of 1 volume of carbonic oxide gas, and 1 volume of chloretheride. With solutions of alkalies and earths chloral yields a formicate.

H. *Hydrate of Chloral.*

By allowing chloral to stand several days in contact with water, it becomes changed into a solid white mass. By dissolving chloral in water, and allowing it to evaporate slowly, crystals are procured, which, without undergoing any change, are distilled over with concentrated sulphuric acid, giving off fluid chloral, which, in contact with water, becomes, after some time, solid. These crystals, as well as chloral, are decomposed by potash. If hydrate of chloral be analysed, we find that 1 volume of this substance in a gaseous form ($=2{\cdot}855$) consists of $\frac{1}{2}$ volume of chloral ($=\frac{5{\cdot}09}{2}=254$), and $\frac{1}{2}$ volume of vapour of water ($=\frac{0{\cdot}620}{2}=0{\cdot}310$). A solid substance, insoluble in water, which is produced by allowing chloral to stand with sulphuric acid at a common temperature, and is also insoluble in water, ether, and alcohol, appears to result from a decomposition of chloral.

I. *Bromal.*

This substance is procured from alcohol in the same manner as chloral, by gradually adding to 1 part of alcohol $2\frac{1}{2}$ to $3\frac{1}{2}$ parts of bromine, and heating the retort till a sixth of the fluid remains; this consists of bromal and heavy bromic ether. Exposed to the air in a damp place the ether evaporates, and hydrate of bromal remains in a crystalline shape. Bromal is more conveniently obtained, by gradually adding to ether as much bromine as the ether is capable of dissolving, and allowing the solution to stand 10 or 12 days; there form hydrobromic acid, hydrobromic ether, heavy bromic ether, and bromal. By adding to the residue some water, and allowing it to evaporate in the air, we obtain large crystals of hydrate of bromal, from which, by the aid of sulphuric acid and lime, bromal may be procured in a state of purity. It is a colourless fluid of the specific weight of 3·35, boils at a temperature above 257°, and is easily soluble in water, alcohol, and ether: from sulphuric acid it undergoes no change. Aqueous metallic oxides are decomposed by it, as well as by chloral.

Bromal is composed in the same proportions as chloral; so that instead of $1\frac{1}{2}$ volume of chlorine vapour, which chloral contains, $1\frac{1}{2}$ volume of bromine are substituted in bromal. The same correspondence exists between chloral and bromal in decomposition by alkalies, whereby brometheride and a formicate result. By analysing the fluid at different periods, whilst chlorine is passing through alcohol, we easily perceive that very different combinations are formed; in the middle of the operation, for instance, by an addition of water, a combination separates, which boils at about 480°, and is again decomposed during the operation. There forms also, from the action of chlorine and bromine, on alcohol and ether, a combination, consisting of 2 volumes of chlorine or bromine with 1 volume of ether vapour; which when heated with water, or exposed to the light of the sun, yields hydrochloric or hydrobromic acid, and acetic ether.

It is very probable that before chloral is formed many combinations are produced and decomposed again. Chloral is so composed, that if 1 volume of alcohol vapour, and 4 volumes of chlorine operate on each other, $2\frac{1}{2}$ volumes of chlorine gas separate, combined with $2\frac{1}{2}$ hydrogen gas, as hydrochloric acid, and $1\frac{1}{2}$ volume of chlorine gas, and $\frac{1}{2}$ a volume of hydrogen gas remain combined with the whole quantity of oxygen and carbon of the alcohol.

K. *Heavy Muriatic Ether.*

Heavy muriatic ether is best obtained by saturating cold alcohol with chlorine, adding as much water to the fluid by volume, and distilling, then separating the ether over peroxide of manganese. What passes over first is acetic ether, then the heavy muriatic ether, and a solid chloride of carbon sublimes in the retort. Mixed with a solution of potash and alcohol, it yields chloretheride: saturated with hydrate of potash, there passes over an oleaginous body, which boils at 265°, and has a specific gravity of 1·174. Heavy muriatic ether boils at 284°; its specific weight is 1·227, Spiritus muriatico-etherius procured by distilling 16 parts of chloride of sodium, 6 parts of peroxide of manganese, and 12 parts of sulphuric acid, diluted with 48 parts of water, and the portion that has passed over, rectified by magnesia, is a solution, as follows from analysis, consisting of heavy muriatic ether, acetic ether, some light muriatic ether, and oxidized ether in alcohol.

III.—METHYLE,

CARBURETTED HYDROGEN OF PYROXYLIC SPIRIT.

1 volume of methyle vap. $= \frac{1}{2}$ volume of vap. of carbon $+ 1$ volume of hydrogen gas.

If the combinations, which are formed by means of pyroxylic spirit are properly studied, it would be found not to be inferior in this respect to alcohol. Carburetted hydrogen, which in these combinations has the same relation as etherine has in those of alcohol, has up to this time never been procured pure, though all these combinations are so composed, that if we take carburetted hydrogen, 1 volume of which contains $\frac{1}{2}$ volume of vapour of carbon, and 1 volume of hydrogen, we shall find them composed in the same proportions as those which etherine forms.

Carburetted hydrogen, which is selected for this purpose, and which has been termed methyle (from *μέθυ*, wine, and *ὕλη*, wood), contains accordingly carbon and hydrogen in the same proportion as etherine; one volume of it, however, contains only half of the carbon and hydrogen, so that its specific weight amounts to 0·4907, the half of what etherine gas amounts to. Consequently those combinations which yield etherine and methyle in the same quantity of other substances, contain the same amount of methyle according to volume, but only half as much by weight. Pyroxylic spirit is so composed, that with $\frac{1}{2}$ a volume of vapour of carbon, and 1 volume of hydrogen gas (= 1 volume of pyroxylic spirit vapour), 1 volume of vapour of water; whilst with the same quantity of vapour of water in alcohol, 1 volume of the vapour of carbon, and 2 volumes of hydrogen gas (=1 volume of etherine vapour) are combined.

1. *Pyroxylic Spirit.*

This spirit is contained in the watery fluid, which is obtained by submitting wood to dry distillation, consisting principally of acetic acid dissolved in water; besides which it contains empyreumatic oil, acetate of ammonia, and 1 per cent. of pyroxylic spirit. It boils at 180°, it may be strengthened by distillation, as alcohol and brandy. From pyroligneous acid about 7 per cent. are procured. The fluid is distilled with lime, and the operation is repeated; a liquid is then obtained, which boils at 235°, and contains ammonia; by saturating this with sulphuric acid, as well as the raw pyroxylic spirit, which is found in commerce, and is used for lamps in England instead of alcohol, and in other countries to counterfeit rum; and by distilling at first by itself, and then twice over an equal weight of lime, it is found in a state of purity.

It is a colourless fluid, of a peculiar spirituous smell, similar to acetic ether of the specific gravity of 0·798, it boils at 180°. In boiling it is violently agitated; but this may be prevented by the addition of mercury, as then the ebullition proceeds from the mercury. The specific weight of this spirit in a gaseous form is 1·11.

$$\begin{array}{c}\text{1 volume of pyroxylic}\\ \text{spirit }(=1{\cdot}11) =\end{array}\left\{\begin{array}{l}\tfrac{1}{2}\text{ vol. of vap. carb. } =0{\cdot}4219\\ 2\text{ —— hydrogen gas} =0{\cdot}1376\\ \tfrac{1}{2}\text{ —— oxygen gas } =0\;5512\end{array}\right\}=\left\{\begin{array}{l}\text{1 v. vap. of}\\ \text{methyle}\\ \text{1 v. vap.}\\ \text{of water.}\end{array}\right.$$

This spirit, when kindled by means of platinum sponge, burns like alcohol; it is oxidized, and becomes formic acid;

chlorine acts on it; acids yield with it varieties of ether. Potash and soda are soluble in it; barytes combines when heated. It dissolves the combination, which is obtained from the solution under the receiver of an air-pump, in crystals in which the oxygen of the spirit bears the same proportion to that of the barytes as 2 to 1. It acts as a solvent in the same manner as alcohol.

2. *Pyroxylic Ether.*

By distilling 1 part of pyroxylic spirit with 4 parts of concentrated sulphuric acid, a mixture is given off, from whence, if allowed to remain some time in contact with potash, sulphurous and carbonic acids are removed. The remaining gas is pyroxylic ether. It is colourless, and of ethereal odour; at —4° it is no longer found in a fluid state; one volume of water solves 37 volumes of it; alcohol and ether still more.

$$\begin{array}{r}\text{1 volume of pyroxylic}\\ \text{ether vap.}(=1{\cdot}60)=\end{array}\left\{\begin{array}{l}\text{1 vol. vap. of carb.}\\ \text{3 —— hydrog. gas}\\ \tfrac{1}{2}\text{—— oxygen gas}\end{array}\right\}=\left\{\begin{array}{l}\text{2 vol. methyle gas.}\\ \text{1 vol. vap. water.}\end{array}\right.$$

Pyroxylic ether has, therefore, the same relation to the spirit as ether to alcohol. The correspondence of alcohol with pyroxylic ether is of the greatest importance; both consist of the same elements, which are combined according to the same proportions by weight, and the specific gravity of both is the same; their chemical and physical properties, however, are very different. It is a most beautiful instance of isomeric bodies. Isomeric substances are such as have the same composition, but still are endowed with different chemical and physical properties.

A. *Sulphate of Pyroxylic Ether.*

By distilling 1 part of pyroxylic spirit with 8 to 10 parts of sulphuric acid by slow and continued boiling, the distilled portion amounts to as much by weight as the pyroxylic spirit that was employed. It consists of an oleaginous and a watery fluid ; the oleaginous portion, which is separated by decanting, is agitated with water, to remove the sulphuric acid ; with chloride of potassium, to remove the water ; and several times distilled with barytes, to remove the sulphurous acid. Under an air-pump it loses its last remains of pyroxylic spirit and sulphurous acid.

The oleaginous fluid is colourless, smells like leeks, having a specific weight of 1·324 ; boils at 376°, and distils over unchanged ; the specific weight is 4·37 : and analysed like pyroxylic spirit.

$$\begin{array}{r}\text{1 v. of sulphate of pyroxylic}\\ \text{ether vap. } (=4{\cdot}37) =\end{array} \left\{\begin{array}{l} \left.\begin{array}{l}\text{1 v. sulphuric acid}\\ \quad\text{gas} \quad = \quad 2{\cdot}77\end{array}\right\} = \left\{\begin{array}{l}\tfrac{1}{6}\text{ v. vap. sulph.}\\ 1\tfrac{1}{2}\text{ v. oxygen —}\end{array}\right. \\ \left.\begin{array}{l}\text{1 v. of pyroxylic}\\ \quad\text{ether vap.} = 1{\cdot}60\end{array}\right\} = \left\{\begin{array}{l}\text{1 v. vap. carbon.}\\ \text{3 — hydrog. gas}\\ \tfrac{1}{2}\text{ — of oxygen.}\end{array}\right. \\ \qquad\qquad\qquad\quad \overline{4{\cdot}37}\end{array}\right.$$

This combination is slowly resolved in cold water, but quickly in boiling, into pyroxylic spirit and a peculiar acid, pyroxylo-sulphuric acid. By bringing in contact sulphate of pyroxylic ether with a hydrate of barytes, or a solution of alkalies, then it is resolved at the same time into pyroxylic spirit and pyroxylo-sulphuric acid, which combines with a base. By heating pyroxylic ether with chloride of calcium, we obtain hydrochlorate of methyle ; with fluoret of calcium, gaseous hydrofluorate of methyle; with cyanuret of mercury, hydrocyanate of methyle, with benzoate of potash, benzoate of pyroxylic ether, with formicate of soda, formicate of pyroxylic ether; and with hydrosulphate of sulphuret of potassium, a combination of hydro-sulphuric acid with hydrosulphate of methyle; the sulphuric acid remains combined with the base as a sulphate.

Pyroxylo-sulphuric acid is obtained by carefully decomposing pyroxylo-sulphate of barytes with sulphuric acid, and evaporating the solution under an air-pump, in the form of white acicular crystals: this acid combines with all bases.

The salt of barytes is obtained by mixing 2 parts of sulphuric acid and 1 part of pyroxylic spirit, and saturating the fluid with carbonate of barytes. The solution is evaporated to the consistence of syrup, and crystallizes under the receiver of an air-pump.

B. *Nitrate of Pyroxylic Ether.*

Diluted nitric acid may be distilled with pyroxylic spirit, without producing any action. By mixing, on the other hand, 5 parts of the spirit, 5 parts of nitre, and 10 parts of sulphuric acid; the distillation commences by reason of the heat arising from the mixture, and kept up by this action. The ethereal fluid should several times be distilled over oxide of lead and chloride of calcium. It is distilled alone, after one part has passed over, the boiling point is fixed. That portion which passes over at 188°, as far as the analysis of the present day goes, is nitrate of pyroxylic ether, which is colourless; its specific weight is 1·182, and has a slightly ethereal smell; heated above 370° it evaporates. Its specific weight, in a gaseous form, is 2·653. It is probable from analysis, that

$$\left.\begin{array}{r}\text{1 vol. of nitrate of}\\ \text{pyroxylic ether}\end{array}\right\} 2{\cdot}653 = \begin{cases}\text{nitric acid} = \begin{cases}\tfrac{1}{2}\text{ vol. nitrogen gas.}\\ 1\tfrac{1}{4}\text{ — oxygen gas.}\end{cases}\\ \tfrac{1}{2}\text{ vol. pyroxylic ether.}\end{cases}$$

Added to a solution of potash in alcohol, and heated, it yields nitrate of potash. Nitrite of pyroxylic ether has not yet been prepared.

C. *Oxalate of Pyroxylic Ether.*

By distilling equal parts of oxalic acid, sulphuric acid, and pyroxylic spirit, a fluid is obtained, from which, when exposed to the sun, crystals are formed; these are laid on blotting paper and distilled with oxide of lead. The oxalate of pyroxylic ether, which is thus obtained in a state of purity, is colourless, has the smell of oxalic ether, fuses at 147°, and boils at 395°. It is soluble in alcohol and pyroxylic spirit, as well as in cold water; it is, however, easily decomposed, and still more quickly if heated, into alcohol and oxalic acid. With ammonia in excess, it yields pyroxylic spirit and oxamide; added in smaller quantity it yields pyroxylo-ether-oxamide. The specific weight of oxalate of ether vapour has not yet been ascertained. Oxalate of pyroxylic ether consists of

Oxalic acid = 2 vols. vap. carbon + 3 vols. of oxygen gas.
+ Pyroxylic ether = 2 —— + 1 —— 6 hydrogen.

D. *Acetate of Pyroxylic Ether.*

By distilling 1 part of sulphuric acid, 1 part crystallized acetic acid, and 2 parts of pyroxylic spirit, and pouring the distilled portion on chloride of calcium, the acetate of pyroxylic ether separates as a light ethereal fluid, from which the sulphurous acid is removed by lime, and pyroxylic spirit by digesting with chloride of calcium. Its smell resembles that of acetic ether, has a specific weight of 0·919, and boils at 150°. Its gravity is 2·57, consequently

$$1\ \text{vol. of acetate of pyroxylic ether} = (2{\cdot}57)$$

$$=\left\{\begin{array}{llllll} \text{acetic acid} & =1\ \text{v. vap. carb.} & 1\tfrac{1}{2}\ \text{v. hydrogen,} & & \tfrac{3}{4}\ \text{v. oxygen gas,} & \\ \left.\begin{array}{c}\tfrac{1}{2}\ \text{v. pyroxylic} \\ \text{ether vap.}\end{array}\right\} & =\tfrac{1}{2}\quad \text{——} & 1\tfrac{1}{2} & \text{——} & \tfrac{1}{4} & \text{——} \end{array}\right.$$

E. *Formicate of Pyroxylic Ether.*

This is procured in the most convenient manner, by gently heating dry formicate of soda with sulphate of pyroxylic ether; the fluid that passes over must be again distilled over formicate of soda, and then by itself. It has been analyzed; and

$$1\ \text{vol. of formicate of pyroxylic ether} = (2{\cdot}08)$$

$$=\left\{\begin{array}{llllll} \text{formic acid} & =\tfrac{1}{2}\ \text{v. vap. carb.} & \tfrac{1}{2}\ \text{v. hydrogen,} & & \tfrac{3}{4}\ \text{v. oxygen gas.} & \\ \left.\left(\begin{array}{c}\tfrac{1}{2}\ \text{pyroxylic} \\ \text{ether vap.}\end{array}\right)\right\} & =\tfrac{1}{2}\quad \text{——} & 1\tfrac{1}{2} & \text{——} & \tfrac{1}{4} & \text{——} \end{array}\right.$$

F. *Benzoate of Pyroxylic Ether.*

By distilling 2 parts of sulphuric acid, 2 parts of benzoic acid, and 1 part pyroxylic spirit; precipitating the distilled portion with water; and washing and distilling the oleaginous residue over oxide of lead, and heating what passes over, to the usual boiling point, we obtain benzoate of pyroxylic ether in a state of purity. It is an oleaginous, colourless fluid, of a pleasant smell, not soluble in water, easily so in pyroxylic spirit, of a specific weight of 1·1 : it boils at 475° :

$$1 \text{ vol. of benzoate of pyroxylic ether vap.} = (4{\cdot}75)$$

$$= \begin{cases} \text{benzoic acid} & = 3\tfrac{1}{2} \text{ vap. of carb.} & 2\tfrac{1}{2} \text{ vol. hydrogen,} & \tfrac{3}{4} \text{ v. oxygen,} \\ \left(\begin{array}{c} \tfrac{1}{2}\text{ pyroxylic} \\ \text{ether vap.} \end{array}\right) & = \tfrac{1}{2} \quad \text{——} & 1\tfrac{1}{2} \quad \text{——} & \tfrac{1}{4} \quad \text{——} \end{cases}$$

G. *Chloro-carbonic Oxide gas, and Pyroxylic Spirit.*

By allowing pyroxylic spirit to pass over chlorocarbonic oxide gas, in the same manner as alcohol, the same phenomena take place, and the same products are the results. By purifying the ethereal fluid thus obtained, it is found by analysis, compounded as chloro-carbonic oxide gas with alcohol; only instead of methyle, etherine is present : it consists of

$$1 \text{ vol. vapour of carb. } 1\tfrac{1}{2} \text{ v. hydrogen gas, } \tfrac{1}{2} \text{ chlorine, } 1 \text{ oxygen gas}$$

$$= \begin{cases} \quad \tfrac{1}{2} \text{ vap. carb.} & \tfrac{1}{2} \text{ oxygen,} & 2 \text{ hydrogen gas} & = 1 \text{ v. vap. pyroxylic spir.} \\ +\tfrac{1}{2} \quad \text{——} & \tfrac{1}{2} \quad \text{—} & 1 \text{ chlorine gas} & = 1 \text{ chloro-carbonic oxide gas.} \\ - & \tfrac{1}{2} \text{ hydrog.} & \tfrac{1}{2} \text{ chlorine gas} & = 1 \text{ hydrochloric acid gas.} \end{cases}$$

In the formation of this body, half the chlorine combines with the hydrogen, and is separated as hydrochloric acid. Should the whole quantity of chlorine combine with the hydrogen and separate, we should find a combination of equal parts of carbon, oxygen, and hydrogen, a combination which would correspond with a variety of sugar, which contains, instead of alcohol, pyroxylic spirit.

H. *Hydrochlorate of Methyle*

Is obtained as a colourless vapour, by submitting to distillation 2 parts of chloride of sodium, 1 part of pyroxylic spirit, and 3 parts of sulphuric acid ; at $-8°$ it is no longer fluid. 1 volume of water dissolves about three volumes of it; by washing with water, it is easily separated from foreign substances.

$$\begin{array}{l}\text{1 vol. of hydrochlorate}\\ \text{of methyle}\end{array}\left\{=(1{\cdot}7378)=\right\}\begin{array}{ll}\text{1 vol. vap. of methyle} & =0{\cdot}4904,\\ \text{1 v. hydrochloric acid gas} & =1{\cdot}2474.\end{array}$$

This vapour is entirely decomposed at a red heat.

I. *Hydriodate of Methyle.*

This substance is obtained by dissolving iodine in pyroxylic spirit, gradually adding phosphorus in small quantities. Hydriodic acid, which is formed by the decomposition of water, combines with methyle, and the combination passes over by distilling the fluid. The distilled portion is mixed with water; the oleaginous fluid that separates is distilled over chloride of calcium, and then over oxide of lead. The pure combination is colourless, of specific weight of 2·237, and boils between 122° and 145°, consisting of 1 volume of methyle, and 1 volume of hydriodic vapour.

K. *Hydrofluorate of Methyle.*

This vapour is given off by gently heating together sulphate of methyle, and fluoride of calcium: 1 volume of water takes up $1\frac{2}{3}$ volume of this vapour; it may be collected over water, and after washing, may be procured in a state of purity. It has never yet been obtained in a fluid state. A volume of this vapour, whose specific weight is found to be 1·186, consists of 1 volume of methyle and 1 volume of hydrofluoric vapour.

L. *Combination of Chlorine and Pyroxylic Spirit.*

Chlorine produces no effect on pyroxylic spirit: it must be conducted several times through the retort, filled with chlorine gas, and distilled with it; the complete operation then takes place. In this way two combinations are obtained, of which one is more volatile than the other; the less volatile combines with ammonia, forming a crystallizable body. By distilling a solution of one pound of chloride of lime with an ounce of pyroxylic spirit, we obtain a body with the same properties and the same composition as if alcohol had been employed: this body has been termed chloretheride.

IV. DIFFERENT VARIETIES OF CARBURETTED HYDROGEN IN OIL GAS.

Attempts have been made to compress, within a narrow space in a vessel, gas obtained by decomposing oil at a red heat, and which is employed to furnish light, so as to be rendered portable.

By compressing this gas thirty times as much as gas usually is, the fourth part is separated as a fluid substance, which is allowed to flow into a flask, cooled to a very low temperature.

This fluid consists of three different substances, one of which can be obtained in a solid, and the other two in a fluid state. The solid and one of the fluid substances, whose boiling points are 225°, can be easily separated by distillation, from the other, which boils even under the freezing point; and the solid substance, which assumes a solid form at 42°, can be easily separated, by pressure between paper, from the fluid one which does not become solid at —8°. The solid combination is benzin. 1 volume of this combination consists of 2 volumes of vapour of carbon, and 4 volumes of hydrogen gas: it contains, therefore, the same proportion of vapour of carbon and hydrogen gas, as etherine and methyle. The specific weight of the fluid combination is 0·602; it is the lightest therefore of all known fluids.

The specific weight of this gas is double that of etherine. It is therefore easy to define how the combinations this body enters into are composed; they contain in the same quantity of carburetted hydrogen, only half as much of other substances as combinations of etherine or olefiant gas. The fluid combination, which boils at 225°, is, by analysis, so composed, that in 1 volume, 3 volumes of vapour of carbon and 4 volumes of hydrogen gas are contained.

V. SAPONINE AND CETINE.

In comparing the composition of crystallized stearic acid, which, by analysis, contains 70 volumes of vapour of carbon, 136 volumes of hydrogen gas, and 6 volumes of oxygen gas, with that of benzoic acid, it does not appear improbable, that it consists of pure carburetted hydrogen =(66 volumes of vapour of carbon, and 132 volumes of hydrogen gas), and oxalic acid=(4 volumes of vapour of carbon, and 6 volumes of oxygen gas. As crystalline margaric acid, which is found composed of 35 volumes of vapour of carbon, 67 volumes of hydrogen gas, and 4 volumes of oxygen, may be considered as consisting of 1 volume of carburetted hydrogen, and 4 volumes of carbonic acid; perhaps it may consist of 32 volumes of vapour of carbon, 64 volumes of hydrogen gas, and 4 volumes of carbonic acid gas; or of 1 volume of carbonic acid and 1 volume of carburetted hydrogen; of which 1 volume contains 8 volumes of vapour of carbon, and 16 volumes of hydrogen gas.

1. *Margarine.*

By distilling margaric acid with $\frac{1}{4}$ of its weight of lime, and purifying the distilled portion by crystallizing with alcohol, we obtain a white, shining, mass, which fuses at 205°, and is easily soluble in ether, but slightly so in alcohol; boiled in a solution of potash, it undergoes no change, but is decomposed by sulphuric acid. From analysis, it is formed by 2 volumes of oxygen gas combining with 1 volume of vapour of carbon, and producing carbonic acid, which remains with the lime. By assuming the above-mentioned theory on the composition of margaric acid: therefore,

Margaric acid=	32 vol. vap. carb.,	64 hydrogen,	2 carb.,	4 oxygen,
—Carbonic acid =			1 —	2 —
—Water =		2 —		1 —
therefore,				
Margaric acid=	33 ——	62 —		1 —

2. *Stearine.*

By treating in a similar manner stearic acid, and the products of distillation, we obtain a crystalline substance, which fuses at 158°, consisting of 4 volumes of oxygen, which combine with 2 volumes of carbon of the stearic acid, as found in the salt, forming carbonic acid, which remains with the base. Oleic acid undergoes a similar decomposition.

3. *Saponine.*

The separation of margaric and stearic acids, does not succeed, as of benzoic acid, into benzin and carbonic acid: besides the gaseous products, a fluid is obtained, which is easily distinguished from many others, inasmuch as it is lighter than anhydrous alcohol: whatever medium may be employed, it is not always procured at the same boiling point.

It is found from the analysis of the fluid which has been purified by several distillations over lime, and has remained some time in contact with potassium, that it contains only a trace of oxygen; but hydrogen and oxygen almost in the same proportions as etherine. It is probable that this fluid contains carburetted hydrogen of margaric and stearic acids, which may, in the meantime, be termed saponine; still there are many other combinations of carburetted hydrogen contained in it.

4. *Cetine.*

From ethal, which is obtained from boiling spermaceti with alkalies, a preparation of carburetted hydrogen is procured, consisting of 8 volumes of vapour of carbon, and 16 of hydrogen gas; it is procured by distilling ethal with phosphoric acid, as an oleaginous fluid. It boils at 650°; as it is derived from spermaceti, it has obtained the name of cetine.

Ethal has the same relation to cetine, as alcohol to etherine; it consists of 8 volumes of vapour of carbon, 16 of hydrogen gas, (which most probably form 1 volume of cetine vapour, the specific weight of which has not yet been discovered,) and of 1 volume of hydrogen gas, and $\frac{1}{2}$ volume of oxygen gas; therefore, from equal parts of cetine vapour and vapour of water. Chloride of phosphorus distilled with ethal, yields phosphoric acid and hydrochlorate of cetine, which consists of equal parts of cetine vapour and hydrochloric acid gas.

VI. NAPHTHALINE, PARANAPHTHALINE, AND IDRIALINE.

Naphthaline is obtained from all substances, as far as has been discovered, containing carbon and hydrogen, by exposing them to a white heat; consequently, from all vegetable and animal bodies. By submitting these in the usual manner to distillation, at a slowly rising heat, there remains carbon; an aqueous and oleaginous fluid condense in the receiver, various kinds of gas are disengaged, but naphthaline is not formed. By conducting this oleaginous fluid through an iron tube heated to whiteness, and the combinations formed by decomposition at a high temperature, through a cold tube, naphthaline is deposited in beautiful crystals.

Wood tar, coal tar, and animal tar, contain in general no naphthaline; still the distillation may be so conducted, that naphthaline may be procured, by placing the retort so deep in the fire, that one part of its neck might be heated to whiteness, and the combinations arising from the substances found in the retort, may be decomposed, by passing through its neck, as if it were a heated tube. In coal tar, which is procured during the preparation of gas for illumination, naphthaline is contained, provided the combinations resulting from the distillation of coals at times, come in contact with a part of the apparatus which is heated up to the temperature necessary for the preparation of naphthaline: for the same reason, it is procured during the formation of lamp black: in fact, it may be found during the process of any incomplete combustion. It is, however, procured in the easiest manner, by submitting to a slow distillation coal tar, at the conclusion of which it sublimes as a crystalline mass. It is also procured in a larger quantity, by distilling off 3 parts of 6 of coal tar; the portion that has passed over is conducted for some time through chlorine; the fluid is then washed with water, and again distilled, and is cooled to 10°; naphthaline then settles in large quantities. The crystals are dissolved in boiling alcohol, and naphthaline is obtained in a state of purity from them.

Naphthaline is formed besides, by exposing benzoate of lime, after it has lost 2 volumes of vapour of water, to a high temperature, a combination of lime takes place with 14 volumes of vapour of carbon, 10 volumes of hydrogen, and 3 volumes of oxygen gas. The affinity of lime for carbonic acid causes the combination of 3 volumes of oxygen gas with 1½ of vapour of carbon; and a combination of 12½ volumes of vapour of carbon, and 10 volumes of hydrogen gas passes over.

By distilling benzoate of lime carbobenzide is obtained. This preparation is a proof that naphthaline is formed by decomposition at a high temperature. Naphthaline fuses at 207°, and boils at 505°, and is characterised by its peculiar odour, which resembles much that of elder.

From a calculation of its specific weight in a gaseous form, and its analysis, it appears—

$$\text{1 vol. naphthaline vap. } (=4{\cdot}494) = \begin{cases} \text{5 of vapour of carbon} & =4{\cdot}219 \\ \text{4 of hydrogen gas} & =0{\cdot}275 \end{cases}$$

By heating naphthaline with concentrated sulphuric acid, a peculiar acid is obtained, namely a combination of naphthaline with sulphuric acid, which is composed as the acids of this class. From the action of chlorine and bromine on naphthaline, and from the treatment of substances procured from thence, a large number of combinations can be obtained. Chlorine combines directly in two proportions with naphthaline; the combination containing 1 volume of naphthaline vapour to 1 of chlorine gas, may be termed chloruret of naphthaline; whilst the one containing 2 volumes of chlorine gas is chloride of naphthaline; both are decomposed by heat; hydrochloric acid escaping, and two new combinations are formed. Perhaps there may be two more, in one of which 4 volumes of chlorine gas, and in the other 6 volumes combine with one of naphthaline vapour. The first may be termed perchloruret of naphthaline, and the second perchloride: of these we are, up to the present day, only acquainted with combinations, which arise when one part of chlorine with hydrogen separates as hydrochloric acid.

A. *Chloruret of Naphthaline.*

=1 volume of chloruret of naphthaline vap. (=5 volumes of vapour of carbon, 4 volumes of hydrogen gas) +1 volume of chlorine gas.

This combination is obtained by conducting chlorine over naphthaline till from the oleaginous body a solid substance, chloride of naphthaline, settles. We have endeavoured to separate the fluid, by means of dissolving in ether, and partly by evaporating and cooling, from chloride of naphthaline, which is slightly soluble in ether, as well as from naphthaline. It is an oleaginous, yellowish coloured body, which is soluble in alcohol, and in ether, in every proportion.

B. *Chloruret of Naphthalide.*

=5 volumes of vapour of carbon, 3½ volumes of hydrogen gas, ½ volume of chlorine gas.

By distilling repeatedly chloruret of naphthaline, at every time hydrochloric acid is disengaged. By distilling it over potash, chloride of potash and water are formed, and a clear, colourless fluid, chloruret of naphthalide passes over, which is distilled without decomposition taking place; it is formed by half of the chlorine combining with the necessary quantity of hydrogen, and separating as hydrochloric acid.

C. *Chloride of Naphthaline.*

1 volume of naphthaline vap.+2 volumes of chlorine gas.

By conducting chlorine over naphthaline, as long as any is taken up, and heating only very gently naphthaline and chloruret of naphthaline, so much only that an aqueous surface may be present, on which chlorine may act, then chloride of naphthaline is formed, which, after the chloruret of naphthaline is separated, is dissolved in hot ether, and forms crystals from the solution.

D. *Chloride of Naphthalide.*

5 volumes of vap. of carbon+3 hydrogen, 1 volume of chlorine gas.

By distilling chloride of naphthaline, hydrochloric acid is disengaged, and an oleaginous body, which concretes into a crystalline mass on cooling, passes over; by distilling this a second time, pressing the crystals between paper, dissolving them in alcohol, we find the combination pure, and in a well defined crystalline form. It fuses at 132°, and is distilled without undergoing any decomposition; nitric and sulphuric acids produce no effect on it; potash as little, though the solution be very concentrated. The combination is formed in a similar manner as chloruret of naphthalide. From this combination there results a body, which has entirely the same composition, but which, from its peculiar properties, seems to be totally different. This is procured by boiling chloride of naphthaline with a solution of potash in alcohol: the essential difference consists in its point of fusion, which stands in this combination from 72° to 77°.

E. *Perchloruret of Naphthalide*

=5 volumes of vapour of carbon, 2 volume of hydrogen gas + 2 volumes of chlorine gas.

By conducting chlorine over naphthaline, or the four above-mentioned combinations, as long as any action continues, when the temperature rises to the boiling point, a developement of hydrochloric acid takes place. By interrupting the chlorine gas, the fluid mass, when allowed to cool a little, immediately concretes; it is then dissolved in boiling alcohol, from whence crystals are formed: this operation is repeated several times. This combination is white, free from taste and smell, somewhat more soluble in alcohol and ether than perchloride of naphthalide: it is evaporated and is not taken up by boiling acids.

F. *Perchloride of Naphthalide*

=5 volumes of vapour of carbon, 3 volumes of hydrogen gas +5 vol. of chlorine gas.

This combination is obtained by conducting chlorine over chloride of naphthaline. From the action of chlorine on naphthaline, we obtain, probably, no perchloride nor perchloruret of naphthaline, whilst the temperature which is necessary for the formation of these combinations, already produces a decomposition, and developement of hydrochloric acid. The combination is washed with ether, and the residue in boiling ether, from which, on cooling, crystals form. It fuses at 330°, it is distilled without being decomposed, and is not taken up by aqueous solution of potash, nor by nitric or sulphuric acids; boiled with a concentrated solution of potash in alcohol, it yields hyperchloruret of naphthalide.

By adding to the chloride of napthaline bromine, it is dissolved, forming after some time a solid mass. By washing with ether, dissolving in boiling ether, and crystallizing, the combination is obtained pure; it consists of 5 volumes of vapour of carbon, 3 volumes of hydrogen gas, 1 volume of chlorine gas, and 2 volumes of bromine vapour.

G. *Bromuret of Naphthalide.*

By adding to naphthaline bromine, a strong action takes place, hydrobromic acid is disengaged, and an oleaginous body is formed. This substance has never yet been prepared pure.

H. *Bromide of Naphthalide.*

=5 volumes of vapour of carbon, 3 volumes of hydrogen gas, and 1 volume of bromine vapour.

This combination is procured by allowing bromine to operate on naphthaline as long as hydrobromic acid is disengaged; the mass becomes solid. It is rendered pure by solution in alcohol, and crystallizing. This combination is white, free from smell, easily soluble in alcohol and ether, insoluble in water, distils over without being decomposed: it forms crystals at 150°. It is but slightly taken up by sulphuric acid, not at all by cold nitric acid. By conducting chlorine into a heated combination of this substance, perchloruret of naphthalide is obtained.

Persons have not succeeded in procuring combinations of naphthaline with iodine and cyanogen.

I. *Nitronaphthalide.*

Nitric acid produces commonly no effect on naphthaline; boiled with it, but slight action; by adding, however, to naphthaline fuming nitric acid in drops, violent action takes place. On the surface of the nitric acid an oleaginous fluid forms, from which, as well as from the nitric acid, a crystalline body separates. This oleaginous body has not been sufficiently analyzed. The crystalline mass consists of two substances, of which one, the nitronaphthalide, is more easily soluble in alcohol than the other, binitronaphthalide.

Nitronaphthalide is obtained in the easiest manner, by pouring fuming nitric acid on naphthaline, and heating the fluid till a solution takes place, from which, when cooled, nitronaphthalide separates, which is first washed with water, and is obtained pure by repeated crystallization by means of alcohol. Its crystals are found in fine, yellow, acicular masses, which are soluble in ether and alcohol, but not in water; it fuses at 128°, and volatilizes without being decomposed; by conducting it through a heated tube a slight detonation takes place. Sulphuric and nitric acids dissolve it completely. By allowing chlorine to act on it, we have perchloruret of naphthalide. It consists of 5 volumes of vapour of carbon, 3½ volumes of hydrogen, ½ volume of nitrogen, 1 volume of oxygen gas. It consequently bears the same relation to naphthalide as nitrobenzide does to benzin.

1. *Binitronaphthaline.*

By adding naphthaline in small quantities to fuming nitric acid, heated to its boiling point, a violent action takes place. When about a quarter of the nitric acid has been used, and the clear fluid has been boiled some time, and allowed to cool, there forms a crystalline mass ; this is well washed with water, and is boiled with alcohol. Whatever substance the nitronaphthalide contained is removed by the solution, and what remains, is dissolved in larger quantities of alcohol, and pure crystals are formed. It is insoluble in water, but easily soluble in alcohol and ether ; it fuses at 448° ; heated cautiously it sublimes ; and conducted through a red hot tube, a detonation takes place. Nitric and sulphuric acids dissolve it completely. It consists of 5 volumes of vapour of carbon, 3 volumes of hydrogen gas, 1 volume of azote, and 2 volumes of oxygen gas. It is thus formed :—double as much nitric acid combines with the same quantity of naphthaline as in nitronaphthalide, and twice as much water separates.

By distilling nitronaphthalide and binitronaphthalide with lime, they become decomposed. Among the resulting products which have, as yet, never been sufficiently investigated, naphthaline is found ; and in binitronaphthalide, ammonia.

2. *Paranaphthaline.*

If during the distillation of coal tar the receiver be filled four times, the first two quantities that pass over consist of an oleaginous fluid, and the two last of a mucilaginous liquid. The fluid of the first receiver contains only naphthaline, and the second, third, and fourth, paranaphthaline. Paranaphthaline is crystallized from the fluid of the second receiver, if cooled down to 9° from that of the third and fourth it must be separated by a little oil of turpentine, in which it is slightly soluble; and then the solution must be cooled down to 10° in oil of turpentine, from which it is equally as well obtained in crystals. The crystals must be compressed in linen, then washed with alcohol, and distilled.

Thus purified, it fuses at 435°, and boils at a temperature above 708°. Cautiously heated, it is sublimed without being decomposed. It is not soluble in water, but only slightly in alcohol and ether, therefore

$$\begin{array}{l} \text{1 vol. of paranaphthaline} \\ \text{vap. } (=6{\cdot}741) \;= \end{array} \left\{ \begin{array}{l} 7\tfrac{1}{2} \text{ vol. vap. of carb. } = 7\tfrac{1}{2} \times 0{\cdot}8438 = 6{\cdot}328 \\ 6 \text{ vol. of hydrog. gas} = 6 \;\; \times 0{\cdot}0688 = 0{\cdot}413 \end{array} \right.$$

$$\overline{\quad 6{\cdot}741 \quad}$$

It follows that carbon and hydrogen combine in the same proportion in paranaphthaline as in naphthaline; the only difference is that the vapour of the latter is $1\frac{1}{2}$ times heavier than that of the former. By boiling for a long time paranaphthaline with nitric acid, crystals are separated from the fluid, which are insoluble in water and alcohol, and only slightly so in ether. With potash, lime, or hydrochloric acid it undergoes no change; but sulphuric acid dissolves it. The crystals consist of 7½ volumes of vapour of carbon, 4 volumes of hydrogen gas, 1 volume of oxygen gas=1 volume of paranaphthaline (=7½ volumes of vapour of carbon, 6 volumes of hydrogen gas,) 2 volumes of oxygen gas—2 volumes of vapour of water=(2 volumes of hydrogen gas, and 1 volume of oxygen gas).

3. *Idrialine.*

This product is met with in the quicksilver mines of Idria; it can be separated by oil of turpentine; and from a warm solution of this it can be easily crystallized. It is decomposed, in a great degree, by distillation, and fuses at so high a temperature that it begins to be decomposed. It probably consists of 1½ volume of vapour of carbon, and 1 volume of hydrogen gas.

Schererite and hatchetine, which are found in nature, are identical with idrialine, or, at least, similar to it.

VII. OIL OF TURPENTINE, AND OIL OF LEMONS.

From various kinds of firs there flows, from the bursting of the bark, a thick sap, which is procured in large quantities, and in a state of purity, by making a hole in the tree, and allowing it to flow into a vessel; this sap consists of volatile oils, which hold in solution various chemical combinations called resins.

By adding water to turpentine, and distilling it, there passes over with the vapour the oil of turpentine, which amounts to about a fourth of the weight of turpentine. It floats on water, consequently it has a specific weight of 0·86, and is insoluble in it. It is procured in a state of purity, by being dissolved in anhydrous alcohol, in which it is soluble in every proportion; and to the solution of common spirit as much alcohol should be added till it attains the specific weight of 0·84. As 100 parts of this alcohol dissolve only 13½ parts of oil of turpentine, and hold in solution all the resins, the oil is procured pure. For this purpose it must be agitated with water, to disengage it from the alcohol, in which it is held in solution, and allowed to stand some time in contact with pulverized chloride of calcium, and then distilled with it.

By allowing hydrochloric acid to pass through this oil, as long as any is taken up, we obtain, if the vessel with the combination be placed in ice, a solid crystalline substance, as well as a fluid, of which the relative quantities may be different in various kinds of oil of turpentine. The solid combination is procured pure, if it be compressed between paper, then dissolved in alcohol, and allowed to form crystals, which are washed in alcohol. It is almost insoluble in water, soluble in alcohol and ether, and fuses at a temperature of 335°, and boils at 404°, consequently 1 part is decomposed, and hydrochloric acid is given off.

By allowing the vapour of this substance to pass several times over red hot lime, it becomes decomposed; the hydrochloric acid combines with the lime, and a colourless aromatic-smelling oil is given off, which boils at 358°, and does not become solid at 32°, having a specific weight of 0·87; it consists of 5 volumes of hydrogen gas, and 8 volumes of vapour of carbon. If the fluid hydrochloric combination be decomposed in a similar manner, then an oil equally colourless is procured, of the specific weight of 0·86, which boils at 332°. The oil of turpentine contains, therefore, at least, 2 different volatile combinations; it consists by analysis with oxide of copper, of 88·4 carbon, and 11·6 of hydrogen. According to calculation of the specific weight of the vapour of turpentine oil, it follows—

$$\begin{array}{l} \text{1 vol. of vap. of turpen-} \\ \quad\text{tine oil } (=4{\cdot}769) = \end{array} \left\{ \begin{array}{ll} \text{5 vol. of vap. of carbon} & = 5 \times 0{\cdot}8438 = 4{\cdot}219 \\ \text{8 vol. of hydrog. gas} & = 8 \times 0{\cdot}0688 = \underline{0{\cdot}550} \\ & \hfill 4{\cdot}769 \end{array} \right.$$

Therefore, the substance furnishing a solid combination with hydrochloric acid, is compounded like the mixture; so the other, which furnishes the fluid combination, must also have this composition; the two are, therefore, isomeric. Turpentine oil boils at 383°, consequently at a higher temperature than that of both substances, *per se*.

At times a crystalline body is separated from oil of turpentine, which is soluble in alcohol, ether, and oil of turpentine, fuses at 370°, volatilises at from 370° to 380°. Turpentine oil cannot be separated from this crystalline body by distillation; it is sometimes present in such quantities, that it forms crystals at a lower temperature. It consists of 5 volumes of vapour of carbon, 11 volumes of hydrogen gas, and $1\frac{1}{2}$ volume of oxygen gas. Crystals of the same composition are separated from the volatile oils of basilicum, and cardamomum minus; whether, however, they are isomeric or identical, or whether they must be regarded as a combination formed of 1 volume of vapour of oil of turpentine (=5 volumes of vapour of carbon, and 8 volumes of hydrogen gas) and 3 volumes of vapour of water, future observation must decide. This body is procured by mixing oil of turpentine with water, and allowing it to stand for some time, when crystals are deposited on the walls of the receiver.

1. *Oil of Lemons: Essence of Lemons.*

This oil is found ready formed in the outer rind of lemons procured from Messina and Reggio. After the lemons, which are not fit to be exported, are cut into four pieces, the rinds are pressed against a sponge, and the juice from thence squeezed into a copper vessel, which, when filled, is soldered. In the same manner also oil of bergamot (bergamot is a small kind of lemon) as well as that of oranges is prepared; oil of lemons is considerably adulterated with that of oranges. Oil of lemons, treated in the same manner as that of turpentine, is procured pure; it consists of two different substances, and in distilling for instance 1 pound, the first ounce of the fluid that passes over, boils at 407°, and the second at 420°. By allowing hydrochloric acid to pass over oil of lemons, it combines with it, forming a solid and fluid body, of which the relative quantities in various kinds of oils are different. By means of filtration, pressure between paper, and recrystallizing, through the medium of alcohol, a body is procured in a solid state, in the form of foliated crystals, which fuse at

128°, and boil at 390°, when the combination is partly decomposed.

By conducting this combination over heated lime, and rectifying over lime the fluid that passes, and then over potassium, a colourless oil is procured, of the specific weight of 0·857, which boils at 404°, and is changed by hydrochloric acid into a solid combination. It is composed exactly in the same manner as oil of turpentine; in the solid combination there is only half as much acid in the same quantity of carburetted hydrogen as in that of oil of turpentine. This would lead us to suppose that this oil has the same relation to that of turpentine as methyle has to etherine, and that the specific weight of the vapour of this oil would amount only to half of what the oil of turpentine does.

The purest oil of lemons is found composed exactly as the oil from the solid hydrochloric combination; it is consequently probable, that the fluid hydrochloric acid contains a combination isomeric with the oil of the solid formation.

2. *Oil of Copaiva.*

By distilling oil of copaiva in the same manner as that of turpentine with water, there passes over with the water an oil of the specific weight of 0·88, which boils at 492°, consisting of 8 volumes of hydrogen gas, and 5 volumes of vopour of carbon. In distilling the oil, *per se*, and allowing hydrochloric acid to pass through what is given over, a solid combination is procured, composed in the same manner as that from the oil of lemons, both from its boiling point, which reaches 448°, and from its relation to sulphuric acid, by which no change takes place in the cold; whilst oil of lemons, being decomposed by it, differs from that with which it is isomeric.

3. *Oil of Juniper.*

By distilling unripe juniper berries with a solution of chloride of sodium in water, so as to reach a higher point of temperature, namely 377°, the fluid that passes over consists of two oils, one of which boils at 403°, the other at 493°, which can be separated from each other by distillation; the first has a specific weight of 0·84; the other of 0·88. From the ripe berries the second only is obtained, and the two are soon oxidized in the air; they both consist of 8 volumes of hydrogen gas, and 5 volumes of vapour of carbon.

4. *Oil of Cloves.*

By mixing oil of cloves with a concentrated solution of potash, it becomes decomposed into two oils, of which one acts as an acid, and combines with the potash; and the other can be separated and procured pure by distillation: this has a specific weight of 0·918, boils at 350° to 355°, and consists of 5 volumes of vapour of carbon, and 8 volumes of hydrogen gas. It unites with hydrochloric acid, forming a fluid combination.

VIII.—RESINS.

Of turpentine, balsam of copaiva, and other substances of this class, various chemical combinations are held suspended in the volatile oils, of which some act on bases as acids, and others are neutral; they are insoluble in water, soluble in alcohol; and some may be obtained in a crystalline form. A crystalline resin from turpentine consists of 5 volumes of vapour of carbon, 8 volumes of hydrogen gas, and ½ volume of oxygen gas; the same also is the composition of a crystalline resin procured from the balsam of copaiva. Another crystalline resin from turpentine consists of 10 volumes of vapour of carbon, 15 volumes of hydrogen gas, and 1 volume of oxygen gas. If oil of turpentine be exposed to the air, it quickly absorbs oxygen, from whence, at the same time, carbonic acid gas is generated, and the crystalline resin does not appear to form. Whether resin is to be regarded with certainty, as a degree of oxidation of the volatile oil, future investigations must decide.

IX.—CAMPHENE.

From many volatile oils, through cooling, and the medium of distillation, solid, crystalline, strong smelling substances are obtained, which are distilled without decomposition. To these substances common camphor belongs.

$$\text{1 vol. camphor vap.} = 5{\cdot}320 \begin{cases} \text{5 vol. vap. of carb.} = 5 \times 0{\cdot}8438 = 4{\cdot}219 \\ \text{8 vol. hydrog. gas} = 8 \times 0{\cdot}0688 = 0{\cdot}550 \\ \tfrac{1}{2}\text{ vol. oxygen gas} = \dfrac{1{\cdot}1026}{2} = 0{\cdot}551 \\ \hline \qquad\qquad\qquad\qquad\qquad\qquad 5{\cdot}320 \end{cases}$$

From whence we may conclude that 1 volume of camphor vapour consists of 1 volume of oil of turpentine (=4·279) and ½ volume of oxygen. But we are not entitled by any analysis to consider camphor as a degree of oxidation of carburetted hydrogen, and much less a degree of oxidation of the carburetted hydrogen of the oil of turpentine; which is more improbable, as it has the same composition as crystallizable resin of oil of turpentine. So, too, many solid substances of volatile oils, as well as a great number of fluid volatile oils may be regarded either as degrees of oxidation, or hydrates of varieties of carburetted hydrogen, more particularly of these combinations, which consist of 5 volumes of vapour of carbon, and 8 volumes of hydrogen; or as neutral combinations of acids and varieties of carburetted hydrogen, composed in a similar manner to carbobenzide, and nitrobenzide.

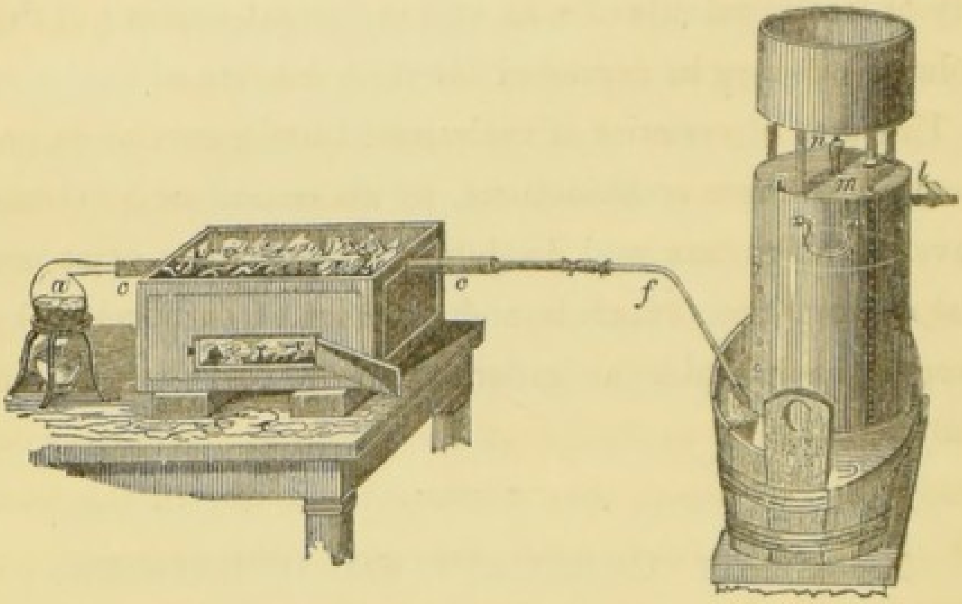
X.—LIGHT CARBURETTED HYDROGEN. INFLAMMABLE AIR OF MARSHES.

By submitting to distillation various organic substances, which consist of carbon, hydrogen, and oxygen, carbon is obtained as a residue; oxygen and hydrogen combine with each other, and with a portion of the carbon.

Combinations thus formed are, at common temperature, partly fluid, partly gaseous; the gaseous compounds are carbonic acid, carbonic oxide gas, and various combinations of carbon and hydrogen.

By heating in a small retort, *a*, alcohol, and allowing the vapour, which consists of 1 volume of vapour of carbon, 3 volumes of hydrogen gas, and $\frac{1}{2}$ volume of oxygen gas, to pass through a heated tube, *c*, $\frac{1}{2}$ volume of oxygen gas combines with $\frac{1}{2}$ volume of vapour of carbon, to form 1 volume of carbonic oxide gas; and $\frac{1}{2}$ volume of vapour of carbon, with 2 volumes of hydrogen gas, to form carburetted hydrogen gas, and 1 volume of hydrogen is parted with. The name of gas of mines has been given to this species of carburetted hydrogen, as it is found in coal mines.

Fig. 60.



It is rendered more pure, by allowing it, when procured by distillation from pure coals, to pass through a red hot tube. Hydrogen and carbon do not combine directly, neither at the usual temperature, nor when heated together; even if water be conducted over heated charcoal, a very slight quantity of this species of gas is procured, mixed with oxide of carbon, and hydrogen gas, arising from the decomposition of water. Mixtures of a similar species of gas can be easily analysed in a graduated tube over mercury. If potash be added to the mixture, the carbonic acid is absorbed; by removing a small piece of potash, and introducing potassium, carbonic oxide gas is decomposed, as carbon is parted with, and potash forms; what remains is carburetted hydrogen gas and hydrogen gas.

The composition of carburetted hydrogen, and the quantity of hydrogen mixed with it, may be calculated from the volumes of oxygen necessary for its combustion.

This gas is procured in the purest state from the decomposition of organic substances in stagnant waters, which have a muddy bottom. By filling a flask with water, and placing a wide funnel into its mouth, and inverting it over a pond, when the ground is stirred up with a stick, and the flask is so held that the bubbles which rise may pass into the funnel, they displace the water in the flask, which is soon filled with the gas. The carbonic acid mixed with the gas, is removed by agitating it with lime water, which combines with the lime, forming a carbonate of lime. A similar decomposition takes place in coal mines, as well as in standing waters, and frequently generated in storehouses and ships. This gas forms with atmospheric air a detonating mixture. In some coal mines it develops itself gradually in large quantities; at times it is condensed in clefts, from whence it rushes out, when the labourers break them open. This gas mixes with the atmospheric air found in mines, and explodes, when kindled, with such violence, that the labourers are struck to the ground, and are often most severely injured.

This is, no doubt, the gas which rises from the earth at Baku, and other parts of Persia, and which was worshipped by the Persians; on the Rhine, near Ems, in the same manner a current of gas flows out of an abandoned mine, which serves for the purpose of giving heat. One volume of carburetted hydrogen gas, mixed with 2 volumes of oxygen gas, gives off, when kindled by an electric spark, 1 volume of carbonic acid gas, and limpid water.

One volume of carbonic acid gas contains $\frac{1}{2}$ volume of vapour of carbon, and 1 volume of oxygen gas; the other volume of oxygen gas is employed for the combustion of the hydrogen which is contained in the carburetted hydrogen; consequently this contains 2 volumes of hydrogen. Therefore in carburetted hydrogen 2 volumes of hydrogen, and $\frac{1}{2}$ volume of vapour of carbon are contained, condensed into 1 volume. By allowing an electric spark to pass several times through carburetted hydrogen; the carbon is deposited, and 1 volume of this gas gives off 2 volumes of hydrogen gas. By allowing this gas to pass through a strongly heated tube several times, a similar decomposition takes place, carbon is deposited, and hydrogen gas is obtained. The specific weight of this gas can be easily calculated from these decompositions:—2 volumes of hydrogen gas $=0·1376$, $\frac{1}{2}$ volume of carbon $=0·4219$; therefore, 1 volume of carburetted hydrogen $=0·5595$; so, in the same manner, a composition of a hundred parts can be easily calculated. This gas does not produce any deleterious consequences, since in the coal mines of England the labourers work in this mixture of gas, (in whose upper layers a safety lamp has caused an explosion,) without their feeling any visible ill effects. Up to the present day this gas has never been known to combine either with acids or any other substance.

XI.—NAPHTHA. PETROLEUM.

As inflammable gas arises from the decomposition of organic substances under water, and from dry distillation, so also, in the same manner, a series of other kinds of varieties of chlorine and hydrogen is formed, from whence, up to the present day, we have only been able to procure paraffine in a pure state, whilst petroleum and eupione are found to be a mixture of various kinds of substances.

In many countries there flows from the earth at the same time with water, an oleaginous fluid, which floats on the surface. By distilling this with water, or in any other way, by which decomposition may be avoided at a high temperature, there passes over from some of this body, which is brought from the neighbourhood of Brunswick, no trace of a volatile oil; whilst from some that comes from near Baku, a greater part may be distilled over: this substance is known by the name of petroleum. In some countries a high temperature is decidedly not necessary for the formation of this substance; for by distilling with water, coals, which have been exposed to no high temperature, and which have undergone an alteration merely from being decomposed by water, a substance quite similar to petroleum may be procured, which is found already formed in coal mines, where the coals have been exposed to distillation.

In other countries, a high temperature, arising from volcanic action, conduces, if not to the generation of this substance, at least to the formation of springs on the upper surface of the earth; these warm springs, and more particularly hot vapour fountains, bring forward petroleum from decomposed organic substances in the centre of the earth. The purest kind of petroleum is obtained from Amiano, in the duchy of Parma, and from the neighbourhood of Baku, where there are not only very many springs where naphtha collects, but also small rivulets. In the neighbourhood of these naphtha fountains, a great evolution of inflammable gas also arises.

In distilling petroleum from Baku by itself, which has a specific weight of 0·835, it begins to boil at 347°; during the distillation the temperature gradually rises as high as the boiling point of mercury. By removing, at short intervals, the fluid that has passed over, and examining it, the boiling point is found to rise each time. Whatever means, however, may be employed for distillation, persons have never succeeded in procuring from petroleum a fluid at a constant boiling point; it consists, therefore, of various fluids, which are characterized by not being taken up by sulphuric and common nitric acids, by which means in general, foreign substances are decomposed and separated. It is not taken up either by potassium or potash. The fluid which has the lowest boiling point, namely, between 246° and 268°, consists of 2 volumes of hydrogen gas, and 1 volume of vapour of carbon.

The fluids which have a low boiling point are soluble in every proportion in anhydrous alcohol; those of a high point are separated on cooling, if they are dissolved in hot alcohol.

XII.—EUPIONE.—PARAFFINE.

By distilling coals, as well as animal and vegetable substances, an oleaginous besides an aqueous fluid is formed. If the oleaginous fluid be submitted to distillation, there first passes over an aqueous fluid on which the oil floats, and next an oleaginous body that sinks after some time in this fluid. By changing the receiver, collecting, until complete carbonization of the employed mass takes place, the substance that passes over, then paraffine is obtained in considerable quantity. This same operation may be repeated several times with the substance that has passed over; at last a mixture of empyreumatic oils with paraffine and eupione is obtained.* By gradually adding half the quantity of sulphuric acid by weight, during continued agitation, then the empyreumatic oil is decomposed. When the mass becomes very fluid, it is placed for a day in a warm spot of about 140°; there collects then on the surface a clear, colourless oil, which may be taken up in a fluid, or, if the mass be allowed to become firm, in a solid state, on cooling. This is paraffine impregnated with a volatile oil. By repeated pressure between blotting paper, in which the oil is absorbed, it can, in a great measure, be separated; but it is more completely parted with, by being dissolved in boiling alcohol, and allowed to form on cooling, crystals, which are found in foliated masses. In submitting wax to distillation, paraffine is obtained in considerable quantities. Paraffine fuses at 130°

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* Eupione was discovered by Dr. Riechenbach of Blanskow, near Brünn, in Moravia, and derives its name from εὖ, well, and πίων, greasy. Though resembling oil with respect to greasiness and inflammability, it is as limpid as alcohol.—Translator.

into a clear oil, and coagulates on cooling into a white mass; it has a specific weight of 0·98; it undergoes not the slightest change from sulphuric acid, if it be not heated above 257°, nor from chlorine, nor hot concentrated sulphuric acid, neither from hydrochloric acid, nor from potassium, nor a solution of potash; on this account the name of paraffine *(parum affinis)* has been given to it. Kindled in the air, at a high temperature, it burns with a beautiful flame. It dissolves fused sulphur, selenium, and phosphorus, and is easily dissolved by ether. Cold alcohol produces little effect on it; 100 parts of boiling alcohol dissolve 3·45 parts of it, and on cooling it crystallizes. It consists of 2 volumes of hydrogen gas, and 1 volume of vapour of carbon; it is, therefore, composed exactly as etherine; it differs only from solid etherine in its point of fusion, and its specific weight. Eupione is obtained with paraffine in the manner described. 100 parts of alcohol dissolve 33 parts of eupione at a common temperature; at a heated point both substances are dissolved in every proportion. Alcohol, therefore, serves as a good medium for separating eupione from paraffine; it is as little taken up by hot concentrated hydrochloric acid, sulphuric acid, potassium, or a solution of potash, as paraffine; up to the present day it has never been found free from foreign ingredients. Eupione procured in the way we have described, appears as petroleum to consist of many combinations of carburetted hydrogen, which show the same indifferent chemical affinity to other substances, and which boil at a different temperature; so that in this respect the same phenomena may be observed as in petroleum. A variety of eupione, which boils at a temperature of 137°, and has a specific weight of 0·65, is procured by submitting to distillation the oil of rape seed, and by heating the fluid that passes over in the manner we have described, by rectifying several times the oleaginous fluid. The eupione thus procured is soluble in every proportion in anhydrous alcohol, and burns free from soot with a white light like a wax taper. In submitting to distillation the last quantity of petroleum that passed over at a low temperature, solid foliated crystals separate, which are rendered pure by washing with alcohol; these consist of paraffine. Petroleum in Rangoon in Ava, is obtained from a substance, which is similar to paraffine in all other properties, except the fusing point, and its specific weight, in such large quantities, that it is easily procured pure by means of distilling, and crystallizing in alcohol. In a similar manner, a substance which corresponds so accurately with paraffine, that it might easily be taken for paraffine, is obtained from an oil (Quirinusöl) which flows from the earth in the neighbourhood of Tegernsee, near Munich. From these appearances it is more than probable that paraffine belongs to those products, which are derived from the decomposition of vegetable and animal substances either in moist places, or through a high temperature. It does not appear unlikely that if eupione was formed in a similar manner, and if petroleum could be procured at the same boiling point, and of the same purity as eupione; both would correspond in properties. The volatile part of petroleum from Rangoon burns with a flame which leaves a very slight soot.

In composition, paraffine, etherine, and these kinds of carburetted hydrogen, correspond with a substance which separates in crystals, if to genuine oil of roses, which is procured from rose leaves, three parts of spirits of wine of the specific weight of 0·860 be added. As it is but slightly soluble in alcohol, it is purified by being dissolved in ether, and then precipitated by alcohol, in which it is washed. Frequently this substance separates in crystals, at a low temperature, from the oil of roses; it has not the smell of oil of roses, fuses at 108°, and boils between 660° and 705°.

XIII.—CAOUTCHOUC,

AND ITS PRODUCTS BY DISTILLATION.

By allowing the milky sap of various trees, for instance, of the *Siphonia Cahuchu*, to stand, there separates on the surface of the fluid, as cream on milk, caoutchouc in the form of a layer: it is purified by a solution of chloride of sodium. It consists of nearly 4 volumes of vapour of carbon, and 7 volumes of hydrogen gas. This substance, which is not taken up by chlorine, hydrochloric acid, ammonia, alkalies, nor diluted acids, and is insoluble in water and ether, possesses this property—namely, its cut edges, when pressed in a pure state against each other, adhere as intimately as the interior of the mass itself; and on this account it is employed very appropriately for various chemical apparatuses.

Caoutchouc fuses at 300°: on cooling it forms a viscid mass; when strongly heated, and by a temperature slowly rising, it is decomposed, giving off very little vapour, and a large quantity of fluid, which may consist of fluid combinations of carburetted hydrogen. The solid caoutchouc, met with in commerce, for instance, in the form of bottles, is produced, by spreading and heating the milky sap on moulds, commonly on those of clay; as it contains vegetable gluten, a coagulation takes place. In distilling impure caoutchouc, we find, besides these products, carbonic acid, ammonia, and water.

The fluid obtained by this distillation, furnishes, as far as relates to the boiling point, the same phenomena as petroleum. In distilling this fluid, ebullition commences at 160°; by submitting the fluid, which is obtained whilst the boiling point is rising to 148°, partly to distillation a second time, the ebullition of the fluid that then passes over commences at 128°, and by repeating the same operation, the distilled liquid boils at 103°. The fluid that passes over between 105° and 128°, has a specific weight of 0·654; heated sulphuric acid dissolves it; and by an addition of water, a substance insoluble in water is separated, and during the solution, if saturated with carbonate of barytes, it furnishes a soluble salt, which does not crystallize.

The combinations which have passed over at different temperatures, have a specific weight from 0·654 to 0·962, the boiling point of the same also rises nearly to a red heat. The fluids, at whatever temperature they may pass over, have never a constant boiling point, so that when again distilled, they produce more or less volatile combinations. At no temperature are they solid, and furnish nothing solid.

The more volatile combinations are soluble in alcohol in every proportion; those which boil at a higher temperature are slightly so; whilst distilled with alkalies, and potassium, they suffer no change. They are but slightly taken up by diluted nitric acid, but more so by fuming concentrated sulphuric acid.

Of these various combinations, those which pass over after repeated distillation between 410° and 416°, are more accurately analyzed. By conducting hydrochloric acid through this oil, it forms a fluid body, from whence, when purified in a solution of alcohol, and precipitated by alcohol and water, and distilled with lime, an oleaginous substance of the smell of oil of oranges, called caoutchin, is procured, which boils at 422°. From analysis of this substance, it appears that 1 volume of caoutchin vapour (4·77) consists of 5 volumes of vapour of carbon, and 8 volumes of hydrogen gas. Caoutchin combines with hydrochloric acid, forming a fluid body, consisting of equal volumes of these two substances. Dropped into anhydrous sulphuric acid, it decomposes the acid, and at the same time an acid is formed, which combines with barytes, forming a salt soluble in water.

By adding the fluid to sulphuric acid, of the specific weight of 1·85 it is decomposed, and an oleaginous fluid resembling impure eupione, separates on the surface of this mixture. Caoutchin is decomposed by chlorine, and hydrochloric acid is given off, and one or more volatile combinations of chlorine take place, which are not decomposed by fuming nitric acid; submitted to distillation, they undergo decomposition. Caoutchin resembles much, as far as relates to its composition and properties, the oil of turpentine, which enters a fluid combination with hydrochloric acid.

Impure eupione, petroleum, the products of distillation of caoutchouc, oil of tar, and other volatile substances, which attain no constant boiling point, consist, by reason of physical grounds either of many oils, or a decomposition takes place during the distillation, and in this respect it would be desirable to refer paraffine to raw petroleum.

XIV.—CHLORINE AND CARBON.

Chlorine and carbon do not combine directly with each other: red hot charcoal may be introduced into chlorine gas, or may be kept red in the gas, by means of an electric spark, without combination taking place. If water is present, it is decomposed, hydrochloric and carbonic acid are formed. Indirectly two combinations may be procured, one solid and the other fluid.

1. *Solid Perchloride of Carbon.*

If chloride of etherine is exposed to the rays of the sun in a large flask filled with chlorine gas, the chlorine partly combines with the hydrogen forming hydrochloric acid, which may be absorbed by water, that is added; partly with the carbon forming perchloride of carbon, which produces a solid crystalline body; the same decomposition takes place by allowing chlorine to pass through chloride of carburetted hydrogen in a state of ebullition. By washing in water, dissolving in ether, this combination, if ether is allowed to evaporate slowly, is obtained in colourless transparent crystals, which fuse at 390°, and boil at 455°. The perchloride of carbon is free from taste, and has an aromatic smell, is insoluble in water, but soluble in alcohol; 1 volume of carburetted hydrogen, (1 volume of vapour of carbon, and 2 volumes of hydrogen gas) condenses 5 volumes of chlorine gas, forming 4 volumes of hydrochloric acid gas =(2 volumes of chlorine, and 2 volumes of hydrogen gas,) consequently, in perchloride of carbon 1 volume of vapour of carbon is combined with 3 volumes of chlorine.

2. *Liquid Perchloride of Carbon.*

By allowing solid chloride of carbon, in a gaseous form, to pass through a red hot porcelain tube, filled with pieces of porcelain to present to the vapour as many points as possible, we obtain a fluid perchloride of carbon, as a part of the chlorine separates from the combination through the heat: this boils from 192° to 205°; is soluble in alcohol and ether, but not in water. Placing this combination in a vessel with chlorine gas, exposed to the rays of the sun, we obtain it combined with chlorine, and a solid formation. Light promotes the combination of chlorine with the volatile chloride of carbon, as well as heat; and this is worthy of observation. The first fluid perchloride of carbon undergoes no change, in contact with chlorine, if exposed to the sun; 1 volume of vapour of carbon and 2 volumes of chlorine are united with each other in this combination. Another combination, which is solid at a common temperature, was only once formed, in an accidental manner in the distillation of nitric acid, and persons have never since succeeded in producing it: it consisted of 1 volume of chlorine, and 1 volume of vapour of carbon. No person has yet succeeded in forming combinations of bromine and iodine with carbon.

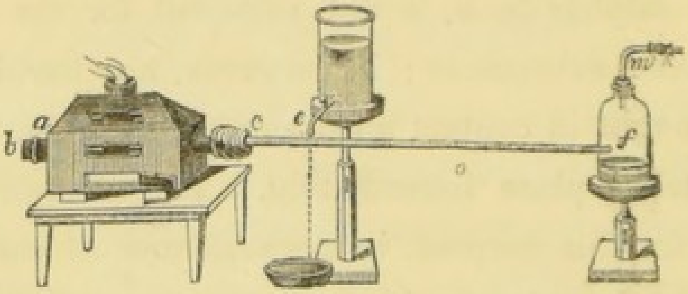
XV.—CARBON AND SULPHUR.

These substances combine in one proportion only. By heating them together, no combination takes place; sulphur volatilizes and charcoal remains. The temperature at which the sulphur boils, is not sufficient for the combination of these substances; if, however, hot burning charcoal is brought in contact with sulphur vapours, the combination takes place immediately. A porcelain tube is employed for this purpose, or perhaps one of cast iron is better adapted: this should be covered on the inner side with a layer of clay; for this purpose clay is formed into a paste with water, and then allowed to flow into the tube, which is subsequently heated; this operation is repeated several times, till the coat of dried clay becomes so thick, that the iron is not affected by the sulphur. The tube is filled with burning charcoal, and is laid in a long stove till it attains a white heat. One end, *a*, of the tube is closed by a cork; a small hole must be bored, which serves for the admission of sulphur. A long glass tube, *o*, arising from the iron pipe, *e*, passes into a capacious flask, *f*, through the side of which an opening is made; a waste pipe, *m*, arising from the upper part conducts through a window into the external air.

At the bottom of the flask, water is present, to cool the tube, which should as well be surrounded through its whole length by ice or snow. When the stove is sufficiently heated, pieces of sulphur should be introduced through *a*, which immediately fuse, flowing into the hottest parts of the tube, which is placed rather inclined towards the flask. The sulphur enters into ebullition, and is converted into vapour, which passing over the heated charcoal, combines with it.

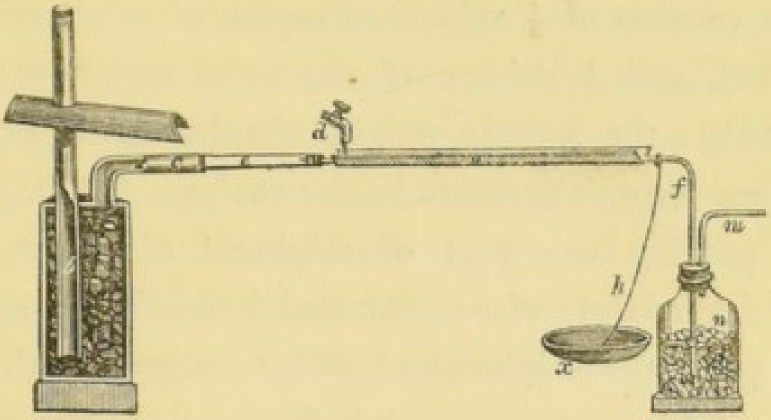
Sulphuret of carbon becomes condensed in the long glass tube, *o* (Fig. 61), from whence it flows into the flask, *f*, and sinks in the water. As charcoal always retains some hydrogen, the sulphur combines, forming a gaseous body, which escapes by the waste pipe, *m*.

Fig. 61.



Sulphuret of carbon is procured more conveniently in large quantities, by filling with charcoal a cast iron cylinder of a foot high, and closed by a cast iron cover, through which the tubes *b* and *c* are introduced (Fig. 62). When the cylinder is heated to redness, sulphur is introduced; which passing through the hot charcoal as vapour, it combines with it; bisulphuret of carbon, that is generated, passes through the curved tube as gas. The sulphur condenses in the wide tube with a part of the vapour, and what passes over condenses in the narrow tube, *f*, on which cold water constantly drops from a reservoir, *d*, and is conducted through the canal, and falls, by means of a string, into the bason, *x*. The vessel, *n*, is half filled with pounded ice. This operation must continue till no more sulphuret of carbon is given off; this is a proof that the charcoal is entirely consumed. Bisulphuret of carbon, thus obtained, holds sulphur in solution; but it is rendered pure by being distilled in the same manner as raw ether. After $\frac{9}{10}$ of the bisulphuret are distilled, the remaining quantity may be gradually evaporated in a closed vessel, from whence beautiful crystals of sulphur are produced.

Fig. 62.



Pure sulphuret of carbon is a colourless fluid of a very unpleasant odour; soluble in alcohol and ether in every proportion, but not so in water. Its specific weight is 1·272, boils at 127°, evaporating very rapidly. It is very inflammable, burning with a blue flame; from whence carbonic acid and sulphurous acid are formed. Brought into contact with red hot metals, sulphuret of carbon is decomposed, carbon is deposited, and a metallic sulphuret formed. It dissolves sulphur and phosphorus; of the latter, eight times its volume: a volume of vapour of sulphuret carbon consists of $\frac{1}{3}$ volume of vapour of sulphur$=(\frac{6 \cdot 654}{3} = 2 \cdot 218)$, and $\frac{1}{2}$ volume of vapour of carbon $=(\frac{0 \cdot 8438}{2} = 0 \cdot 4219)$; the specific weight of sulphuret of carbon in a gaseous form, is found to be, by analysis, 2·760.

By pouring one part of sulphuret of carbon, or 16 parts of a mixture of concentrated hydrochloric acid and nitric acid, the sulphuret of carbon is generated, sometimes in a few weeks, commonly however in many months, in a crystalline mass, resembling camphor, which, when heated, fuses, and, on cooling, crystallizes: when heated more intensely, it distils over unchanged; preserved in closed vessels, it sublimes as camphor. This is soluble in ether, alcohol, volatile oils, and sulphuret of carbon. In water however, insoluble; boiled with it, it escapes almost unchanged; and a small quantity is decomposed, forming carbonic acid, sulphurous and hydrochloric acids. Added to a solution of potash, it is entirely decomposed; chloride of potassium, carbonate of potash, and sulphate of potash are formed; it consists, therefore, of 4 volumes of chlorine gas, 2 volumes of oxygen, $\frac{1}{3}$ volume of vapour of sulphur, and 1 volume of vapour of carbon. Neither the formation of this body, nor the decomposition it undergoes, furnish us with any reason to conclude how these ingredients combine with each other.

By adding 4 volumes of vapour of water; 8 volumes of hydrochloric acid, 2 volumes of sulphurous acid, and 2 volumes of carbonic acid gas are formed.

XVI.—CARBON AND NITROGEN. (*Cyanogen.*)

In most animal substances, nitrogen, carbon, hydrogen, and oxygen are found combined. By heating dry cyanuret of mercury in the same manner as oxide of mercury, it is decomposed into metallic mercury and a gaseous body, consisting of carbon and nitrogen, to which the name cyanogen has been assigned: at the same time a small portion of this combination is decomposed; there sublimes also a small portion of cyanuret of mercury undecomposed. At a common temperature cyanogen forms a colourless gas, remarkable for its peculiar pungent smell. By compression and cold, this gas may be rendered fluid. By placing cyanuret of mercury in one end of a tube, *a* (Fig. 63), which is closed and plunged into cold water, whilst the end, where the cyanogen is, is heated; after as much cyanogen of quicksilver is decomposed, as to form four times as much cyanogen gas as entered the tube, the fluid cyanogen collects in the cold extremity, *b*. The gas is so compressed as to occupy only a fourth part of the space it formerly did, and it begins to assume a liquid form. A low temperature produces the same effect; at -8°, the cyanogen gas is condensed into a colourless fluid, which has the specific weight of 0·9; 1 volume of water dissolves $4\frac{1}{2}$ volumes, and 1 volume of alcohol, 23 volumes of cyanogen gas.

Fig. 63.

By conducting cyanogen gas through a tube, in which a metallic oxide, for instance, an oxide of copper, is rendered red hot, and by analyzing the gases that can be easily collected, we find, after introducing a piece of potash to absorb the carbonic acid, that they consist of 1 volume of nitrogen and 2 volumes of carbonic acid. Cyanogen, therefore, consists of 1 volume of vapour of carbon, whose specific weight is 0·8438, and of 1 volume of nitrogen, whose specific weight amounts to 0·976. These two volumes, since the specific weight of cyanogen gas is found to be 1·8604, are thus condensed into one volume.

Cyanogen, on account of the number of the combinations it enters into, ranks among the most important of substances. With some metals it combines directly; potassium, for instance, burns in cyanogen gas, as in oxygen gas, forming cyanuret of potassium: it may also combine with other metals, by means of moisture. These combinations unite again with each other, and may be compared to common salts of oxygen formations. Cyanuret of iron unites with cyanurets of potassium, of calcium, and lead, forming combinations, either crystallizable or insoluble in water, which are composed according to determinate proportions. In the same manner as the cyanuret of iron, the cyanuret of zinc, copper, nickel, and even gold, and platinum, furnish with metallic cyanurets similar combinations, crystallizable, or insoluble in water. As cyanogen plays in these combinations a part similar to oxygen and sulphur, it is desirable to give it a more appropriate name, to be able to distinguish its combinations consisting of nitrogen and carbon.*

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* Its present name is derived from *κύανος*, blue, and *γεννάω*, to generate, as it is an essential ingredient of Prussian blue.—TRANSLATOR.

A. *Mellon.*

By heating sulphuret of cyanogen, or sulphocyanuret of mercury, bisulphuret of carbon and sulphur, or sulphuret of mercury, are disengaged; a yellowish, lemon-coloured powder remaining, which is insoluble in water and other fluids, with which it does not combine, or by which it is not decomposed. Heated to redness, it separates into cyanogen and nitrogen gases; roasted with oxide of copper, it gives off 3 volumes of carbonic acid, and 2 volumes of nitrogen gas. It consists, therefore, of 1½ volume of vapour of carbon, and 2 volumes of nitrogen gas. If heated in dry chlorine gas, a volatile body arises; if heated with potassium, it combines with evolution of fire. This combination is easily fusible. From its solution in water, in which no trace of a combination of cyanogen can be discovered, a white body is precipitated by acids, namely, a combination of mellon with hydrogen=(6 volumes of vapour of carbon, 8 volumes of nitrogen, 2 volumes of hydrogen) which is slightly soluble in water. The combination with potassium is equally as well obtained, by heating a cyanuret of iron and potassium with sulphur at a temperature necessary for the formation of sulphocyanuret of potassium; as this is soluble in spirit of wine, and melluret of potassium is not, it may be employed as a separating medium. By throwing down metallic salts with a solution of this salt, precipitates insoluble in water are obtained. The combination of lead prepared in this manner consists, if dried to 340°, of oxide of lead and melluret of hydrogen. Heated with a solution of potash, mellon is soluble with development of ammonia: on cooling, the crystals separate from the solution.

According to these phenomena, mellon ranks very near cyanogen: an accurate analysis of its combinations will tend to clear up still more, the nature of this substance.

By dissolving cyanogen in water or alcohol, it is decomposed, forming immediately a brown body. The same substance separates on decomposing hydrocyanic acid, or by conducting cyanogen in excess through a solution of ammonia, or by decomposing the cyanuret of mercury by heat; the residue is this substance. It is soluble in concentrated acids, for instance, sulphuric acid; and in a solution of potash, from whence it is precipitated by acids. It must have the same composition as cyanogen. If various animal substances, as blood, albumen, skin, be carbonized, then a species of carbon is procured, containing nitrogen: it is therefore a combination of carbon and nitrogen, which contains more carbon than cyanogen does; but this subject requires further investigation.

B. *Cyanogen and Sulphur.*

By carefully fusing sulphur in excess with cyanuret of iron, and potassium, and saturating the mass with water, the solution contains only sulphocyanuret of potassium: by crystallizing, it is obtained pure. By gradually adding to a solution of this combination, bromic or nitric acids in small quantities, or by conducting chlorine over it, a yellowish red powder separates,—bisulphuret of cyanogen. Bromide of potassium, nitrate of potash, or chloride of potassium are formed. Bisulphuret of cyanogen is insoluble in water and alcohol; but soluble in sulphuric acid. It is decomposed by sulphuric acid and potash. Added to a solution of sulphuret of barium, sulphur separates, and sulphocyanuret of barium is formed. It yields with potassium, besides sulphocyanuret of potassium, sulphuret of potassium and cyanuret of potassium. By heating carefully dry bisulphuret of cyanogen, it sublimes, partly undecomposed, by a slight red heat.

Bisulphuret of cyanogen consists of $\frac{1}{3}$ volume of vapour sulphur, 1 volume of vapour of carbon, and 1 volume of nitrogen gas.

Hydrosulphocyanic acid consists of 1 volume of vapour of carbon, 1 volume of nitrogen gas, $\frac{1}{4}$ volume of sulphur, and 1 volume of hydrogen gas.

C. *Cyanogen, Chlorine, Bromine, and Iodine.*

Chloride of cyanogen is obtained by allowing a small quantity of bicyanuret of mercury, bruised and moistened, to stand in a quart bottle filled with chlorine, half a day in darkness: it becomes gaseous at a common temperature; at 5° it is in a liquid, and at 2° in a solid and crystalline form. The gas is colourless, of a very disagreeable smell: alcohol absorbs 100 volumes, and water 25 of it. In water it is not decomposed; boiled in water, it is given off unchanged. Another substance is formed, by exposing to the light of the sun a concentrated solution in water, of bicyanuret of mercury, in a flask filled with chlorine; it has a yellow and oleaginous appearance. Its composition and decomposition have not as yet been sufficiently analyzed.

A third combination is formed from cyanogen and chlorine: by exposing to the light of the sun a small quantity of anhydrous hydrocyanic acid, in a quart flask filled with chlorine gas, then hydrochloric acid forms; and on the sides of the jar is deposited a crystalline substance, soluble in alcohol and ether, but not so in water, which is precipitated from a solution by water. It fuses at 347°, and boils at 460°. Its specific weight is 1·32. This combination may be obtained as well by conducting chlorine over sulphocyanuret of potassium. With the chloride of sulphur, chloride of cyanogen also passes over; the chloride of cyanogen sublimes also in the neck of the retort in acicular crystals, if at the termination of the operation the temperature is raised. By subliming this substance in a retort where chlorine is allowed continually to enter, the combination is obtained pure. It consists of equal volumes of cyanogen and chlorine gases. It is decomposed by warm water into hydrochloric and cyanic acids. Its specific weight is 1·32.

D. *Bromide of Cyanogen.*

This substance is formed by distilling 2 parts of bicyanuret of mercury, and 1 part bromine in a retort artificially cooled. At 66° it is gaseous: if cooled below this point, it is obtained in colourless crystals. It is soluble in ether and alcohol, decomposed by strong bases. It consists of 1 volume of cyanogen and 1 volume of bromine. Perhaps this is the same combination which is easily obtained, and is devoid of danger, by adding bromine in a solution of hydrochloric acid, saturated with water, to bicyanuret of mercury in a glass tube. Should the fluid appear of a reddish colour, some addition of bicyanuret of mercury and hydrochloric acid should be made; and during the action of these two substances on each other, the tube should be well cooled. By plunging into hot water the end *a* (Fig. 64), after the extremity *b* is closed, to prevent the deleterious spreading of the poisonous vapour, crystals are deposited in the upper end of the glass tube.


Fig. 64.

E. *Iodide of Cyanogen.*

This substance is procured, by slightly heating bicyanuret of mercury, or cyanuret of silver with iodine; a metallic iodide, and iodide of cyanogen form, which sublime in fine white acicular crystals. It is easily obtained in small quantities, by moistening with water bicyanuret of mercury in a glass tube, closed at its extremity, adding iodine, and heating the mixture to the boiling point: the crystals are deposited in the upper part of the tube. It is soluble in water, alcohol, and ether; consisting of 1 volume of iodine vapour, and 1 volume of cyanogen gas.

F. *Cyanogen and Oxygen.*

Fulminic acid = 2 vols. of cyanogen and 1 vol. of oxygen gas.
Cyanic acid = 2 —— + 1 ——

Oxygen combines with cyanogen only in one proportion. These combinations cannot be produced directly; indirectly two acids result, which are both similarly composed, though in their properties they present a striking difference. One of these acids is termed fulminic acid, and the other cyanic: this last substance, on account of the numerous combinations it enters, and decompositions it produces, is one of the most important in the theory of chemistry.

1. *Fulminic Acid.*

Fulminic acid = 2 vols. of cyanogen + 1 vol. of oxygen gas.

This acid is generated by dissolving nitrate of oxide of silver, or nitrate of protoxide of mercury, in a small quantity of nitric acid; adding alcohol to the solution, and afterwards fuming nitric acid. At a gentle heat a strong effervescence takes place, nitrous ether is evolved, which is easily perceived by its smell, and a crystalline powder separates from the fluid: if the fluid be heated too strongly, it is suppressed by means of an addition of cold alcohol. The precipitate consists of fulminate of oxide of silver, or of protoxide of mercury, both of which are slightly soluble in alcohol or water. With other metallic salts, the preparation of these combinations does not probably succeed, whilst their fulminates are very soluble; and if they are formed, they are again decomposed, as they remain in the fluid. With two or three grains of nitrate of oxide of silver, a sufficient quantity of fulminate may be formed, to enable us to study the important phenomena this acid presents: the preparation of a larger quantity is accompanied with so much danger, that it has frequently given rise to many melancholy accidents. The preparation of fulminating silver is conducted with the greatest caution possible, in the manufactories where the percussion caps are made. The fulminate of oxide of silver, as soon as it is entirely deposited, is placed whilst yet moist on a filtering machine, and is then divided into small particles. From a somewhat high temperature, from pressure, from slight friction, or from the most trivial circumstances, the fulminates explode most violently; becoming decomposed, two gaseous substances, nitrogen gas and carbonic oxide gas are given off from the solid body in a moment.

Fulminic acid cannot exist by itself; if separated by a stronger acid, it becomes decomposed into hydrocyanic acid, ammonia, and carbonic acid, if an oxacid be employed; on the other hand, if expelled by an hydracid, it yields hydrocyanic acid and a peculiar combination of the radical of the hydracid, with carbon, hydrogen, and nitrogen: these combinations have not as yet been sufficiently examined.

Fulminic acid may be communicated to other metallic oxides, if a fulminate of oxide of silver be agitated with water, in which is placed a metal which has a greater affinity for oxygen, than silver or mercury; for instance, iron, zinc, and copper.

By adding the fulminate of oxide of silver to a solution of potash, soda, barytes, or lime, half of the oxide of silver is parted with, and the solution contains a double salt, which is easily soluble; by adding an acid to the solution, a bifulminate of oxide of silver is precipitated.

In consequence of the other fulminates detonating, as well as the fulminate of the oxide of silver, it is evident the detonating property does not reside in the base. The fulminate of oxide of silver is analyzed by means of the binoxide of copper; very accurate analyses have also given the same composition. From the quantity of oxide of silver it appears that the oxygen of the base bears the same ratio to the oxygen of the acid, as 1 to 1 in the neutral fulminates.

2. *Cyanic Acid.*

Cyanic acid=2 vols. of cyanogen+1 vol. of oxygen gas.

This acid is procured in different manners. It is formed by allowing cyanogen to pass over barytes suspended in water; the cyanuret of barium and cyanate of barytes are formed, therefore a similar decomposition follows, as if chlorine, iodine, or bromine were brought in contact with barytes. It is also obtained by heating carbonate of potash with cyanogen or cyanurets. It is also obtained in the best method by mixing intimately equal parts of the double anhydrous cyanuret of iron and potassium, and peroxide of manganese, and heating them to a slight redness. The mass, when cooled and reduced to a fine powder, is boiled with spirit of wine of the specific weight of 0·86. From the warm fluid, quickly filtered, the cyanate of potash separates in crystalline scales, and the powder, when dried, is boiled with the same quantity of the spirit of wine, as long as any particle is obtained on cooling. The cyanate of potash is insoluble in absolute alcohol; dissolved in water, and preserved moist, it is soon decomposed. Some salts, soluble with difficulty, for instance, cyanate of oxide of lead, or cyanate of oxide of silver, are not so easily decomposed as the salt of potash.

In endeavouring to expel cyanic acid by some stronger acid, there forms a bicarbonate of ammonia, by the immediate decomposition of cyanic acid and water; by employing an excess of acid carbonic acid is disengaged, and ammonia combines with the acid. By knowing from other experiments, the composition of bicarbonate of ammonia, so also that of cyanic acid may be calculated by abstracting oxygen and hydrogen, derived from the decomposition of water.

Bicarb. of ammon. = 1 v. carb. + 2 v. oxygen + 3 v. hydrogen + 1 v. azote,
— Water = 1½ —— + 3 ——

Cyanic acid = 1 v. carb. ½ v. oxygen + 1 v. azote.

Cyanate of potash, either in contact with water or dissolved therein, is decomposed into ammonia and bicarbonate of potash. Since in the bicarbonate of potash, the oxygen of the carbonic acid is to that of the potash as 4 to 1; then it follows, from this decomposition, that the oxygen of the acid and of the base are equal in cyanates.

Cyanic acid may be obtained, chemically combined with water, by submitting to distillation cyanuric acid in a retort, which is connected with a receiver, and which is surrounded by a cooling mixture of ice and chloride of sodium. There is condensed therein a colourless fluid of a penetrating odour, resembling that of acetic acid, of which a drop placed on the skin produces, besides violent pain, a white vesication. The fluid removed from the cooling mixture, without either absorbing or losing a particle, becomes changed first into a paste, and at last, into a dry, solid, spongy substance, without smell; attended with continual ebullition, which is sometimes accompanied with violent explosions, during which it becomes heated.

By conducting the vapour of cyanic acid into water, it becomes absorbed, the fluid has an acid action, is decomposed with effervescence, and beginning to have an alkaline reaction, carbonic acid and ammonia form, as in the decomposition of a cyanate by an acid. From the evaporated solution, the above-mentioned solid substance and urea are obtained, which latter substance results from the action of ammonia, that is formed on an undecomposed portion of cyanic acid. By conducting the vapour to a small piece of ice, it soon melts, and slight development of gaseous bubbles takes place, the fluid smelling very strongly of cyanic acid. The white substance, into which aqueous cyanic acid is transformed, is insoluble in water, in nitric and in hydrochloric acids; it is neither decomposed by nitric nor fuming nitric acid, but completely so when slightly heated with concentrated sulphuric acid; carbonic acid escapes, and ammonia remains with the sulphuric acid. The same decomposition therefore takes place as in cyanic acid. An analysis of this substance with oxide of copper, gives the same composition as that of aqueous cyanic or cyanuric acid. It is easily soluble in a solution of potash; and by evaporation, the same salt of potash is obtained, as is formed in crystals from a solution of cyanuric acid in potash, so that it is again converted into cyanic acid. Submitted to distillation, it gives off aqueous cyanic acid.

3. *Cyanic Ether.*

By conducting the vapour of fluid cyanic acid over anhydrous alcohol, it is completely and quickly absorbed, with development of heat; from the alcohol a crystalline combination is separated, which increases on cooling. By washing with alcohol, it is obtained pure, and from solution in boiling alcohol, which is mixed with ether, in determined crystals, which are almost insoluble in cold water, and are slowly soluble in boiling, from whence on cooling, they again separate. This combination, when heated, fuses; exposed to a warm current of air, it soon volatilizes, and furnishes, on cooling, the same phenomena as benzoic acid. Heated in a retort, it is decomposed; alcohol passes over, and cyanuric acid remains, of which a small portion is decomposed. This combination consists of 4 volumes of vapour of carbon, 3 volumes of oxygen gas, 2 volumes of nitrogen gas, 8 volumes of hydrogen gas, or of aqueous cyanic acid$=$(2 volumes of vapour of carbon, 2 volumes of azote gas, 1 volume of oxygen$+$2 volumes of hydrogen, 1 volume of oxygen) and alcohol ($=$2 volumes of vapour of carbon, 6 volumes of hydrogen, 2 volumes of oxygen). It is free from taste and smell, and both on account of its other properties, as well as its composition, it does not belong to the varieties of ether, but may be considered to resemble the sugar of grapes; but nothing is yet decided as to its composition.

4. *Cyanuric Acid.*

By submitting to distillation urea, which consists of 2 volumes of vapour of carbon, 4 volumes of azote, 8 volumes of hydrogen, 2 volumes of oxygen, ammonia passes over; by interrupting the process, immediately as a white body, cyanuric acid, begins to separate, the residue consists of a salt of ammonia: by continuing the distillation as long as ammonia passes over, there remains a white-yellowish body, cyanuric acid, and this contains in general some ammonia. It is easily procured in a state of purity, by being dissolved in hot sulphuric acid, to which nitric acid should be added, until the foreign substances mixed with it are decomposed; it is again precipitated from this solution by water. Dissolved in water, it is procured in beautiful crystals, on the solution being cooled in a sand-bath. The crystals contain 21·56 water, which is absorbed when exposed to the air. The anhydrous crystals have been analyzed with oxide of copper; they consist of 2 volumes of vapour of carbon, 2 volumes of azote, 2 volumes of oxygen, and 2 volumes of hydrogen; containing 2 volumes of azote and 6 volumes of hydrogen gas less than urea, which combine during the distillation of urea, forming ammonia, which passes off.

As in distilling cyanuric acid, aqueous cyanic acid is formed, it most naturally follows, if the distillation of urea be carried too far, that cyanate of ammonia and purified urea may be obtained from the action of this acid on the ammonia that passes over.

The capacity of saturation of cyanuric acid is determined by the analysis of cyanurate of oxide of silver; and the oxygen of the base in neutral salts bears the same proportion to the oxygen of the acid, as 1 : 3.

With potash, cyanuric acid forms a neutral and an acid salt: a neutral combination is obtained, by adding alcohol to the solution of cyanuric acid in potash; but the acid combination is formed by dissolving cyanuric acid in potash, and allowing it to crystallize. The neutral salt, when heated, is decomposed into bicarbonate of ammonia and a neutral cyanate of potash.

Cyanuric acid	=3 vap. carb.,	3 v. azote,	3 v. hydrog. +	3 v. oxyg.
—Cyanic acid	=2 —	2 —		1 —
Bicarb. of ammonia	=1 vap. carb.,	1 azote	+3 v. hydrog.	2 v. oxyg.

This bicarbonate of ammonia consists of 1 volume of vapour of carbon, 2 volumes of oxygen gas, 3 volumes of hydrogen gas + 1 volume of azote, as appears from the results of other analyses.

5. *Cyanylic Acid.*

By boiling mellon with concentrated nitric acid, it is dissolved by it, with decomposition of the acid. From the acid solution, on cooling, determinate crystals arise, which are purified by washing and recrystallizing. These crystals assume the same form, have a similar composition, and furnish, when heated, the same products as cyanuric acid. This new acid only differs from cyanic acid in its greater solubility in water, and is termed cyanylic. Further analyses must decide whether it differs from cyanuric acid or not.

XVII. CARBON, OXYGEN, AZOTE, AND HYDROGEN. (AMIDE.)

Of the numerous combinations into which these four substances enter, we shall only mention that class, which is distinguished by the name AMIDE, which in many respects is of considerable importance.

In this class ammonia has the same proportion to acids as benzin in benzide combinations; as in the neutral formations of an acid with benzin, 1 volume of oxygen gas united with two volumes of hydrogen is given off, so also the amides are either neutral combinations of ammonia and an acid, or acid formations, from whence in the same quantity of ammonia double as much water is parted with.

The combinations similar to amides, are sulphamide and pyroxylo-etherosulphamide.

1. *Urea.*

This substance is one of the most important in chemistry, both on account of the manner in which it is formed, as well as from its presence in urine, of which it is the principal ingredient, and the decompositions it undergoes. By saturating a cyanate of oxide of silver, with a solution of hydrochlorate of ammonia, a chloride of silver is formed, insoluble in water, and a cyanate of ammonia with water of crystallization, in which it is dissolved.

In this salt, as in ammoniacal salts in general, there is present 1 volume of vapour of water to 2 volumes of ammonia. By examining this solution of salt, ammonia and cyanic acid are discovered, as well by alkalies, as by acids. By boiling this solution, neither ammonia nor cyanic acid can be detected; and on evaporating, a substance forming prismatic crystals is obtained, consisting of a combination of the principles of cyanate of ammonia, forming, in a different manner, a new body.

Cyanic acid	=2 vap. carb.,	2 v. azote+	1 v. oxygen gas,
Ammonia	=	2 —	6 hydrogen gas,
Water	=	1 oxygen	2 hydrogen gas.
The new substance	=2 vap. carb.,	4 v. azote	8 hydrogen, 2 oxygen.

The same body is obtained by pouring ammonia on cyanate of oxide of lead, and allowing the cyanogen gas to be absorbed by water, and the solution to stand some time, in which case it is formed by the decomposition of water.

This body, procured in this manner from substances, which are obtained without employing a combination, formed by an organic process, is the principal ingredient of urine, and is generated in the animal world.

It is easily procured from urine, and in large quantities by evaporating carefully the urine as far as possible, and separating by absolute alcohol, whatever may be dissolved by it. On evaporating this solution, the residue is dissolved in water; on being boiled with animal charcoal, its colour is withdrawn; and to the filtered solution, boiling hot oxalic acid should be added, as long as any precipitate is formed: this consists of oxalic acid and urea. If the temperature rises above 145°, it must be allowed to cool.

The precipitate is again filtered, and washed with cold water, and on evaporation more oxalate of urea is obtained.

If the precipitate is dissolved in boiling water, and heated with some animal charcoal, oxalate of urea is obtained on cooling, as white as snow. The crystals are dissolved in boiling water, to which finely-powdered carbonate of lime is added, carbonic acid is given off with effervescence, and the urea remains in the fluid, in a state of suspension, from whence it is obtained by careful evaporation. The saline mass thus procured, is again dissolved, in absolute alcohol, in which foreign substances remain insoluble, and from this spirituous solution, urea is obtained in crystals, after slow evaporation. Of the many methods recommended for the preparation of urea, this by far deserves the preference.

The crystals of urea are colourless and free from smell, have a cooling taste, somewhat resembling that of nitre, and undergo no change from exposure to the air. In damp atmosphere they liquify, as they absorb water, and are dissolved: their specific weight is 1·35. At a common temperature, they are soluble in an equal quantity of water; but in hot water, in every proportion: the solution does not effect vegetable colours. Heated to 300°, the crystals fuse, and, when heated more intensely, yield ammonia; and cyanuric acid remains.

By boiling sulphuric acid with urea, carbonic acid is given off, and sulphate of ammonia remains: by heating it with potash, ammonia is given off, and carbonate of potash remains.

Carbonate of ammon. =	1 v. vap. carb.	2 v. oxyg.	2 v. azote,	6 v. hyd. gas.
—Urea =	1	1	2	4
Water =		1 v. oxyg.		2 v. hyd. gas.

In decomposing urea by means of sulphuric acid and potash, water is decomposed. The same decomposition takes place if urea be dissolved in a large quantity of water, for instance, 100 parts, and allowed to stand for some time; this takes place much quicker if only a fermenting substance, as mucilage, starch, or some neutral matter be added: and this reason satisfactorily accounts for urine becoming so soon putrid.

From the composition of oxamide we can best perceive the reason why we ought to consider urea as a neutral combination of carbonic acid and ammonia, from whence 1 volume of oxygen and 2 volumes of hydrogen are given off as water. Urea has, however, as yet never been procured directly from carbonic acid and ammonia. In comparing the composition of urea, and of that substance insoluble in water, into which the aqueous cyanic acid is converted, with that of benzamide and bibenzamide, or with that of nitronaphthalide and bininitro-naphthalide, we shall be induced to consider this insoluble substance as a bicarbonate of ammonia, from whence, in the same quantity of ammonia, twice as much water is separated as in the preparation of urea.

Bicarb. of ammon. =	2 v. vap. carb.	4 v. oxyg.	2 v. azote,	6 v. hydrog.
—Water =		2		4
Neutral combin. =	2 v. vap. carb.	2 v. oxyg.	2 v. azote,	2 v. hydrog.

If we wish to bestow similarly formed names on this combination, and on urea, as well as on the other combinations of this class, we should term the first bicarbonamide, and the second carbonamide: for urea, however, in each case, such a name would be inapplicable.

By adding nitric or oxalic acid to a solution of urea, a crystalline precipitate is obtained. By long evaporation both combinations may be procured in large crystals; they are both anhydrous. The oxygen of the urea has the same proportion in combinations of nitric acid to that of the acid as 2 : 5; in combinations of oxalic acid as 2 : 3. 100 parts of cold water only dissolve 4·37 parts of oxalate of urea, and 100 parts of cold alcohol only 1·6; for this reason, this combination is well adapted for the extraction of urea. Urea combines with bases, more particularly weak ones, by adding urea to a solution of nitrate of oxide of silver, and then a solution of hydrate of potash; the oxide of silver is precipitated combined with urea. These combinations deserve more particular attention, than up to the present day has been assigned them, as urea appears to have the same relation to many substances, that water has, which combines with acids, bases, and salts. It has a closer affinity than water, for nitric and oxalic acids, still this is so weak, that a solution of a combination of nitric acid has the same relation as pure nitric acid to oxidizable bodies, as, for instance, copper, when the oxide of nitrogen is disengaged. Many combinations of organic nature, namely, dyeing substances, have the same analogy with urea and water. The combination of such matters with other substances, for instance, with acids and bases, can only be effected by means of water; and this depends either on the affinity of the water, or that of the colouring matters predominating for bodies with which a combination may take place; if the affinity for the water prevails, no combination is produced. Some colouring matters have a greater affinity than water for alum, for others a weaker; from whence it may happen that the strongest base may be incapable of removing from a weak one those substances combined with it, from having a greater affinity for the water, than for the colouring matters. Sulphuric acid, therefore, does not produce any decomposing effect on nitrate of urea, as the affinity of the sulphuric acid for water, and that of the nitric acid for urea, are too strong. Colours, for instance, litmus, have the same relation as urea. Some substances have always a greater affinity both for acids and bases than water; on this depends violet colouring matter, which is obtained by saturating with a sufficient quantity of an acid, the blue colour of litmus, which is a combination of violet colouring matter with bases. Violet colouring matter uniting with bases produces blue, and with acids, red combinations, which possess such a deep colour, that the least trace of a base or acid may be instantly discovered in a solution, by means of paper stained of a violet colour.

2. *Oxamide.*

By dissolving oxalic ether in alcohol, and adding to the solution ammonia in excess, a white powder, oxamide, is separated. It is nearly insoluble in cold water, but slightly soluble in warm water, alcohol and ether. Exposed to a warm current of air, it volatilizes; distilled in a retort, one part is decomposed, and the other sublimes unchanged. Oxamide consists of 2 volumes of vapour of carbon, 2 volumes of oxygen gas, 2 volumes of azote, and 4 volumes of hydrogen gas.

Heated with sulphuric acid in excess, it is resolved into ammonia, which combines with sulphuric acid, and into a mixed gas, of which one half consists of carbonic oxide gas (=1 volume of vapour of carbon, + 1 volume of oxygen gas,) and the other half of carbonic acid (=1 volume of vapour of carbon +2 volumes of oxygen gas.) Treated with a concentrated solution of potash it forms oxalic ether(= 2 volumes of vapour of carbon +3 volumes of oxygen gas,) which combines with the potash, and ammonia escapes.

Besides ammonia and oxalic acid, which heated with concentrated sulphuric acid is always decomposed into equal parts of carbonic acid, and of carbonic oxide gas, no other body is formed. Oxamide is procured too, but only in slight quantities, by submitting neutral oxalate of ammonia to distillation. By adding other kinds of ether, as for instance, acetic ether, benzoic ether, to ammonia, no combination corresponding to oxamide is formed. As oxalic ether consists of oxalic acid (2 volumes of vapour of carbon + 3 volumes of oxygen gas) and ether=(4 volumes of vapour of carbon, 10 volumes of hydrogen, 1 volume of oxygen,) the ammonia combines with oxalic acid, forming oxamide and water, which latter unites with the ether forming alcohol. We may prove as well by synthesis as by dialysis, that oxamide consists of a neutral combination of oxalic acid and ammonia, from whence 2 volumes of hydrogen, and 1 volume of oxygen are parted with as water.

3. *Etheroxamide.*

By cautiously adding ammonia in small quantities to a solution of oxalic ether in alcohol until a precipitate, which is oxamide, begins to form, a peculiar combination is obtained in large and beautiful crystals, one part of which can be procured by allowing it to stand, and the other by evaporation. Boiled with different salts—for instance, with acetate of oxide of lead, which is precipitated at a boiling heat by means of etheroxalate of potash, in which ether-oxalic acid is decomposed, and oxalate of lead formed; it gives off no precipitate. Analyzed with oxide of copper, it is found to be composed of 8 volumes of carbon, 14 volumes of hydrogen, 2 volumes of azote, 6 volumes of oxygen, or of a neutral combination of etheroxalic acid, which consists of oxalic acid=(2 volumes of vapour of carbon, 6 volumes of oxygen gas,) and ether=(4 volumes of vapour of carbon, 10 volumes of hydrogen gas, and 1 volume of oxygen gas,) and ammonia (2 volumes of azote gas, 6 volumes of hydrogen gas,) — water (2 volumes of hydrogen gas, and 1 volume of oxygen gas.) It, therefore, has the same relation to etheroxalic acid as oxamide has to oxalic acid.

4. *Pyroxylo-etheroxamide.*

By allowing ammoniacal gas to pass over oxalate of pyroxylic ether (=2 volumes of vapour of carbon, 3 volumes of oxygen gas + 1 volume of oxygen, 6 volumes of hydrogen gas, 2 volumes of vapour of carbon) till it reaches the fusing point, a solid mass is procured in crystals, which are rendered pure by being dissolved in boiling alcohol. These crystals consist of 6 volumes of vapour of carbon, 10 volumes of hydrogen gas, 2 volumes of azote gas, 6 volumes of oxygen; or,

$$\begin{array}{lllll}
\left.\begin{array}{r}\text{Pyroxylo-ethero-}\\ \text{oxalic acid}\end{array}\right\}=\left\{\begin{array}{l}\\ \\ \end{array}\right. & \begin{array}{l}4\text{ v. carb.}\\ +2\ \text{—}\end{array} & \begin{array}{l}6\text{ v. oxyg. gas.}\\ 1\ \text{—}\end{array} & \begin{array}{l}\\ 6\text{ hydrog.}\end{array} & \\
+\text{Ammonia} & & & 6\text{ hydrog.} & +2\text{ nitrog.}\\
\cline{2-5}
 & 6\text{ v. carb.} & 7\text{ v. oxyg.} & 12\text{ hydrog.} & +2\text{ nitrog.}\\
-\text{Water}= & & 1\ \text{—} & 2\ \text{—} & \\
\cline{2-5}
\text{Pyroxylo-etheroxamide}= & 6\text{ v. carb.} & 6\text{ v. oxyg.} & 10\text{ hydrog.} & +2\text{ nitrog.}
\end{array}$$

This combination has the same relation to pyroxylic ether, as etheroxamide to ether. The pyroxy-etheroxalic acid has not yet been discovered.

5. *Benzamide.*

By conducting dry ammoniacal gas over chloride of benzule it is quickly absorbed, and a solid body is formed: if the chloride of benzule is so enveloped that it cannot come in contact with the gas, it must be finely powdered, when complete decomposition takes place. By moistening the white mass with cold water, sal ammoniac is dissolved, and the residue, which is benzamide, forms a solution with boiling water, and crystals are produced on cooling. It is almost inscluble in cold water, easily soluble in alcohol and ether, and is procured in beautiful crystals from the solution of ether. It fuses at 290° ; when heated more intensely, it boils and volatilizes without being decomposed. Benzamide consists of 14 volumes of vapour of carbon, 14 volumes of hydrogen gas, 2 volumes of azote, 2 volumes of oxygen gas.

The formation of benzamide may be explained thus :—

Chloride of benzule	=14 v. vap. carb.	10 v. hydrog.	2 v. oxyg.	2 v. chor.g.	
Ammonia	=	12 v. ——	4 nitrogen gas.		
Benzamide	=14	14 hydrog. g.	2 nitrog.g.	2 oxygen.	
Sal ammoniac	= 2 chlorine	2 ——	2 ——	6 hydrog.	

At a common temperature, from a concentrated solution of potash and benzamide, no ammonia is given off; heated with it, ammonia is given off, and benzoate of potash forms. By dissolving benzamide in sulphuric acid, sulphate of ammonia and benzoic acid are formed. Benzamide has the same relation to benzoate of ammonia as oxamide has to oxalate of ammonia, and urea to carbonate of ammonia,

Benzamide	=14 v. vap. carb.	14 v. hydrog. g.	2 v.oxyg.	2 v. nitrog.g.
+Water	=	2	1	
Benzoate of Am.	=14 v. vap. carb.	16 v. hydrog. g.	3 v.oxyg.	2 v.nitrog.g.

6. *Bibenzamide.*

In distilling oil of bitter almonds at 435°, at the end of the operation the temperature rises very high; by interrupting the process, and separating the oil with a little alcohol, then a residuum remains, which is dissolved in boiling alcohol, and, on cooling, is separated in crystals. This substance is also separated from the last quantity that is distilled over in the preparation of oil of bitter almonds from the almonds themselves. It is solid, and free from smell, insoluble in water, only partly soluble in boiling alcohol and ether. It fuses at 405°, and is partly decomposed by distillation. Concentrated nitric acid dissolves it; and by adding some alcohol, benzoic ether is formed; boiling hydrochloric acid also dissolves it; sulphuric acid also dissolves it in the cold, giving out a beautiful blue colour; and by heating this solution benzoic acid sublimes. Boiling solution of potash does not decompose it; but if pieces of potash are dipped into alcohol, and heated, then ammonia and benzoic acid are procured. It consists of—

28 vol. vap. of carbon, 22 vol. hydrog. gas, 2 vol. nitrogen gas, 4 vol. oxygen gas

$$=\left\{\begin{array}{llllll} \text{Benzoic acid} & = & 28 \text{ v. vâp. carb.} & 20 \text{ v. hydrog. gas,} & 6 \text{ vol. oxyg. g.} \\ +\text{Ammonia. g.} & = & 2 \text{ azote} & 6 \text{ ———} & \text{———} \\ -\text{Water} & = & & 4 \text{ ———} & 2 \end{array}\right.$$

Or of bibenzoate of ammonia, from whence 4 volumes of vapour of water are parted with. Benzamide and bibenzamide in these combinations have the same relation to ammonia, as nitronaphthalide, and binitronaphthalide to naphthaline.

7. *Bisuccinamide.*

By allowing ammoniacal gas to act on anhydrous succinic acid, which is obtained by distilling crystalline succinic acid with anhydrous phosphoric acid, they combine with an evolution of heat. This combination is easily soluble in water, less so in alcohol, and very slightly so in ether. When warmed it fuses, and more intensely heated it sublimes unchanged. This combination consists of—

8 vol. vap. of carbon, 10 vol. of hydrog. gas, 2 vol. azote, and 4 vol. of oxygen gas

$$=\left\{\begin{array}{lll} \text{Succinic acid} = 8 \text{ vol. vap. carb.} & 8 \text{ vol. hydrog. gas,} & 6 \text{ vol. oxygen.} \\ +\text{Ammonia} = 2 \text{ azote} & 6 \text{ hydrog.} & \\ -\text{Water} \quad = & 4 \text{ ————} & \text{— } 2 \text{ vol. oxygen.} \end{array}\right.$$

By allowing the aqueous solution of this combination to evaporate large crystals are obtained, which are bisuccinate of ammonia (=8 volumes of vapour of carbon, 8 volumes of hydrogen gas, 6 volumes of oxygen gas +2 volumes of azote gas, 6 volumes of hydrogen gas,) without water. This sublimed combination has the same relation to succinic acid as bibenzamide to benzoic acid.

8. *Sulphamide.*

By conducting dry ammoniacal gas into a receiver, in which so much anhydrous sulphuric acid has been distilled, that the sides have become covered with it, then the ammonia combines with the sulphuric acid. By adding to the aqueous solution of this combination chloride of calcium, as long as any precipitate is formed, filtering the solution which is carefully evaporated, and separating from the residuum, by means of alcohol, the chloride of calcium, on pouring water upon the undissolved residuum, in which some sulphate of lime remains, there is then formed a combination, which in a pure state does not throw down salts of barytes, nor more particularly such salts, with whose bases sulphuric acid unites, forming insoluble combinations.

If the solution of this combination be thus heated, more particularly if mixed with a salt of barytes, the composition changes, and it contains sulphuric acid in its common state. If heated it is decomposed, like the crystalline sulphate of ammonia, from whence it is separated, from its containing water. This combination contains only sulphuric acid and ammonia. Whether the combination obtained by saturating a sulphate of pyroxylic ether with a solution of ammonia consists of sulphate of pyroxylic ether and sulphamide, more accurate experiments must decide.

9. *Asparamide. Asparagin.*

This substance is found ready formed in young asparagus roots, in many different species of potatoes, in the liquorice root, and in the root of marsh mallow, from which it is obtained in the greatest quantity—about 0·7 per cent. from the weight of the root. The root is cut and crushed, and covered with four times its weight of cold water: it is allowed to stand 48 hours, then strained, and the residuum is once more separated; the solution is evaporated to half, and the deposit is filtered and evaporated in a water bath down to the consistence of syrup.

Asparamide is soluble in 58 parts of cold water, but is not affected by anhydrous alcohol and ether. Dried at 300°, it loses 12·13 per cent. of water. Anhydrous asparamide is found to consist of 8 volumes of carbon, 16 volumes of hydrogen gas, 4 volumes of azote, 6 volumes of oxygen. Asparamide when boiled some time in a solution of strong base, is decomposed entirely; ammonia escapes, and a salt is contained in the solution, consisting of a combination of a peculiar acid, aspartic acid, with the base. Besides this acid and ammonia no other substance is formed: the salt of barytes, which is soluble in water, can be decomposed by sulphuric acid; the barytes is separated; and if the solution be filtered, when still hot, the acid separates, which is slightly soluble in cold water: on cooling, it forms small glossy crystals. By heat no water can be abstracted from aspartic acid; it combines with oxide of lead, and loses 7·42 per cent. water. The anhydrous acid consists of 8 volumes of vapour of carbon, 10 volumes of hydrogen, 2 volumes of azote, and 6 volumes of oxygen gas. It therefore combines with the bases and water, in such proportions, that the oxygen of them is to the oxygen of the acid as 1 : 6.

Asparamide = 8 v. vap. carb. 16 vol. hydrog. 4 vol. azote, 6 v. oxyg.
— Aspartic acid = 8 ———— 10 ———— 2 ———— 6 ———

Ammonia = 6 vol. hydrog., 2 vol. azote.

Asparamide consists, therefore, of aspartic acid and ammonia.

In comparing the composition of asparamide and aspartic acid with that of citric acid or malic acid, which consist of 4 volumes of vapour of carbon, 4 volumes of hydrogen gas, and 4 volumes of oxygen gas, we may be induced to consider asparamide as an amide of citric acid, and the aspartic acid as a combination of citric acid with this amide.

Neutral citrate of ammonia = { 8 v. vap. carb. 8 v. hydrog. 8 v. oxygen. +4 v. azote, 12 v. hydrog.
— Water = 4 v. hydrog. 2 v. oxygen.

Anhydrous asparamide = 8 v. vap. carb. 16 v. hydrog. 4 v. azote, 6 v. oxyg.

Asparamide has the same relation to citric acid as oxalic ether to oxalic acid, and aspartic acid to asparamide, as etheroxalic acid to oxamide. It is too much to imagine that ammonia furnishes with acids combinations similar to those which varieties of carburetted hydrogen produce, for instance, ether: no person has as yet succeeded in discovering them.

XVIII. SILICIUM.

Of all the substances which form the solid crust of the globe, none is found in such quantities as silicious earth. Quartz, sand, as found in a loose state, as well as in a solid, in the form of sand stone, is a calcareous earth, mixed with a few foreign ingredients. In fluor spar, and other minerals, it is found in combination with alum and potash, and furnishes besides, when united to other substances, a large number of minerals. Silicic acid may be decomposed by heat with potassium or sodium; these are then oxidized and silicium is separated, proving that silicic acid consists of oxygen and silicium. A large quantity of silicium is procured by decomposing a combination of fluoride of silicium and fluoride of potassium, which are procured by saturating with potash a solution of a silico-fluoride, or silico-fluoric acid. The combination thus procured, which is only slightly soluble in water, is separated by filtering, and dried by a high temperature, which must not be allowed to reach a red heat. In a glass tube, which is closed at its extremity, a part of this combination is united to $\frac{8}{10}$ or $\frac{9}{10}$ of potassium; the tube is gently heated till the potassium fuses, and the mixture is stirred; it is then heated over a spirit-lamp, and before the glass becomes hot, the contents are highly heated. The potassium combines with the fluoride of silicium, and the silicium that is set free with a portion of potassium. On pouring cold water upon this mixture, consisting of fluoride of potassium, siliciuret of potassium, and somewhat undecomposed silico-fluoride of potassium, hydrogen first escapes, then the siliciuret of potassium is decomposed, silicium being parted with, and potash formed by decomposition of water; the water has an alkaline action. By placing the insoluble portion on a filtering machine, and washing it with warm water, the affinity of free potash for silicic acid produces a decomposition of water, and oxidation of silicium; this must be washed only with cold water. After some time the fluid that passes has an acid action, as the silico-fluoride of potassium, which has an acid action, is decomposed. The washing is continued, as long as any particle is dissolved by water. Silicium thus procured in a state of purity, is a dark red powder, which leaves a deep stain; heated and exposed to the air, a third only, but in oxygen $\frac{3}{5}$ is consumed, because the silicic acid, which is formed, envelops the remainder of the silicium, which, when heated, burns no longer in air. It may be heated to redness without much loss in a small platinum crucible, half filled, and closed with a cover; the silicic acid that forms on the

Fig. 65.

surface is easily removed by means of hydrofluoric acid, by which it is dissolved.

When heated more intensely silicium contracts, assuming a more chocolate brown colour, becoming so thick and heavy, that it sinks in sulphuric acid; silicium is neither before nor after its calcination oxidized by nitric sulphuric, or nitro-muriatic acid. It combines before calcination with oxygen; when cold it is dissolved by hydrofluoric acid, from whence hydrogen gas escapes, and fluoride of silicium is formed, as well as by a concentrated solution of potash, from whence a silicate of potash arises. After calcination, when it becomes contracted and thick, it is no longer inflammable in oxygen gas; heated by a strong flame of a blow-pipe it undergoes no change, and is neither oxidized by nitre, nor chlorate of potash in fusion. Solutions of hydrofluoric acid and alkalies, even if boiled with silicium, produce no effect on it. Combustion of similar bodies in the air furnish examples of analogous phenomena, viz. porous charcoal is more easily oxidized than that of a thick structure; various metals, for instance, iron, are more readily ignited in a state of fine division; but they require a very high temperature when they form a compact mass. Silicium heated and mixed with carbonate of potash, is completely oxidized, even before the temperature is raised to redness; by taking but a small quantity of carbonate of potash, active ignition is set up, silicic acid forms, and carbon separates; by taking carbonate of potash in large quantities carbonic oxide gas is also generated. Fused with alkalies, potash or soda, from whence, by means of heat, the last trace of water chemically combined is not given off, silicium is oxidized, decomposing the water, from whence, as in the decomposition of alkaline carbonates, silicates are formed. 100 parts of silicium combine, when oxidized, with 108 parts of oxygen. Besides silicic acid, silicium is not known to furnish any other combinations with oxygen.

By heating silicium with gaseous sulphur it combines with evolution of fire, forming, if complete combination ensues, a white mass, which, brought in contact with water, is dissolved without residuum ; the water becomes decomposed, the hydrogen of the water combines with the sulphur, forming sulphuretted hydrogen, which escapes as gas ; and as much oxygen is set free, as is necessary to form with silicium silicic acid, which, notwithstanding it is usually insoluble in water, is yet dissolved by it. From this decomposition the formation of sulphuret of silicium may be ascertained, which contains 70 per cent. of sulphur. By allowing chlorine gas to pass in a small globe over silicium the silicium ignites, and combines with chlorine, forming a volatile body, which can be obtained in a fluid state, by connecting with the first globe a second, which must be kept very cool. Chloride of silicium may be obtained in larger quantities by intensely heating in a porcelain tube silicic acid and charcoal, which must be intimately mixed. Chlorine is allowed to pass over, and the different kinds of gases that are given off are allowed to escape into a receiver, which is kept very cool.

Chlorine is not able to abstract oxygen from silicious earth ; but, by adding charcoal, the affinity of the latter substance for oxygen assists in the operation, carbonic oxide gas and chloride of silicium are formed. The yellowish colour of chloride of silicium depends on some chlorine being absorbed; agitated with mercury, which combines with the free chlorine, it is obtained colourless. Brought in contact with water it is decomposed immediately; hydrochloric and silicic acids are produced. Chloride of silicium contains, therefore, 82·7 per cent. of chlorine, and silicic acid separates in a gelatinous shape. The specific weight of gaseous chloride of silicium amounts to 5·9: 1 volume of the vapour contains 2 volumes of chlorine. Fluorine and silicium easily combine, forming a gaseous body, which has the properties of an acid. The specific weight of gaseous fluoride of silicium is 3·6, and 1 volume contains as much silicium as 1 volume of chloride of silicium. Silicium combines with various metals, in particular with platinum and iron, but only at the moment it separates from its combinations.

XIX. BORON.

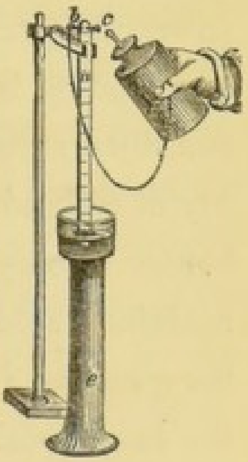
In borax, a salt found in commerce, soda is combined with boracic acid, which consists of oxygen, and a simple body, to which, from the name of the acid, the term boron has been assigned. Boron is found in nature, combined with oxygen, as boracic acid; it is extracted from the acid, and is rendered pure, by being fused and reduced to a powder, then mixed with potassium, and heated; a part of the boracic acid is decomposed, boron is separated, the oxygen that was combined unites with potassium, forming potash, which with the other portion of boracic acid forms a borate of potash. Boron, however, is obtained in an easier and better method, if treated in the same manner as silicium. For this purpose a combination of fluoride of boron and fluoride of potassium is obtained, by saturating hydrofluoric acid with boracic acid, and adding in drops fluoride of potassium. This combination, which is very sparingly soluble in water, must be treated in the same manner as the silicofluoride of potassium, in order that the boron may be separated by potassium, with only this difference, that equal parts of potassium and of the double fluoride of potassium and boron be employed; and instead of a glass tube an iron cylinder should be used. When heated the potassium combines with fluorine, and a mixture of fluoride of potassium and boron is obtained. Treated with water the fluoride of potassium is dissolved, and boron remains. For further washing pure water should not be employed, but a solution of sal ammoniac, as boron is soluble in water, but not so in sal ammoniac; this latter substance may be removed by washing in alcohol. Boron thus prepared is obtained as a dark greenish brown powder; heated to redness in a vacuum, or in gases which do not combine with it, it becomes crumpled and gives a very intense colour, but undergoes no other change. Heated in atmospheric air, or in oxygen gas, it burns with a very strong light, throwing down sparks, and forming boracic acid. Fused with carbonate of potash it decomposes carbonic acid, and borate of potash is formed. It is easily oxidized by nitric acid and various other substances, forming always boracic acid. No other degree of oxidation of boron is known. Sulphur and boron unite with development of light, if boron is heated in sulphur vapour; this combination is soluble in water, and it is then decomposed; boracic acid is formed, and the hydrogen of the water is sufficient to form, with sulphur, sulphuretted hydrogen. If chlorine gas comes in contact with boron, which has not yet been exposed to a red heat, it kindles spontaneously. With calcined boron this combination takes place, if it be heated; there forms a colourless, gasiform body, which decomposes water, hydrochloric and boracic acids being generated. The specific weight of this gaseous chloride of boron is 4·035, and 1 volume of it contains $1\frac{1}{2}$ volume of chlorine. Fluor spar heated with boracic acid forms borate of lime, and fluoride of boron, which is an acid. The specific weight of fluoride of boron is 2·308; and 1 volume of fluoride of boron contains as much boron as 1 volume of chloride of boron.

XX. COMPOSITION OF ATMOSPHERIC AIR.

Four ingredients are always found in the atmosphere; of which, two, oxygen and azote, are present in large quantities; the other two in smaller, namely, water, in the form of vapour, and carbonic acid. All the experiments on combustion prove the presence of oxygen in the air; and to calculate its quantity several methods have been adopted, among which, that by means of hydrogen gas deserves the preference. For this purpose a piece of phosphorus is introduced into a given quantity of atmospheric air; we then observe how much disappears whilst the phosphorus is in the act of being oxidized: the portion that disappears is oxygen gas, which combines with the phosphorus. As some of the phosphorus may be dissolved in the remaining azote gas, and many other circumstances may arise; this method does not furnish any accurate results. In the analysis of the atmospheric air by means of hydrogen, a tube is employed, which is graduated; at the upper extremity two holes, *b c*, are made opposite each other, through which two platinum wires are introduced. At the lower extremity the tube is pierced by a hole, *a*; it is then filled with mercury, and some atmospheric air is admitted. The tube is then depressed in mercury, which stands both within and without on a level, and the quantity of atmospheric air is ascertained, and about half as much hydrogen is allowed to enter; the tube is again depressed till the mercury stands on a level both within and without the tube, and we ascertain how much hydrogen is added. By an electric spark the mixture is kindled; and it may be distinctly seen how combustion proceeds throughout the whole mass. By removing the cork the mercury rises in the tube, which is again sunk till the mercury stands on a level both within and without the tube, and we find how much has disappeared from the mixture, and this is

Fig. 66

Fig. 67.



fluid water, consisting of 1 volume of oxygen gas, and 2 volumes of hydrogen. The third portion of the gas that has disappeared, is therefore oxygen, which was contained in the air. By taking 56 parts of air, the quantity of additional hydrogen gas makes up the mixture to 89 parts: after combustion $53\frac{3}{4}$ still remain, $35\frac{1}{4}$ therefore have disappeared, of which the oxygen amounts to a third part of $35\frac{1}{4} = 11\frac{3}{4}$; consequently 56 parts of air contain $11\frac{3}{4}$ parts of oxygen gas, 100 parts very nearly 21 parts of oxygen gas; and as the specific weight of oxygen gas is 1·1026, 100 parts contain 23·1 by weight.

The quantity of carbonic acid in the air may be ascertained by filling a globe, the capacity of which is known, with air, and agitating with water of barytes; this is a powerful base, and unites with carbonic acid, forming a combination insoluble in water. The globe may be emptied and filled several times; and in this manner a large quantity of carbonic acid may be abstracted from the air. Carbonate of barytes thus formed is filtered and weighed: it contains 22·34 per cent. of carbonic acid. From this weight the quantity in volumes may be ascertained; and thus in the neighbourhood of Geneva, at Chambeisy, the quantity of carbonic acid in 100 parts is on an average 0·0415. The greatest quantity found amounted to 0·0574, and the smallest 0·0315. This analysis proves, as we might have foreseen, that the quantity of carbonic acid is somewhat changed by chemical processes, which take place in various countries at different seasons of the year. Various chemical processes arising from the surface of the earth, more particularly the composition of mineral springs, are found attending the change of the different quantities of carbonic acid in the air. The quantity of azote is proved from the indifferent relation this species of gas bears; as what is not oxygen, vapour of water, or carbonic acid, is azote; so that atmospheric air contains, by measure, 21 parts of oxygen, and 79 of azote. In order to examine the atmosphere of any particular spot, small flasks are filled with mercury, which we allow to be expelled by the air of the spot we wish to analyze; and these flasks should be closed with the greatest care. In this way the air from the most distant parts of the globe,—from the neighbourhood of the poles, and the equator, from the highest mountains and the lowest valleys, has been procured and analyzed, and it has been found always to contain the same quantity of oxygen and azote gases, whether taken from the summit of Mont Blanc and Chimborazo, or from the deepest valleys; except in those places where peculiar local circumstances interfere; caution should be observed, therefore, that the air should not be taken from confined spots, for instance, from cellars, or pits where organic substances may be found in a state of putrefaction. The constant proportion these four bodies bear to one another has given rise to an erroneous idea, that atmospheric air is a chemical combination, and not a mixture. Nevertheless, we never find that an artificial mixture has the same properties as a chemical combination. An artificial mixture, consisting of 21 parts of oxygen gas and 79 azote, is analogous in chemical and physical properties to air. In every chemical combination a development of heat takes place; in a mixture of oxygen and azote, constituting artificial atmospheric air, no development of heat results. As atmospheric air is a mixture of oxygen and azote gases, it is very astonishing that, as oxygen gas is heavier than azote, (their specific weight being to each other as 1·1026 : 0·976) these two gases invariably unite. Such an uniform mixture of gases, notwithstanding they may be heavier or lighter, is a general fact, which is repeated with all kinds of gases. We fill a reservoir, *a*, with hydrogen gas, and another, *e*, with carbonic acid gas, and connecting the two by means of an intermediate tube, we open the cocks, *b c*. Although the apparatus is so placed that the vessel containing hydrogen, which is twenty times lighter than carbonic acid gas, should be uppermost, nevertheless a mixture of the two gases takes place; after a few hours the same quantity of hydrogen is found in each reservoir, and the same quantity of carbonic acid gas is present. This uniform mixture takes place the quicker, the more the specific weight of each gas differs.

Fig. 68.

XXI. CIRCULATION OF OXYGEN GAS.

As the weight of atmospheric air approaches the weight of a column of water of about 32 feet high, and 100 parts of air contain 23·1 parts of oxygen; then 7·4 feet of this column balance the oxygen; this gives a good idea how slight the quantity of oxygen gas is that surrounds the globe. Oxygen is consumed by combustion, by respiration, or by the putrefaction of organic substances: persons have thus calculated how much oxygen gas disappears in 100 years, and they have valued it as $\frac{1}{7200}$ part of the oxygen of the air.

Such calculations cannot be depended on with certainty; it may be proved, however, in any method, that oxygen of the air makes only a circuit. On a soil containing very few organic substances, a tree grows, which furnishes a large quantity of wood. The wood consists of carbon, hydrogen, and oxygen, the two last ingredients exactly in the same proportions as found in water. The carbon in plants is to be ascribed principally to the decomposition of carbonic acid of the atmosphere, so that the oxygen which combines with the carbon during combustion or putrefaction of organic substances, is again parted with, through the organic process which takes place in plants. Other substances, distinguished from their odour, which are of importance from their influence on health, are found in the atmosphere, arising from local decompositions and combinations.

Small quantities of volatile oils, formed during the flowering of plants, indicate their presence in the air by their odour; matters arising from dry marshes during the heat of summer, propagate diseases in the neighbourhood in which they are generated; and chemical combinations transfer diseases from one person to another, without direct contact taking place. Such substances are found in the air, but only in such very minute particles that they escape detection by analysis; it is proved, however, that they are material substances, from the fact of their being decomposed by chlorine.

Vegetable substances are decomposed under water, producing carbonic acid and light carburetted hydrogen gas; it is therefore not improbable, that this latter gas forms a part also of the atmosphere. We may conclude that a watery substance is present in the air, by conducting atmospheric air through a tube containing asbestos, saturated with sulphuric acid, and then through a heated tube filled with copper filings, to present many hot points of contact; from this tube the air passes into another, also containing asbestos soaked with sulphuric acid. In the heated tube, with the oxygen of the air, some hydrogen was combined, which settles as water in the last tube: the quantity of hydrogen, from whence this water is produced, amounts to $\frac{4}{100,000}$ to $\frac{13}{100,000}$ part of the air that was used.

XXII. ANALYSIS OF THE COMBINATIONS OF CARBON, HYDROGEN, OXYGEN, AND AZOTE.

The method by which these analyses are made, is most important, as by means of it we not only become acquainted with other substances, through the combustion of which we obtain light and heat, but more particularly with the composition of important combinations, formed both in the vegetable and animal kingdoms. During the combustion of wood, oil, or any other substance consisting of carbon, hydrogen, and oxygen, we perceive that there is no residuum, or, at least, a very inconsiderable one in the form of ashes; we have therefore to inquire, what combinations have taken place, which have escaped our observations. In burning substances under bell-glasses, or in closed vessels, we find carbonic acid and water are formed, with the composition of which we are sufficiently acquainted. We may, therefore, calculate accurately, how much carbonic acid and water are procured from burning a substance; we first ascertain how much carbon and hydrogen it contains; the quantity of oxygen is obtained by weighing the body before the operation; what additional weight it has gained above the hydrogen and carbon, is oxygen. The quantity of oxygen may be discovered in a direct manner, by finding what quantity of oxygen is necessary for the purpose of combustion. One volume of oxygen gas produces one volume of carbonic acid gas; what has therefore disappeared of the gas through combustion, becomes combined with the hydrogen of the substance employed. By calculating the water formed by combustion, determining its quantity of oxygen, and deducting from it the quantity of oxygen which has disappeared from the gas employed for combustion, we obtain the quantity of oxygen the substance contained. Complete combustion, and an accurate collection of substances formed during combustion in oxygen gas, offer many difficulties.

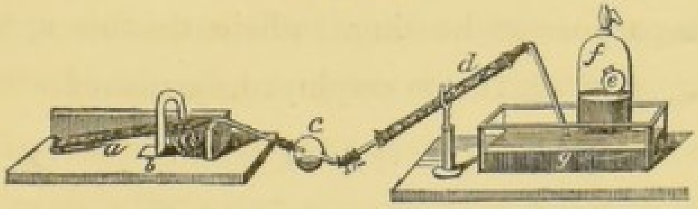
Persons have endeavoured to unite oxigenous substances with combustible combinations, to which they impart at a high temperature their oxygen, and to calculate the water and carbonic acid which are formed by heating the mixture. Formerly chlorate of potash was employed as an oxigenous combination; instead of which, at present, oxide of copper is used, which is ascertained to be the best means of conveniently arriving at an accurate result. In employing chlorate of potash, oxygen is disengaged at the same time with carbonic acid and water: from the oxide of copper however no oxygen can be expelled by heat. Oxide of copper furnishes only oxygen, which is employed for the production of carbonic acid and water. Should the combination employed for this analysis contain nitrogen, it will separate as gas, which may be collected and calculated.

The oxide of copper is best prepared, by dissolving pure copper in nitric acid, by evaporating the solution in a porcelain saucer, and by raising the temperature by means of a sand-bath, so as to decompose the dry salt: then heating for half an hour, or even longer, in a Hessian crucible, without fusing the oxide, which remains. The same oxide may be employed for several experiments; by merely pouring a little acid on it, the metal is oxidized afresh, and the oxide is restored to its former purity by calcination.

We will describe two methods of conducting these analyses; the first is interesting, as it serves to examine so accurately many important combinations, that it is unnecessary to employ any other means. The second differs only from the first in as far as it combines all the various measures which have been discovered up to the present day.

If the organic substance be an acid, it must be combined according to the first method with a base, for instance, oxide of a lead, in a given quantity. From the substance under examination, all the water, as far as possible, must be abstracted. For this purpose, a saucer filled with sand, heated from 280° to 300°, or to a higher degree, according to the temperature the substance is able to bear without undergoing decomposition, is placed under the receiver of an air pump, with a tube containing the substance to be analyzed, as well as a small vessel with sulphuric acid. The receiver is pumped empty; all volatile fluid is abstracted from the substance by the sulphuric acid having a strong affinity for water. The substance then weighed is mixed in a warm saucer with pulverized chlorate of potash, to which chlorate of sodium in sufficient quantity is added, to render the mixture less fusible; this is introduced into a glass tube, *a*, (Fig. 69,) closed at one end, and the other is drawn out to a fine point, to which is attached a small globe, *c*, communicating with the pipe *d*, containing chloride of calcium, from whence an elastic tube passes under the bell-glass, *f*, standing in mercury. The glass tube is gradually heated by burning charcoal, and the screen, *b*, serves for the purpose of preventing the heat from spreading too rapidly, lest the glass should become fused. By means of heat, carbon and hydrogen of

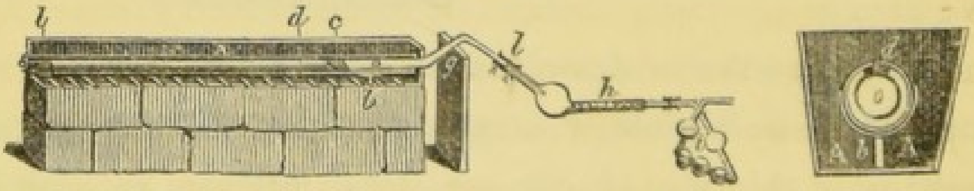
Fig. 69.



the substance unite with the oxygen of the chlorate of potash, forming carbonic acid and water. The water collects in the globe *c*; that portion which passes over as vapour is absorbed by the chloride of calcium. This portion of the apparatus is weighed before and after the operation: what additional weight it has acquired, is due to the formation of water. The carbonic acid escapes as gas into the bell, *f*, under which a small glass globe is placed, filled with moist potash, the opening of which is somewhat wide, and is covered with leather, which prevents the admission of mercury, but not of the gases; thus the potash combines with the carbonic acid that is given off, and the additional weight of the globe is owing to the generated carbonic acid. The second method depends on the same principle, differing only from the first in the introduction of some improvements, by which the analysis is rendered less difficult.

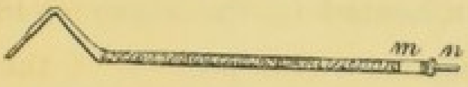
For the purpose of heating sufficiently this apparatus, a small stove, *a*, (Fig. 70,) is employed, furnished with several

Fig. 70.



apertures on the under part, for the admission of the necessary current of air. On the upper part of the stove rests a gun-barrel, into which a glass tube is introduced. Throughout this barrel, the heat is equally distributed, by means of heated charcoal, without incurring the danger of fusing the glass tube, which is filled with oxide of copper; to the extremity, *m*, (Fig. 71,) a hand pump is affixed, and air is pumped through the oxide of copper, till no stain is observable in the intermediate tubes.

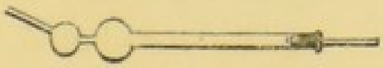
Fig. 71.



To effect combustion of a given quantity of volatile fluid substance, we select a tube of thick glass, one end of which is fixed to the pump; the centre of the tube is blown into a globe, (Fig. 72,) the walls of which are very thin. A current of air is driven through the globe to expel every trace of moisture which may have been introduced. The extremity of the tube is plunged into the fluid under examination, and by means of the pump as much fluid is drawn into the globe and half the upper tube, which is closed and plunged into cold water. In this manner the globe may be filled with so much fluid, that its expansion being greater than of the glass, the globe cracks in the centre. We then weigh the globe and its contents, and subtracting the weight of the tube, we find that the additional weight is produced by the liquid in the globe. To ascertain the quantity of water, the tube with the chloride of calcium is attached to a tube composed of several globes, (Fig. 73,) containing a solution of potash; by introducing the liquid as well as air, the former rises in the last globe, and the gas

Fig. 72.

Fig. 73.



passes from one globe to another, and is brought into immediate contact with the liquid.

The tube, *l*, (Fig. 74,) is then heated in the stove; and when the oxide of copper becomes heated, the temperature is raised in the globe, which cracks, and the moisture is absorbed by the oxide of copper. This assumes a gaseous form, in proportion as the heat spreads; a part passes through the heated oxide of copper, the greater part becomes condensed in the cool part of the tube (Fig. 75). The oxide of copper yields its oxygen to the vapour, forming carbonic acid and vapour of water; the latter passes into the tube *l*, and is absorbed by the chloride of calcium. But few volatile bodies can be introduced into the tube *l*; some solid bodies are weighed and placed in an open tube, which is plunged into oxide of copper. Carbonic acid mixed with air passes through the solution of potash; after a time it is rendered quite pure. In proportion as the air enters, and the mercury is depressed, the cylinder is raised, to prevent pressure on the glass.

Fig. 74.

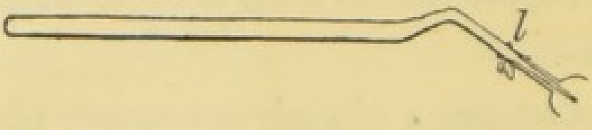
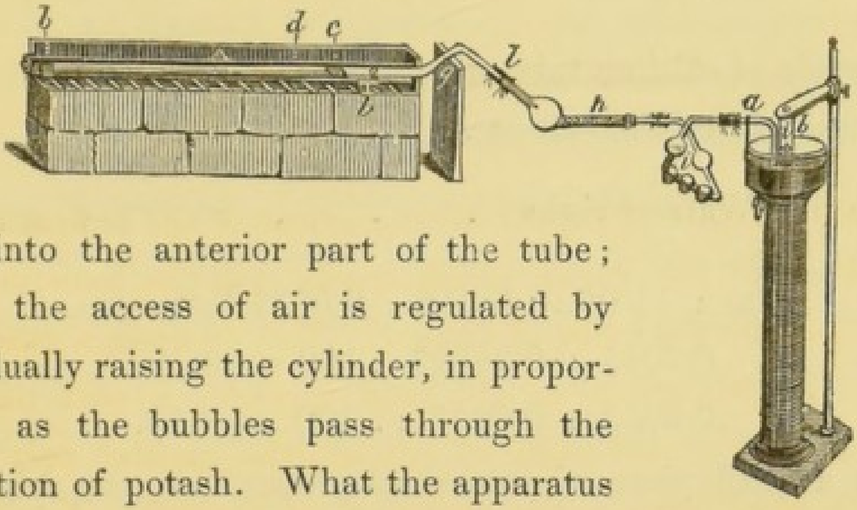


Fig. 75.

This operation is conducted in proportion to the rapidity with which bubbles of carbonic acid gas are developed.

When the substance is entirely consumed, the whole apparatus (Fig. 76) is filled with carbonic acid and vapour of water; these are driven by the admission of atmospheric air into the anterior part of the tube; and the access of air is regulated by gradually raising the cylinder, in proportion as the bubbles pass through the solution of potash. What the apparatus of potash has acquired in weight, is due to the formation of carbonic acid, which contains 27·675 per cent. of carbon. To ascertain the quantity of water, the apparatus with the globe is weighed, then washed and dried, and weighed a second time: the excess of the first weight over the second is owing to the water that was formed, containing 11·09 per cent. of hydrogen. What additional weight the hydrogen and carbon together have acquired, is due to the quantity of oxygen. We will give an analysis of benzin:

Fig. 76.



Glass ball filled with benzin . .	=1·702	grains.
———— empty	=1·3965	
Benzin weighs . . .	=0·3055	

Apparatus with potash and carbonic acid absorbed . . . . . . =38·368 grains.
Apparatus with dry potash . . . . =37·3455

Carbonic acid . . . . = 1·0225 grains.

Chloride of calcium tube and water . =22·534
Chloride of calcium alone . . . . =22·320

Water weighs . . . . = 0·214 grains.

100 : 11·09 : : 0·214 : 0·0237 hydrogen.
0·3055 : 0·28297 : : 100 : 92·62.
0·3055 : 0·0237 : : 100 : 7·76.

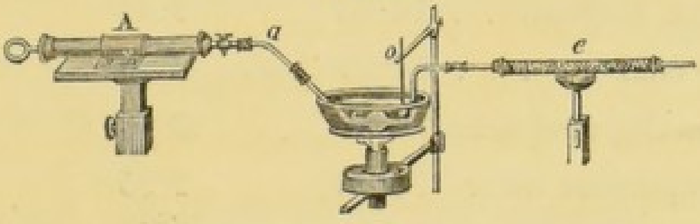
If a small piece of potassium produces in the cylinder no diminution of gas, the substance contains no oxygen: analysis, however, cannot furnish more accurate results. Benzin consists of equal volumes of vapour of carbon and hydrogen gas; therefore 100 parts contain

92·46 parts of carbon,
7·54 —— of hydrogen.

The analysis of a non-volatile substance is conducted in the same manner; it must, however, be well dried before mixed with oxide of copper. If the substance be an acid, it must combine with oxide of lead or silver, and the quantity of base is ascertained by another analysis. It is introduced into a glass globe, which is weighed; it is placed in a sand-bath and heated; hot dry air is now forced through it, which expels all the fluid: the substance is weighed, and we ascertain by its decrease of weight what water has been expelled.

If the substance be decomposed before acting on the oxide of copper, as is usually the case, whilst the apparatus is heated, a large quantity of volatile substances settle in the lower part of the glass tube, which can be removed only at the close of the operation. In combinations containing no nitrogen, the result is the same; in those containing nitrogen, the formation of a certain quantity of carbonate of ammonia, according as the operation is conducted, may alter the proportion nitrogen bears to carbonic acid. The gradual heat of the tube spreading, produces a larger quantity of nitrogen in the vessels than in the bell-glass; if however the whole tube containing the substance be gradually heated, so as to expel all the volatile principles before the remaining charcoal can act on the oxide of copper, the quantity of nitrogen contained in the tube would be less than that in the bell-glass.

Fig. 77.



If the substance contains nitrogen, the quantity of carbon and hydrogen must first be ascertained, and, by a peculiar analysis, the quantity of nitrogen: this is effected by attaching to the tube containing chloride of calcium another which passes under a bell-glass, to the upper end of which is affixed a pump to exhaust the tube. The carbonic acid and nitrogen, resulting from combustion, are collected; a small piece of moist potash introduced under the glass absorbs all the acid, and the proportion, in volumes, the carbonic acid bears to nitrogen, as well as the quantity of nitrogen the substance contains, are accurately calculated.

In analyzing a gaseous combination, for instance of olefiant or cyanogen gas, the further extremity of the tube is not closed, but the oxide of copper is only heated to redness, and the gas conducted over the copper is collected under the bell-glass.

The following is an enumeration of the composition of substances usually employed to furnish either warmth or light, which have been analyzed according to the methods already described :—

	Carbon.	Hydrogen.	Oxygen.
Alcohol consists of	53·650	12·896	34·454
Oil of Olives	77·21	13·36	9·43
Oak-wood	52·53	5·69	41·78
Wax	81·79	12·67	5·54
Beech-wood	51·45	5·82	42·73
Cannel coal, English	74·83	5·45	19·72
Newcastle coal	84·99	3·23	11·78
*Coals from the royal mine	78·89	3·22	17·89
*From Leopoldine mine	76·08	2·85	21·07

XXIII. DEVELOPMENT OF HEAT AND LIGHT FROM COMBUSTION.

From the composition of substances employed for the purpose of combustion, it appears, that during this process,

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* There are two mines situated in the neighbourhood of Berlin, from whence large quantities of coals are annually consumed in that city.—Translator.

carbonic acid and water are formed, which unite with the azote of the atmosphere, the oxygen of which has been employed for the support of combustion. Two phenomena accompany this chemical process, namely, warmth and light. Warmth results from every chemical combination; light only from substances, raised to a certain temperature by means of the generation of heat. Warmth produced by chemical combinations is calculated, in the simplest manner, by ascertaining to what point it can raise the temperature of a given quantity of water, or how much water a given quantity of substance raises to a certain degree. How many degrees a given quantity of another body is heated may be easily discovered from its capacity for heat. It has been ascertained by experiments, which, however, can only furnish results approaching probability, that the combustion of the following substances can raise from the temperature of 32° to 257°, the specified quantity of water.

	lbs. of water.
1 lb. of pure coals raises	78
1 — charcoal	75
1 — dry wood	36
1 — wood, containing 20 per cent. moisture	27
1 — oily coal	60
1 — turf	25—30
1 — alcohol	$67\frac{1}{2}$
1 — oil of olives, oil of turnips, wax	80
1 — hydrogen gas	236·4

These substances naturally require different quantities of oxygen to support combustion; proceeding from oxygen we derive the following facts, that the combination of certain substances may raise the temperature of a given quantity of water from 32° to 257°.

				lbs. of water.
1 lb.	of oxygen	combined with	hydrogen can raise	29½
1	ditto	ditto	charcoal	29¼
1	ditto	ditto	alcohol	28
1	ditto	ditto	ether	28½

A combination, formed by the combustion of a substance, retains at first all the heat that is generated, it then communicates part of that warmth to substances with which it is united, or to such as are placed in its proximity. What height of temperature a combination may reach can be calculated when we are acquainted with its capacity for heat. A combination of one part of oxygen by weight with hydrogen gas produces 1·125 vapour of water. If this vapour had the same capacity for heat as water has, then, as 1 lb. of oxygen, combining with hydrogen, is able to raise the temperature of 29½ lbs. of water from 32° to 257°, the temperature of the vapour of water would be $\frac{29\frac{1}{2}\times 100^\circ}{1{\cdot}125}=2622^\circ$.* If, however, instead of oxygen gas, atmospheric air is employed for the support of combustion, 23·1 parts of oxygen, without calculating the other substances contained therein, are united to 76·9 parts of nitrogen, to which the vapour that is formed communicates its heat. The capacity of nitrogen for heat amounts to $0{\cdot}2734\left(=\frac{0{\cdot}2669}{0{\cdot}976}\right)$, therefore, three times less than the capacity of vapour of water. 23·1 parts of oxygen give off 25·95 parts of vapour

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* The capacity of vapour of water for heat is, however, 0·8407, therefore less than that of water; if the same quantity of heat be added to the water and the vapour of water, the temperature of the vapour of water would be 1·19 $\left(\frac{\cdot10000}{8407}\right)$ higher than that of water. The temperature of vapour of water amounts to $2622^\circ\times 1{\cdot}19=3120^\circ$.

of water; with these parts of oxygen 76·9 parts of nitrogen gas are combined, therefore nearly three times as much by weight. If the heat which is contained in the vapour of water that is formed, be communicated to the nitrogen, then half as much heat is sufficient to give the same temperature to the vapour of water and nitrogen gas, though three times more nitrogen is present than vapour; the capacity of nitrogen for heat is therefore three times less.

If hydrogen gas is consumed in atmospheric air at 32°, the mixture which produces the flame has only a temperature of 3440°, which is only half as high as if the hydrogen is burnt in oxygen gas. Such observations on heat, developed during the process of combustion, even though the observations on all the facts from which we proceed, may be sufficiently good, admit of but a slight degree of accuracy, as many accidental circumstances may happen during combustion, which can never be taken into account; a great point, however, is gained, to be able to fix in an exact manner all the phenomena connected with combustion. What has been advanced clearly proves the reason, why, during combustion in oxygen gas, a much higher temperature is developed, than in atmospheric air. The temperature of a flame of hydrogen presents a fixed point to ascertain the temperature at which various phenomena are observed. In the flame of hydrogen, during the combustion of hydrogen in the atmosphere, we may fuse a thin platinum wire. The temperature necessary for this purpose is much higher than that required for smelting iron, granite, and more particularly than that which we are enabled to produce in our blast furnaces. The temperature at which basalt is rendered fluid, and that of a volcano, calculated in a similar manner, do not exceed 2280°. The temperature at which the surface of the earth is rendered fluid, which is attained in our furnaces, is below 3440°.

The varieties of gas, which are generated during combustion, are dilated by heat, and becoming much lighter than the surrounding atmosphere form an ascending current. By placing a body therein, they communicate to it their heat; and in this manner advantage may be taken of these currents to raise substances to a very high temperature. By transmitting them through canals (stoves), they give off their heat to the walls of the canal, which serve for distributing warmth to an apartment.

By heating a gaseous body to 2280°, or even to 4532°, it gives off a very feeble light; a solid or fluid body heated only to 1157°, or 1382°, commences to be red hot; heated to 2280°, it attains a white heat, and gives off a very strong light. Hydrogen combining with oxygen gas forms vapour of water, which has a very high temperature; but as it is a gaseous body furnishes but little light. In igniting iron, a very intense light is given off, as the oxidized iron is never found in a gaseous, but only in a fluid or solid state. Phosphorus in combustion furnishes a strong light, whilst phosphoric acid becomes gaseous at the temperature of a white heat. By placing a platinum wire, or a piece of chalk, in the flame of hydrogen, (which gives off a feeble light,) an intense light is produced, which equals that of the sun, if a stream of oxygen gas be transmitted through the flame, generating a high temperature. As the vapour of water communicates its contained heat either to the platinum or to the chalk, the two therefore have a lower temperature than the vapour of water alone. A solid body separates in the flames we make use of, for the purpose of affording light, for instance, in the flame of oil or tallow; and this solid body acquires a white heat in the centre of the flame itself.

XXIV.—PHENOMENA OF IGNITION AND EXTINCTION.

Some bodies burn at a common, some at a moderate, whilst others require a very high temperature. Phosphorus kindles at a common temperature in the atmosphere, with the oxygen of which it combines. Potassium requires to be only slightly heated. Charcoal requires a higher temperature, the oxide of nitrogen gas combines with the oxygen of the air without being heated. The temperature which bodies require to be enabled to combine with oxygen gas does not depend, according to these examples, on their affinity for oxygen.

The true reason we are ignorant of, we know only from experience, what temperature substances require to be able to combine with oxygen gas, which may be different in one and the same body, in as far as it forms either a solid mass or a finely divided powder.

A kindled body burns for some time; this depends on the combustion of a part of the substance communicating so very high a temperature to its neighbouring parts, that they are enabled to combine with oxygen. Iron, for instance, once kindled, continues to burn in oxygen gas; the part of the burning iron communicates to its adjacent parts a sufficient quantity of heat produced by combustion, without which temperature the combination of oxygen cannot take place. By transporting heated iron into atmospheric air, to the nitrogen of which, heat is at the same time imparted, the part adjacent to the burning iron cannot retain sufficient heat, as is required for its combining with oxygen; the burning iron, in consequence, soon becomes extinguished in atmospheric air. By placing burning charcoal on a cold body, for instance, on iron, it absorbs from the charcoal a part of its warmth generated during combustion, and the charcoal, which would otherwise continue to burn, becomes extinguished. The same thing occurs to different varieties of gas, should little oxygen be contained in the air; for instance, in wells or cellars, the light is extinguished, though a person may continue to respire, as too large a quantity of warmth is absorbed by the nitrogen gas in proportion to the oxygen gas, which combines with a combustible body. Hydrogen gas requires a temperature of about 700° to be enabled to combine with oxygen gas; if both gases be mixed with each other, and kindled, the burning parts communicate to the adjacent parts the temperature necessary for their combination.

If combustion of hydrogen gas takes place in the atmosphere, the temperature which is generated is sufficiently elevated to raise the warmth of the nitrogen to 700°. By adding, however, more nitrogen gas to a mixture of hydrogen gas, and atmospheric air, for instance, seven times as much as it contained, then this nitrogen gas absorbs so much heat that the oxygen and hydrogen no longer continue to burn. The same effect takes place, by adding to 1 volume of a mixture of gases, consisting of 1 volume of oxygen gas, and 2 volumes of hydrogen gas, 8 volumes of oxygen gas, or 9 volumes of hydrogen gas. Of carbonic acid it is only necessary to add half as much. Phosphorus on the other hand, which combines at a common temperature with oxygen gas, abstracts the last trace of oxygen from a mixture of gases.

The diamond and graphite require a very high temperature to be enabled to burn; charcoal is consumed with greater facility. In general charcoal is much more inflammable the lighter it is; this too is the case with tinder, which results from the incomplete combustion of linen. Even iron, and other bodies, which burn only at a very high temperature, may be so prepared that they will kindle at a common temperature; they are then termed pyrophori. If oxides of iron, cobalt, or nickel are reduced by hydrogen gas, at a low temperature, and this takes place at 640°, then the smallest particles of the oxide are deprived of their oxygen, without the metal, which is with difficulty fusible, being rendered vitreous: the metal is therefore found in the most finely divided state possible. By agitating it in the atmospheric air it kindles spontaneously. By mixing with these metallic oxides an infusible body, for instance, alum, in such a manner that the single parts of the reduced metal be separated still more from each other, a higher temperature may be employed for the reduction, without the reduced metal losing its property of spontaneously igniting in the atmosphere.

By reducing easily fusible metals, for instance, lead, the particles agglutinate together, and do not ignite in the atmospheric air.

Silicium, which separates in the state of fine powder, on reducing double fluoride of potassium, and silicium with potassium, and pouring the hot mass into water, when dried, is easily inflammable ; should it, however, be calcined in closed vessels, whereby the single particles form an agglutinated mass, it no longer kindles spontaneously either in atmospheric air or in oxygen gas. Carbon, which in a compact state, in the form of a diamond or graphite, burns with so much difficulty, may be soon rendered inflammable, by mixing the substance to be converted into carbon, for instance, chips of cork, with hydrochlorate of ammonia and platinum, and heating the mixture till it is completely carbonized ; the carbon is then found in a fine powder, by the interposition of platinum. Very finely powdered charcoal, when piled in heaps for the manufacture of gunpowder, has often ignited spontaneously. Two parts of sulphate of potash, heated with one part of charcoal so intensely that sulphuret of potassium is produced, also forms a self-inflammable mass. The long-known pyrophorus, which is obtained by mixing and heating alum (which is a double sulphate of potash and alumina) with lamp-black, arises from the formation of sulphuret of potassium, which is also found in a very finely divided powder.

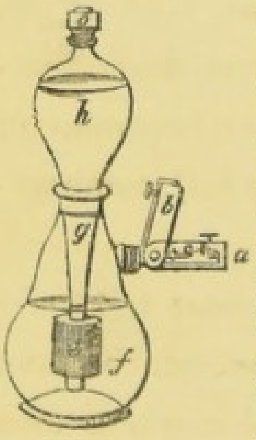
In a pyrophorus there are two circumstances requiring explanation; the act of ignition, and the continuance of combustion. The ignition may ensue if a chemical combination takes place on a single spot of a combustible mass; from this spot the combustion may spread to the adjacent parts, by means of the heat arising from the first spot; and from this it passes throughout the whole mass. If the single particles of a combustible substance adhere together, forming a solid or compact mass, then so much heat is given off to be distributed throughout the neighbouring parts, which are in immediate contact with the heated point, that either no combustion can take place, or it is immediately extinguished, as happens when a heated piece of charcoal is placed on cold iron. If, however, the mass be reduced to a very fine powder, in which there are but few points of contact, there can take place but a slight conduction of heat, so that it is not quickly given off; thus combustion may spread through the whole mass. What are the necessary conditions, from whence without an elevation of temperature, or by such an elevation of temperature as may be produced through a condensation of gases on the surface of a solid body, a chemical combination follows, are not yet sufficiently known.

Combustible bodies in a porous state combine not only with oxygen, but many porous metals produce, without undergoing any change themselves, chemical combinations of gases with which they come into immediate contact.

Platinum has become of great importance in this point of view, as it can be prepared easily in a very finely divided state; the combinations of platinum being decomposed by heat at a low temperature, and platinum itself fusing with more difficulty than iron. Hydrogen is easily kindled in oxygen gas, as well as in atmospheric air, through the medium of platinum. Phosphorus too, whilst it kindles at a common temperature, absorbs every trace of oxygen from a mixture of gases; platinum also, in a state of sponge, (finely divided metallic platinum,) which produces at a common temperature a combination of hydrogen and oxygen, abstracts every trace of hydrogen gas from mixtures of gases, to which a sufficient quantity of oxygen has been added; so that we can prove with the greatest facility that the atmospheric air contains no hydrogen gas.

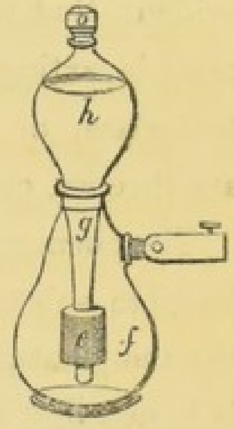
The property of spongy platinum having the power of igniting hydrogen gas in the atmospheric air, has given rise to a very convenient machine for producing an instantaneous flame. The apparatus (Fig. 78) consists of two glass vessels, *h, f*; from the under one a spout is fixed, furnished with a cock. Immediately before the opening hangs a piece of spongy platinum wire, *a*, which is incrusted with a paste of platino-bichloride of hydrochlorate of ammonia. In the upper part of the vase, *f*, is an opening, in which is hermetically fixed an open tube, which constitutes the lower part of the second vessel, *h*, and to this is affixed a piece of zinc. Diluted sulphuric acid is poured into the lower vessel, and the tube is introduced belonging to the upper vessel; hydrogen gas is generated, which expels the fluid

Fig. 78.



in the vessel, *f*, through *g*, into the upper part of *h*, till the zinc is left dry; by opening the cock the gas is compressed by the fluid in the vessel, *h*, and coming in contact with the platinum becomes kindled. This machine may be used until all the acid is saturated with oxide of zinc, or the zinc is dissolved: the zinc and sulphuric acid must be constantly renewed. This apparatus should be often used, otherwise the platinum absorbs moisture, and will no longer inflame the hydrogen gas. The metal, however, soon recovers its lost property by being heated by hydrogen gas, kindled by means of a lighted candle. Platinum is endowed with the property of producing at a common temperature the combination of hydrogen and oxygen, not only when it is in a pulverized state, but even as a wire. As the combination is only conducted through the medium of spongy platinum, the smallest quantity is therefore sufficient. A glass, covered with a thin layer of platinum, which is laid on with a pencil dipped in a solution of chloride of platinum in alcohol, and heated to produce complete decomposition of the salt, is a beautiful instance of this property. Platinum wire, and platinum in plates, if their surface is entirely pure, produce the same effects; so that platinum, whatever form it may assume, which may be purified by means of heat, or friction, by alkalies, or acids, may bring about the combination of hydrogen and oxygen gases; and should the case not turn out so, the reason must depend on some foreign object, oftentimes impercep-

Fig. 79.

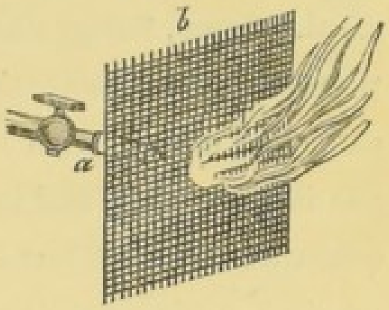


tible. Other metals, which are fusible with difficulty, and can assume a finely divided condition, act as platinum; to this class belong palladium, rhodium, and iridium. Gold, too, effects this combination, though only at 300°: even porous charcoal, namely, that from the box tree, acts in the same manner, when introduced into a mixture of sulphuretted hydrogen and oxygen gases, which is ignited by means of an inflammable body; a violent explosion takes place, water is formed, and sulphur is deposited.

As combustion in the atmosphere depends on a combination of an inflammable substance with oxygen, it is self-evident, that if access of oxygen be prevented, the ignited body is extinguished. A burning body, covered with a bell-glass, or lighted charcoal, over which ashes or sand are thrown, ceases to burn.

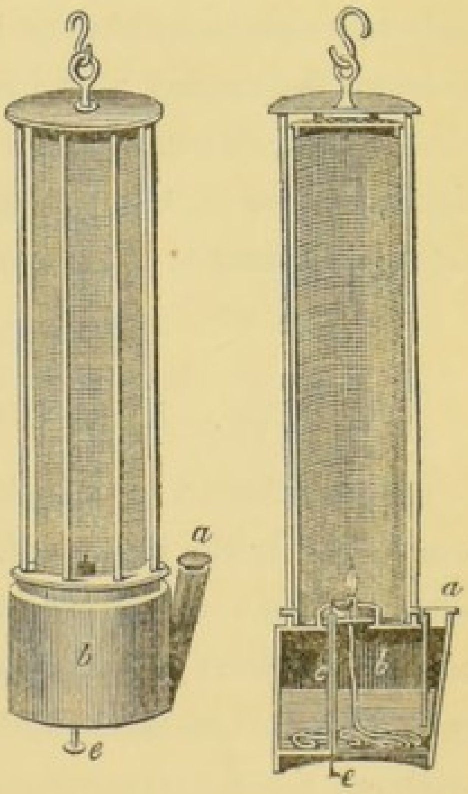
The phenomena are more complex which arise when combustible substances are extinguished by the abstraction of the temperature requisite for their combustion. If a candle is blown out, or a burning fire is quenched by water, it is the cold current of air, or cold water, which lowers the temperature of the burning matter to such a degree that it can no longer continue burning; thus burning iron is cooled in the air, as too much heat is taken up by the nitrogen: this, too, is the case with burning coal, when placed on cold iron. Mixtures of gases, which, when ignited, burn briskly, cannot continue to support combustion if they become mixed with other gases, by means of which they become cooled down below the temperature necessary for their combination. The continuance of combustion of a mixture of gas may be also interrupted by the interposition of a metallic netting. By placing, for instance, a metallic net over a flame, (Fig. 80,) the flame does not pass through, provided it has 400 meshes to a square inch, and the wire (copper wire is generally preferred) must be from $\frac{1}{40}$th to $\frac{1}{50}$th of an inch thick. By allowing light carburetted hydrogen gas to flow from a receiver, and holding before the cock, *a*, such a kind of net, *b*, as previously described, the stream of gas passes through the meshes; it burns, when ignited, before the netting, but not behind it. From this experiment we observe that the gas which burns before the netting, where it comes in contact with it, is so cooled that it cannot communicate to the gas found on the other side of the netting the temperature necessary for the support of combustion.

Fig. 80.



This circumstance has given rise to the discovery of an important lamp (Fig. 81)—the safety lamp, which depends on the same principle. The construction of it is very simple. The flame of a common oil lamp is surrounded on all sides with a netting of

Fig. 81.



copper wire, so that the air can only reach the flame by passing through the meshes. Oil may be introduced into the reservoir, *b*, through the opening, *a*, and the wick is regulated by means of a wire, *e*. By allowing inflammable gas to flow on the flame, the gas only ignites within the netting; on extinguishing the flame the combustion ceases. By the combination of carbon with hydrogen, light carburetted hydrogen gas is generated, and is sometimes disengaged in such large quantities, that at last it forms a detonating mixture on the admission of atmospheric air. If this is ignited by the lamp of a workman, the expansion of the air becomes so violent that the labourers are often much injured. In such mines the safety lamp is recommended to be used; of its construction the present plan and etching may serve to convey an idea. Should a person approach with a safety lamp a mine charged with this detonating mixture, the explosion only takes place within the lamp; the ignition cannot pass through the meshes to the external air, and the miners are thus preserved unhurt. The mine may be freed from this dangerous gas by the admission into its deepest parts of an artificial current of fresh atmospheric air.

XXV.—PHENOMENA OF FLAME.

When iron burns, separate luminous parts are alone formed, whilst neither the iron itself, nor the oxidized iron, (notwithstanding a strong white heat is established near the point of combustion,) becomes gaseous. Ignited hydrogen gas, on the other hand, flowing from a tube, *a*, (Fig. 82,) produces a flame consisting of two parts; the inner one, *b*,

Fig. 82.

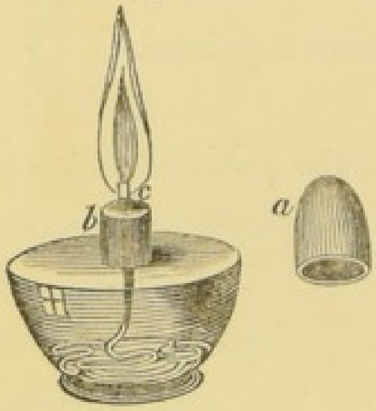
is formed by the stream of hydrogen gas; the outer one, *c*, which surrounds the inner part as if by a mantle, and in which the oxygen of the air combines with the hydrogen gas, consists of heated vapour and nitrogen gas. The current of air arising from the ascending power of heated gases regulates the form of the flame.

In igniting a piece of phosphorus, at the point at which it kindles, so much heat is evolved that the phosphorus adjacent to this point assumes the form of gas, and a flame results, whose internal part is gaseous phosphorus, and its luminous envelope is phosphoric acid. The same process of combustion observed in phosphorus, also takes place in common lamps, in which wicks are employed: a wick serves merely for the purpose of continually supplying the flame with fresh quantities of inflammable fluid. By placing in a fluid two glass rods (Fig. 83) in such a position that they lie contiguous to each other below, but separated above, we perceive that the fluid ascends between the two rods as high as *b*. A wick is nothing more than a collection of cotton threads placed contiguous to each other, between which the fluid rises by attraction, as was shown in the instance of the glass rods. By placing such a wick, *c*, with one end in a vessel, *a*, which contains a fluid, either water, oil, or alcohol, and allowing the other end to hang lower on the outside than the surface of the liquid, it rises by one end, and flows off

Fig. 83.

through the other, till the vessel be completely emptied. Of the processes of combustion, that by means of alcohol is the most simple; it is effected in the common spirit-lamp, which is employed for many experiments. (Fig. 84.) The wick, which passes through the nozzle, *c*, which is firmly fixed in the upper part, *b*, of the glass lamp, attracts the fluid even to its extremity. Alcohol, when kindled, generates so much heat, that the upper part of the wick is entirely surrounded by gaseous alcohol, which, combining with the oxygen of the air, forms carbonic acid and vapour of water. By introducing into the flame a thin iron wire it remains in the centre, where the alcohol is found in a gaseous state, of an entirely dark colour, but in the hot envelope, in which the process of combustion takes place, it becomes white from the heat. As alcohol easily evaporates, the flame is readily extinguished by placing on it the cap, *a*, which is air-tight.

Fig. 84.



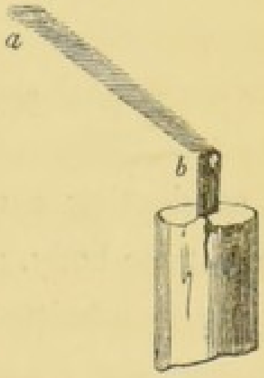
Much less simple, however, are the flames in which the inflammable substances, before they are consumed, undergo a species of decomposition, and in which one substance is consumed before the other; this last case occurs to all our common luminous flames. In gas light, for instance, the two component parts of carburetted hydrogen combine, but not at the same moment, with the oxygen of the atmosphere; but hydrogen combines sooner than the carbon: carbon separates, which becomes heated to whiteness by means of the temperature generated by the combustion of hydrogen, and is consumed as soon as more air be admitted. A similar decomposition takes place in the flames of our candles. (Fig. 85.) The centre of a flame is occupied either by a stream of gas flowing from an opening, or by a substance, *b*, raised by the wick, and rendered gaseous by the heat arising from the combustion. This is surrounded by the luminous part, *c*, as by a mantle, and the luminous part is again enveloped in a similar manner, by a thin slightly luminous covering, *e*, in which the carbon separating in the luminous part combines with the oxygen of the air, forming carbonic acid.

Fig. 85.

Underneath the flame, at *i*, the temperature is somewhat lowered by the stream of cold air always flowing on it, from whence arises its blue colour, as described in carbonic oxide gas.

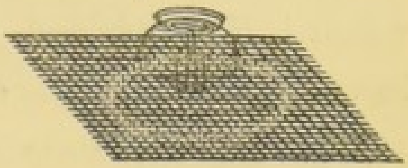
After blowing out a flame, (Fig. 86,) for instance, a wax light, inflammable varieties of gas arise immediately from the wick, which may be rekindled at some distance from the wick itself, as from *a* to *b*.

Fig. 86.



By placing over a flame a metallic netting, through which it does not pass, we may more conveniently observe the internal space, and the inflammable gases arising. (Fig. 87.)

Fig. 87.



By introducing a thin iron wire into a flame it is scarcely heated in the centre of the flame, in the luminous part but very slightly; but in the outer envelope, *e*, in which a high temperature is produced by the combustion of carbon, it is intensely. By holding a knife blade, or any other cold body in the luminous part, *e*, of the flame, it is covered with carbon, as it abstracts from the carbon, which separates in the luminous part, the temperature necessary for the support of combustion. By placing the same cold body in a flame which gives off no light, for instance, in a spirit flame, it is by no means stained. The luminous property of a flame depends on this circumstance; there is separated in the body of the flame itself, carbon, which becomes of a white heat, and is then consumed.

XXVI.—LAMP-BLACK.

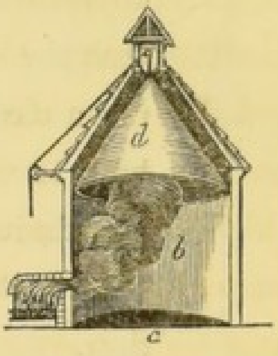
By conducting combustion in such a manner, that to a combustible body, producing a brilliant light, only as much oxygen is admitted, as to allow of only hydrogen, or only hydrogen and a part of carbon, being consumed, we obtain a larger quantity of carbon, which separates.

This operation is conducted on a large scale; the carbon which is thus obtained, and which is used as a black colouring matter, is termed lamp-black.

Resinous substances are selected for combustion, for instance, rosin or pitch, which is heated in a caldron, *a*, (Fig. 88,) and ignited, but little air being admitted.

From the caldron, an opening leads into a round chamber, the walls of which, *b*, (Fig. 88,) are covered with skins, which above is provided with an apparatus resembling a roof, not unlike an inverted cone, *d*, formed of coarse linen. The carbon that separates is driven by the current of air into this chamber, and settles partly on the floor, partly on the rough skins, and partly on the linen. The inverted cone can be lowered by means of a pulley, and sweeps off at the same time the lamp-black from the skins. Besides this apparatus, there are several others which may be employed for the preparation of finely divided carbon, which are prepared on the same principle.

Fig. 88.



It may also be obtained, by placing a lamp in such a manner, that but little air can be admitted, and the flame projects against a cover, on which the black settles, which may be removed from time to time. Lamp-black, as well as finely divided carbon, contains some foreign substances, arising from incomplete combustion.

XXVII.—DISTILLATION AND CARBONIZATION OF WOOD.

Besides the separation of carbon, another phenomenon occurs in our luminous flames; before a combustible body is consumed, it undergoes a decomposing distillation. By igniting, for instance, a piece of wood, (Fig. 89,) by means of the heat arising from combustion, the wood adjacent to the burning part is so strongly warmed, that the volatile parts are expelled from it, forming a clear envelope around the non-volatile carbon, to which the oxygen of the atmosphere can be admitted, whereby it also can be consumed, before the volatile ingredients suffer combustion.

Fig. 89.

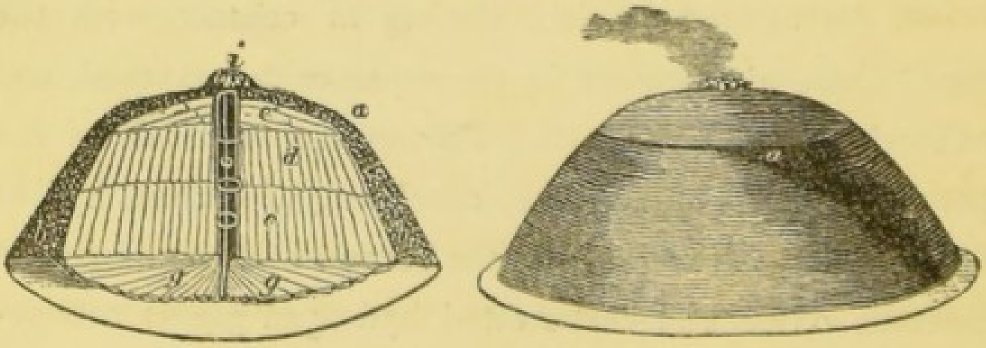
The best means of observing these phenomena, is to submit to distillation in a retort, combustible substances. Alcohol and ether pass over unchanged; in these no further decomposition takes place, before actual combustion. Wood, coals, oil, and other substances of this kind undergo a change in their constitution, and furnish various products, according to the temperature at which they are distilled; as the three ingredients, composing these bodies, re-unite, forming new combinations, which were not previously contained in them. As the changes they undergo are of the greatest importance for practical use, we will briefly describe what admits of a theoretical explanation.

By submitting wood to distillation in a retort, the gaseous or fluid substances that arise from it, may be collected in a receiver; at first, water condenses, a white smoke fills the vessels, and gases are disengaged, mixed with vapour: a yellowish-coloured oil condenses also in the receiver. The water and oil gradually become brown, and the latter black, and thickened, sinking in the water, and at last hardens in the neck of the retort in the state of pitch. Decomposition is complete when the retort is heated to redness. In the commencement of the operation, the gas consists of carbonic acid, afterwards of carbonic oxide gas; at the same time also olefiant gas, but principally light carburetted hydrogen gas, are disengaged. In the receiver are found two fluids; one of a watery nature, is water, in which acetic acid and empyreumatic oil are principally suspended, and the other is oleaginous, consisting of empyreumatic oil and resin. In the retort remains charcoal. In the great majority of different varieties of wood or straw, which are dried merely by the air, and therefore contain about 25 per cent. of water, not chemically combined, the quantity of charcoal is found, after a rapid distillation, to be never less than 12, nor above 17 per cent.; after a slow operation however, at a low temperature, it is never less than 24, nor above 28 per cent. This difference in the quantity of charcoal depends on the vapour of water passing over the heated charcoal, and becoming decomposed, whence carbonic oxide and hydrogen gases are formed. The wood, touching the sides of the retort, becomes carbonized; this charcoal is heated: then the wood in the centre of the mass is so strongly heated, that water is still disengaged, which, coming in contact with the heated charcoal, becomes in consequence decomposed, and is absorbed by the charcoal. During the first half of the operation, combinations form, consisting of carbon, hydrogen, and oxygen, and during the second half, combinations (carbonic oxide and carburetted hydrogen gases) consisting of only two simple bodies. In the flame produced by wood, in which the same process takes place as already described, empyreumatic oil and resin furnish the carbon, which supplies the flame with its luminous property.

By consuming charcoal, a residue is found, differing, according to varieties of wood, both in its quantity, as well as the chemical nature of its ingredients. Oak-wood leaves $\frac{2}{5}$ per cent.; box-wood $\frac{1}{2}$ per cent. of ashes; though this quantity is very inconsiderable, it is still very important, on account of the ingredients of their ashes.

After kindling a long wooden match and plunging it, as the flame advances, into a tube, which is closed at its farther extremity, the charcoal, from which the air is prevented admission, is not consumed: this is wood carbonized on a small scale. By holding the wooden match with its burning part upwards, and depressing the glass tube with the extremity closed, in proportion as the flame spreads downwards, the charcoal is not consumed: this is the principle of carbonizing wood on a large scale, which is effected by placing logs of wood perpendicularly, as well as horizontally to each other, so as to form a large circular mound, (Fig. 90,) leaving, however, a canal, *o*, in the

Fig. 90.



centre. The whole exterior is covered with turf or wet cinders, or sand, *a*, *b*: at the foot of the mound a number of holes, communicating with the central canal, are formed. Inflammable substances in a state of ignition are introduced into the canal, and combustion spreads throughout, particularly on the upper part, from *a* to *a*, where the layer of ashes is not so thick as on the sides. Through these ashes the current of warm gases takes place. Should the wood around the canal bear the appearance of being carbonized, those spots should be covered with a thicker layer of cinders, that the current of air be directed to another course. Should the smoke which arises become clearer, or a blue flame appear, then the whole upper part receives a double layer of cinders, which are well trodden down, and all the openings at the under part are closed. The operation being terminated, the mound is thickly covered, that no air be allowed access, and the logs cool in a few days. Wood furnishes about $\frac{7}{10}$ of its quantity as charcoal, when the process is well conducted: generally we may reckon on 61 to 65 parts of charcoal from 100 parts of wood, in volume; or by weight, 24 parts. After distillation in closed vessels, 100 parts of wood furnish 82 parts by volume, which, as this charcoal is very light, amount to but 23 parts by weight.

XXVIII.—DISTILLATION OF COAL. GAS-LIGHT.

By submitting coal, in a similar manner as wood, to distillation, a residue remains, as well as two fluids and a mixture of inflammable gases. The residue is termed, in common language, coke; it differs according to the different composition of coal, varying in all the intermediate degrees, from a thick and solid mass, to a highly porous and spongy substance. Coal may be easily analyzed, by reducing it to a fine powder, and heating in a retort. The coal from the Leopoldine mine leaves 61·5 per cent. of coke, containing 2·88 of ashes, which retains its form of powder, and is commonly called pulverulent coke. The coal from the royal mine leaves 69·3 per cent. coke, containing 0·63 of ashes; this powder coalesces into a compact mass; such is termed coalescing or vitreous coke. The coal obtained from Newcastle, furnishing 70·0 per cent. of coke, and containing 0·863 ashes, fuses together, swells up, and on being removed from the crucible, it is found to retain its form: this is termed caking coke.

It is not, as its composition proves, the different proportion of coke to the other two ingredients, from whence this unequal composition of coal depends, but on the proportion of hydrogen and oxygen to each other. Thus they are found to be,

In the coke from the Leopoldine mine = 2·85 : 21·07.
In that from the Royal mine . . = 3·22 : 17·89.
In that from Newcastle . . . = 3·23 : 11·78.
In the Cannel coke . . . . = 5·45 : 19·72.

The greater the preponderance of hydrogen is, the lighter the coke fuses. The fluid and gaseous products of distillation are influenced accordingly. Should oxygen of hydrogen predominate, one or the other produces the effect on the coal. In the coal from the Leopoldine mine, containing 76·08 parts, and leaving 57·62 coke after distillation, it is principally the oxygen; whilst in the cannel coal, which contains 74·83, and leaves 51·32 coke after distillation, it is principally the hydrogen, which combines with a portion of carbon, which is lost during the distillation.

The liquid product of distillation consists of two fluids, of which one is water containing some carbonate and sulphite of ammonia in solution, and the other is pitch. Pitch contains a resin, a volatile oil, and some naphthaline. The oil may be separated from the water by distillation, and may be employed for dissolving caoutchouc.

Though the gaseous products of distillation of wood are of little importance, those of coal are become of the utmost consequence. The gas procured from coals, in which hydrogen principally prevails, contains olefiant gas, and burns with such a brilliant flame, that it surpasses all other modes of lighting. As this gas is prepared in large quantities in most European capitals, its formation will not be uninteresting. The gaseous mixture procured from the distillation of coals, consists principally of light carburetted hydrogen, olefiant and hydrogen gases; it is variously composed, according to the nature and quality of the coals, as well as the temperature at which the distillation is conducted. That temperature exerts a great influence has already been described from carburetted hydrogen and olefiant gases becoming decomposed, when conducted through heated tubes, into carbon and hydrogen gas.

Gas of the best quality and in the greatest quantity is obtained from cannel coal, as might be expected from its composition: 1 pound furnishing 4½ cubic feet of gas. During distillation, conducted on a large scale, and continued several hours, the mixture of gas thus obtained consists, at the commencement of the operation, of

13 parts of olefiant gas,
82·5 — of light carburetted hydrogen gas,
3·2 — of carbonic oxide gas,
·0 — of hydrogen gas,
1·3 — of azote gas,

and has a specific weight of 0·650.

The gas which is obtained after five hours' distillation, consists of

7 parts olefiant gas,
56 — light carburetted hydrogen gas,
11 — carbonic oxide gas,
21·3 — hydrogen gas,
4·7 — nitrogen,

and has a specific weight of 0·500.

After ten hours' operation it contains,

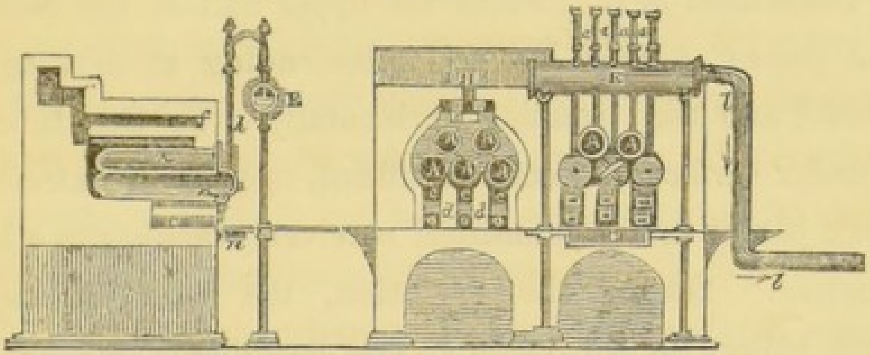
0 parts olefiant gas,
20 — light carburetted hydrogen gas,
10 — carbonic oxide gas,
60 — hydrogen gas,
10 — azote gas,

and has a specific weight of 0·345.

In olefiant gas should be included empyreumatic oil, one part of which is not condensed; it remains suspended in the gas, contributing much to the beauty of the flame. Sulphuretted hydrogen gas, from which the gas which is employed for the purpose of giving light must be carefully freed, is formed from pyrites, found mixed very often with coals.

According to the demand for the consumption of gas, several furnaces are built near each other. In each furnace five iron cylinders, *a*, (Fig. 91,) commonly called

Fig. 91.

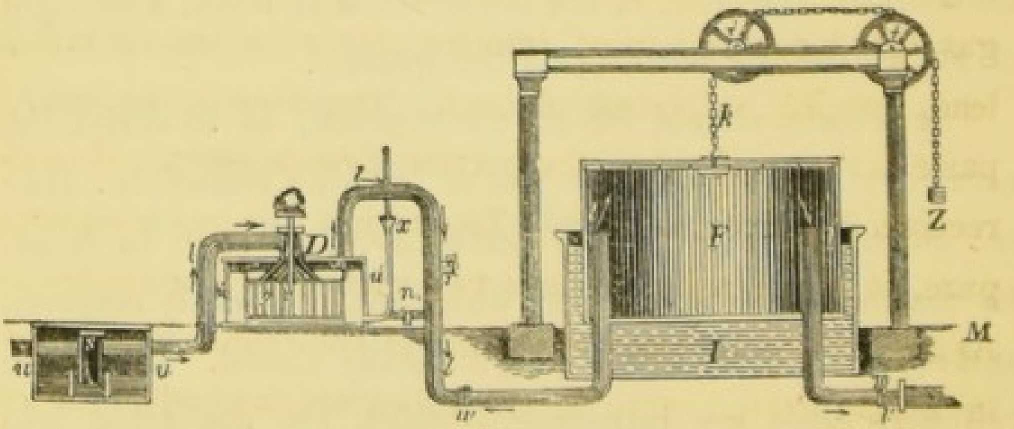


retorts, are placed so near each other, that they become intensely heated from the fire burning in the grate *c*; *o* is the ash-pit, and *f*, *e*, *h*, are constructed to admit a draught of air, to the fire burning on the grate *c*.

The retorts should be so constructed, as to derive the necessary heat at the least loss of burning materials: they are closed at their further extremity, and open in front. By means of an iron cover, which may be easily removed and replaced, they may be hermetically closed. Into these cylinders coals are introduced, which are converted into coke when the gas is all expelled. The cylinders are then opened, and the red-hot coke is raked out, which falls into the vaulted chamber under the grate; by which means the workmen do not suffer any inconvenience from the heat.

The gas which is given off, passes through the iron tube, *h i*, at the further extremity of the retorts, into the common canal, E, which is half filled with fluid. The tube passes under the surface of the fluid, that each cylinder may be isolated, and may be opened without the gas escaping from the apparatus through the open cylinder. Into this tube the gaseous substances that are given off enter, of which such as are fluid at a common temperature are condensed in it. From the upper half of the canal, a tube passes, *l*, (see Fig. 92,) descending at first to the ground, and then running horizontally. To this tube, at its under surface, a second is affixed, open at its extremity; which passes into a cylindrical receiver, standing in a large reservoir. During the operation, the fluid substances which collect in the canal *e*, are continually flowing into the tube *s*, (Fig. 92,) and from thence into the reservoir,

Fig. 92.



from whence from time to time they are removed. The gas which by this apparatus is entirely secluded from the atmospheric air, passes through the horizontal tube into the purifying apparatus, D: this consists of a large cylindrical vessel, and to its cover a funnel is affixed. Through the extremity of this a piece of wood passes, moved by a wheel and handle, and to this a frame is fixed with transverse rods. This vessel is more than half filled with lime dissolved in water. By turning the wheel, the rod and frame revolve on its axis; the lime that had sunk to the bottom is then stirred up, and floats in the fluid (Fig. 92). The gas flows through the tube *l*, and its bubbles rising through the fluid, come into numerous points of contact with the lime, which is the express object of this operation, for the lime combining with the sulphuretted hydrogen, entirely removes all its unpleasant smell. With a solution of acetate of lead, it can be easily proved whether the gas still retains any sulphuretted hydrogen.

To the tube *l*, another is affixed with a cock, *y*, and this is plunged into a solution of acetate of lead; on the cock being opened, the gas passes through the solution: the slightest trace of sulphuretted hydrogen, mixed with the gas, produces the most intense colour in the acetate of lead, forming sulphuret of lead. The lime in the form of paste is renewed, when the portion already contained in the receiver has become inert. To procure this gas completely pure, it is necessary to have two such purifying apparatus. As the gas compresses the fluid in the funnel, it is found in a compressed state in the tubes which conduct to this apparatus; and the pressure corresponds to that of a water-column, whose height amounts to as much as the fluid stands higher within, than without the tube. To prevent this pressure, in some gas manufactories, a similar large reservoir, as D, is employed to purify the gas, which is filled with hay moistened with milk of lime ; the gas enters underneath, and passes out above, through another tube. When conducted through two similar vessels, it is completely freed from all sulphuretted hydrogen gas.

From this vessel the gas passes into the reservoir F, that is formed of strong plates of iron riveted together, which stands in a large cylindrical tun, almost filled to the brim with water. The gasometer hangs from a chain, *k*, which passes over two wheels, *r*, *r*, at the other end of which are suspended weights. When the operation commences, the cock, *m*, is closed, and that at *w* is opened; the gasometer then stands on the ground I. The more gas that is given off, the more the gasometer rises ; and the chain escapes to the other side of the wheel, and prevents, as that side is the heaviest, the gas from becoming compressed by the weight of the gasometer, by rendering it equivalent to the weight it has acquired by rising from the fluid. The pressure on the inside of the gasometer may also be more accurately regulated by means of the weight suspended to the chain at Z.

When as much gas is collected as is necessary, the cock, *w*, is closed : when the gas is required for use, so much of the weight at Z is removed, that the gas may be compressed by the weight of the gasometer itself. The pressure employed must be so regulated, that the water to a given quantity should stand higher without than within the gasometer. By opening the cock, *m*, the gas flows out to the different parts requiring a supply.

By submitting fatty oils (oil of olives or oil of poppies) to distillation in a retort, at a temperature at which they enter into ebullition, but little carbon remains. The fluid that passes over consists of fatty acids, and other combinations: of gas, however, but little is given off. By allowing oils to fall, drop by drop, into a red-hot vessel, from 1 volume of oil, 750 volumes of gas are obtained, containing about 30 per cent. of olefiant gas, seldom 40 per cent., and commonly only from 18 to 25. The specific weight of this gas differs, according to this proportion; it is commonly 0·8 to 0·9, though it may be procured from 0·674 to 1·110.

This gas is also well adapted for affording light; for the preparation of it is cheap, and bad oils may be employed: the greater quantity of olefiant gas that it contains, is the reason why it furnishes a more beautiful flame, and gives off $2\frac{1}{2}$ times more light than coal gas.

For the preparation of this gas an iron retort is employed, a third part of which is filled with coke or bricks, to present to the oil more points of contact. The retort, heated to redness in a stove, is connected with an oil reservoir, by means of a tube furnished with a cock; by regulating which, a larger or smaller stream of oil is allowed to flow into the retort. From the retort, in the same manner as in the formation of coal gas, a tube passes into the upper part of the oil reservoir, descending under the surface of the fluid, so that the oil that is not decomposed into a gaseous body, may be therein condensed and again transferred into the hot cylinder. The gas thus formed, without requiring any further purification, is conducted, by means of a tube arising from the extremity of the retort, into the gasometer. This is the gas which has been introduced and compressed into very strong vessels, for the purpose of being employed as a portable gas-light.

XXIX.—ARTIFICIAL CURRENT OF AIR.

The admission of cold air, or an insufficient quantity of air to a burning light, disturbs regular and complete combustion; carbon separates unconsumed; the flame burns dull, and yields an unequal light. To counteract this effect, the current of air must be so regulated, that to a certain quantity of a substance in combustion a given quantity of air be admitted; this object is attained by surrounding the combustible body with a canal (chimney) of a determinate breadth and height. Such an erection is at the same time necessary to procure a very high temperature, by means of the rapid admission of air to combustible bodies; for this purpose it is necessary to consume, in the shortest time possible, in the smallest chamber, well protected from cooling, the largest quantity of combustible substances which are likely to furnish the greatest heat.

We cannot here allow ourselves to explain the law which regulates the admission of cold air into a perpendicular canal, in which the gases which ascend, become warmer and more elastic, but must be content to mention this law as it commonly exists.

The external air rushes into a chimney with the same rapidity with which a body falls, after it has made some way, which amounts to the difference between a column of air dilated by the high temperature in the chimney, (if reduced to the temperature of the external air,) and the length of the chimney; or what is the same thing, to the difference of the length of a column of air of the temperature of the external air, which fills the chimney.

If the chimney is 27½ feet high, and the temperature of the air within it amounts to 257°, and the external air be cooled down to 32°; the column of air of 27½ feet, cooled to 32°, would only be equal to 20 feet in height; therefore the air would rush into the chimney with the rapidity with which a body falls from a height of $27\cdot5 - 20 = 7\frac{1}{2}$ feet, or with the velocity of 21·65 feet in a second.

From these dimensions of a chimney, we may easily calculate the quantity of air that rushes in at a second: and if the width of the chimney amounts to 2 square feet, then in each second 42·3 cubic feet of air ascend. From this calculation, mentioned merely to give a general idea of a draught of air, and the method of regulating it, it may be seen, that to produce a great heat in a blast furnace, depends on the size of the grate, as well as on the length and width of the chimney, and on the temperature of the air contained therein: the same case applies to our lamps with a regulated draught. Many other circumstances may occur, for instance, the specific weight of gases formed during combustion, that it is almost impossible to determine by calculation the effect we wish to attain.

From different experiments, we are now acquainted with the material best adapted for combustion, as well as the proportions suited for the construction of furnaces, as well as the preparation of lamps; so that if locality, or any peculiar circumstances demand any alterations, they can easily be made, without incurring the risk of materially injuring the object in view.

Combustion in spirit or oil lamps with a double current of air, in furnaces with a free or forced current, is so important a subject, that a short description will be desirable.

XXX.—SPIRIT AND OIL LAMPS WITH A DOUBLE CURRENT OF AIR.

The spirit lamp is among the most indispensable instruments to chemists, as many experiments cannot be performed accurately without it. The wick, *c*, can be raised or lowered at will, by means of a cogged wheel, *e*, and bar, *g*, (Fig. 93,) between two cylinders, connected below by means of an horizontal plate. To the bar, *g*, a transverse bar is affixed underneath, and to this a ring, around which the wick, *c c*, is placed, and in order that the transverse bar may be raised or depressed, the reservoir, *b*, is employed. This is connected with the spirit reservoir, *a a*, (Fig. 94,) by the

Fig. 93.

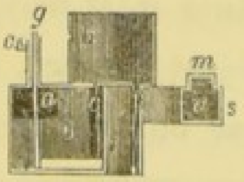
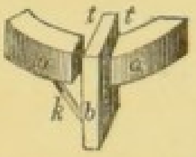
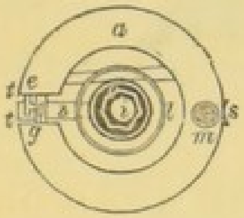


Fig. 94.



medium of the tube, *k*; therefore between *a a*, and *b*, a small space is interposed; and although *a* is soldered to *a*, still no other communication is kept up between them but through *k*. This caution is recommended to prevent the spirit in the reservoir becoming ignited, as a violent explosion would otherwise ensue; when a part of the spirit is consumed, the atmospheric air would enter the reservoir, and unite with the vapour of alcohol (Fig. 95). *l* is the chimney or glass canal. In proportion as the wick is raised or depressed, so the atmospheric air conducts more or less spirit: the current of air is established laterally on the outside, to gain access to the wick, and on the inner side through the centre of the canal. The wick should be trimmed with caution, and never retain a carbonized edge; *m* is an opening for the admission of spirit, and *s* is a small piece of glass to observe how much spirit remains.

Fig. 95.



The chemist ought to have two lamps of similar construction; one (Fig. 96), intended for the purpose of fusion of bodies: it ought to have all its parts formed in a light and thin manner, in order to abstract as little heat as possible: the other, for more general purposes, should be more strongly constructed.

As combustion takes place in this manner in a spirit lamp, so also it is effected in one supplied with oil, in the common shadowless lamps. By the canal *e*, the oil is con-

Fig. 96.

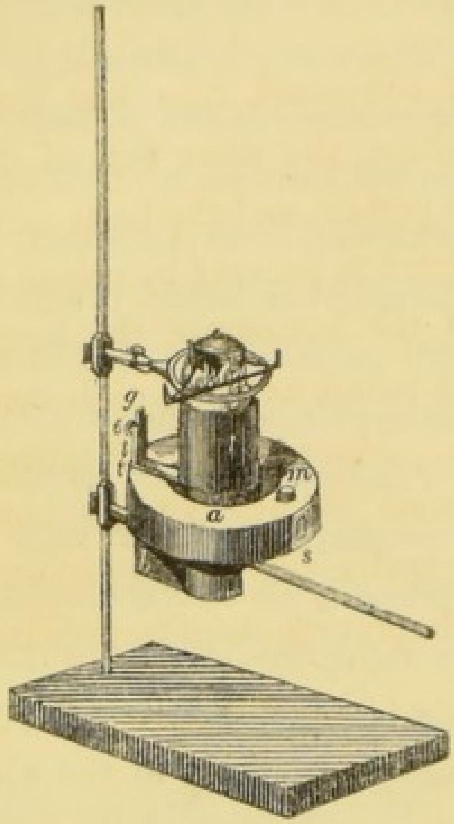
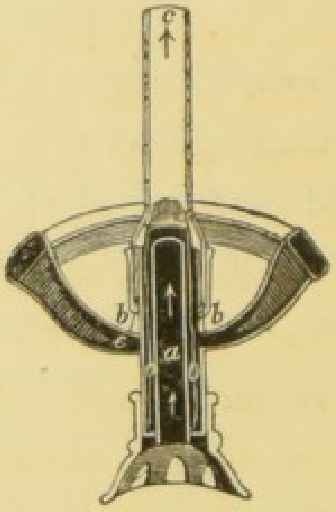


Fig. 97.



ducted from the reservoir, *l*, which is placed as high as possible, to the wick, *o*, which may be raised or lowered by means of an apparatus underneath the flame, producing no shade. The air is admitted through the apertures, *i*, into the inner canal, *a*, and through *b b*, to the outer side of the wick (Fig. 97).

By means of the length and diameter of the cylindrical glass, *c*, which is placed around the flame, and through which the warm gases rise in the air, is the draught regulated. How this little apparatus assists in the process of combustion may be easily seen, on removing the cylinder, and closing some of the apertures. In consequence of oil leaving a residuum in distillation, carbon gradually settles on the wick; it must therefore be from time to time removed.

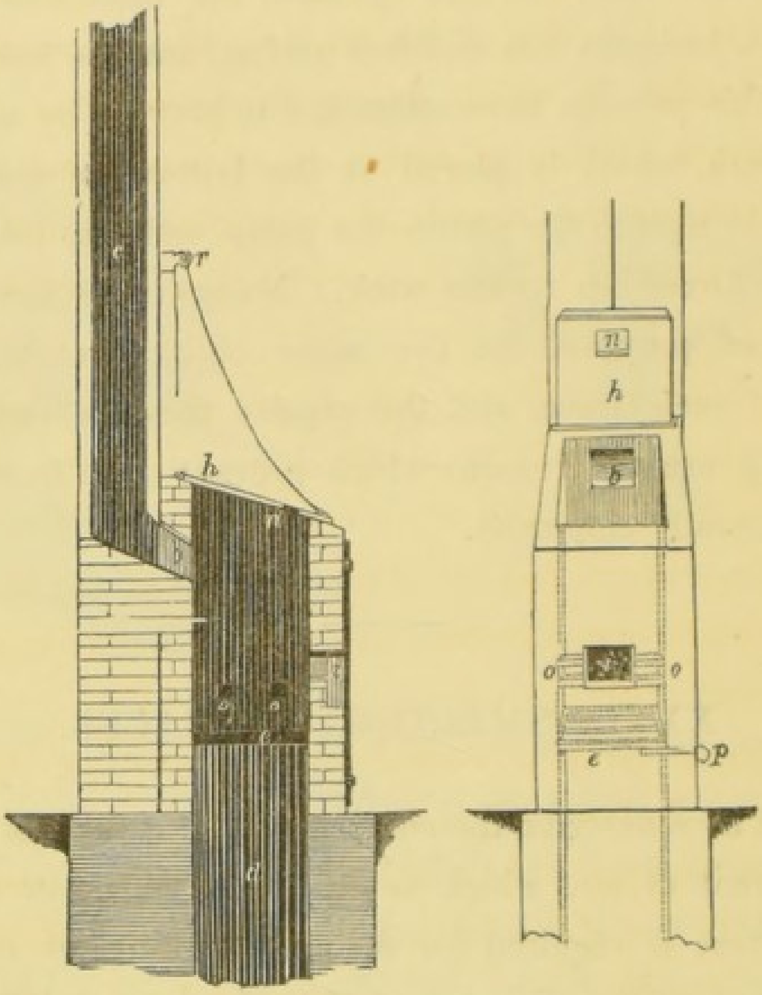
The oil, as it continues to be consumed, rises less high towards the wick, so that ignition, the more the oil diminishes, becomes less and less perfect, and the light more dull. This persons have attempted to prevent by means of clock-work, which is placed at the bottom of the lamp, putting in motion the piston of a pump, and thus oil is continually forced up to the wick. Many other inventions have been proposed for the same object, but the high prices of such lamps, and the repairs they are constantly requiring, are the reasons which prevent them from being very generally employed.

XXXI.—SMELTING FURNACES.

We will here describe the construction of a furnace with a free current of air, which is employed whenever a high temperature is required for fusing, distilling, or roasting (heating in a free admission of air) substances. Whenever such a furnace is proposed to be built, the ground should be excavated and vaulted over, in order that the ashes may fall underneath, from whence also arises the current of air.

The smelting chamber may be either circular or square. For fusing in a crucible, a loss of combustible matter is experienced in a square form; for roasting or distilling however it is preferred. The section of this chamber is a square, of which each of its sides is 1½ feet long, and underneath this chamber is placed a grating, *e*, consisting of cast iron bars connected together, which turns on a hinge, *p*.

Fig. 98.

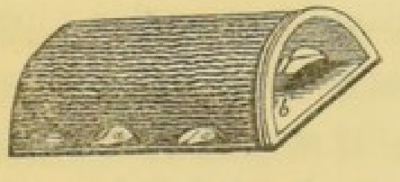


Underneath this grating a canal, *d*, passes of the same dimensions, though 2 feet wider, terminating in the vaulted chamber. (Fig. 98.) Over the upper part of the furnace is placed a sheet, *h*, of a double plate of iron, coated on the inside with fire-proof clay ; by means of a chain and roller, *r*, this can be raised, when it is necessary to throw in fuel, or to rake the fire. In this plate is a small opening, *n*, which may also be covered with sheet-iron, and this serves for the purpose of observing the progress of the operation. From the smelting chamber the hot gases are conveyed through a canal, *b*, called the fox, into the chimney, *c*, whose section is also square. The proportions of each delineation, which represents the section of the furnace, were correctly taken from a furnace, in which, during the preparation of potassium from a mixture of carbonate of potash and charcoal, in the common iron vessels, the potassium distilled over in 20 to 30 minutes. The chimney of this furnace was more than 50 feet high.

The dimensions of the fox, *b*, are generally given too large, consequently it is usually lessened by the introduction of a stone or brick, when required either on account of a difference of the fuel, or of the progress of the operation. The chimney may also be provided with a slide to regulate the current of air.

When the furnace is employed for smelting, then the opening, *i*, is closed with a stone, and on the grating a stone is placed to support the crucible. If we wish to heat a substance with free access of air, a muffle is employed (Fig. 99), a vessel formed of fire-proof clay, resembling in form a baker's oven; this is placed on the bars, *o*, so that the mouth of the muffle may correspond with the opening, *i*. (Fig. 98.) The substance to be heated is placed in a small saucer, *b*, in the muffle; the atmospheric air enters into the heated muffle through the apertures, *a*, three of which are formed on either side; from thence it passes out. By constantly stirring the substance the action of the air is much increased. If we wish to

Fig. 99.

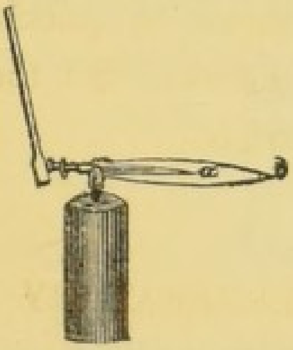


employ the furnace for experiments on distillation, or for the preparation, for instance, of potassium or zinc; the retort is laid on the bars, and the neck communicates with the opening, *i*. In these operations it is of material consequence that the ashes should fall into the vaulted chamber underneath, as the heat spreads less, and the workmen are not much inconvenienced. Should, however, the progress of the operation require that the heat should be quickly diminished, the bar, *p*, (Fig. 98) is withdrawn, and the grating falls, as well as the burning materials.

XXXII.—BLOW-PIPE AND REVERBERATORY FURNACE.

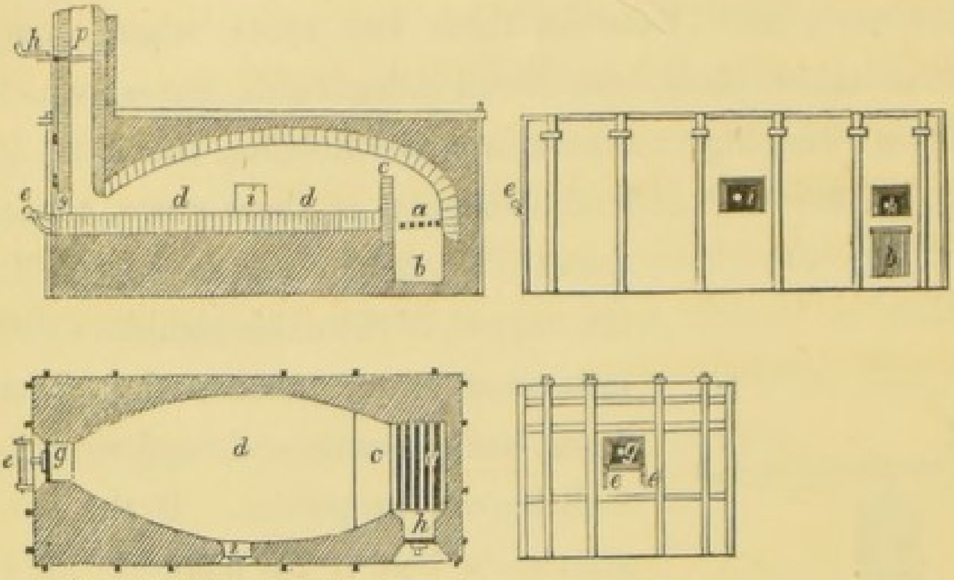
For the purposes of analysis, it is very important to be able to raise rapidly the temperature of small quantities of substances to a very intense degree; for this purpose we make use of a blow-pipe, through which a stream of air is forced upon the flame. By this instrument many different analyses are effected, which tend to render us acquainted with the chemical properties of various substances; the temperature thus obtained may reach a white heat. In this way we may examine substances to discover whether they are volatile or not, what are the products of their decomposition, or whether they admit of fusion, and what phenomena they furnish when fused with other substances: substances may be oxidized or deoxidized by means of the blow-pipe; the deoxidizing effect depends on the part of the flame into which the substance is protruded. A double combustion takes place in the flame, acted on by a blow-pipe; in the interior, by means of the air which is blown on it, and on the exterior by means of the external atmospheric air. Between these two spots, where combustion takes place, are found inflammable gases, which produce a very high temperature. By holding, therefore, an oxide (either that of lead or copper) in these gases, consequently between *a* and *b*, (Fig. 100) the oxygen of the oxide combines with inflammable substances; the metal fuses, and becomes endowed with its well-known properties. If the substances be held in the flame beyond *b*, they become very strongly heated, and combine, if they can be oxidized, with the oxygen of the air, which comes in contact with them.

Fig. 100.



The phenomena which are produced in a blow-pipe on a small scale, may also on a larger be observed in reverberatory furnaces. In proportion as the flame of the combustible substance contains still inflammable matters, or an excess of oxygen gas, so it produces a deoxidizing or an oxidizing effect. This kind of furnace admits of large masses being treated most conveniently; it is absolutely necessary for many chemical operations prepared in large quantities. On the grating, *a*, (Fig. 101) the combustible matter is introduced through the opening, *h*, to which admission of air is allowed through the aperture, *b*. The varieties of gas arising from this combustion can only escape by means of the chimney, *p;* they are, therefore, compelled to pass over the floor of the furnace, *d, d*. The fire-chamber is separated by the smelting chamber, *d, d,* by means of a

Fig. 101.



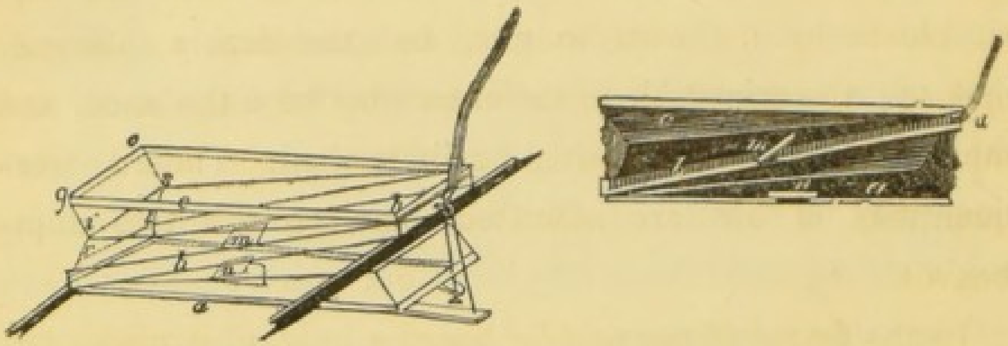
number of stones commonly called the bridge, *c*. By means of the slide, *h,* the chimney may be more or less closed, and thus the draught is regulated. On the floor, *d, d,* are introduced substances which we wish to expose to the fire through the opening, *i; g* is an aperture, through which a bar may be pushed into the furnace, which is easily moved by means of a roller, and thus the mass is often stirred up, and at the termination of the operation is removed. When the process commences, the apertures, *i, h, g,* are closed, and these are only opened to admit new, or to remove the consumed fuel. If the furnace is built to correspond with the dimensions thus given, it may be employed for heating to redness, combinations which may act on each other; thus for the preparation of soda, and principally for the roasting of ores (by which operation the combination of sulphur and arsenic with oxygen of the air is the principal object attained), it is found to be of the greatest importance.

Should we wish to produce a deoxidizing effect with this kind of furnace, the grate must be considerably enlarged, that more combustible substances may be introduced, and the smelting chamber should be diminished. These proportions may be so altered, that from the top of a high chimney a strong lurid flame may burst out which contains many inflammable substances.

XXXIII.—BLAST FURNACES.

To obtain a very high temperature the air is driven by means of a peculiar apparatus or machine, termed bellows, on the burning substances. As the substances to be fused are of different varieties, so also are the machines various. In common life, for instance, in smitheries, a pair of bellows is employed, which differs but little from those used in a chemical laboratory; these latter are, however, prepared with greater care, and formed of the best materials. A pair of bellows consists of three flat pieces of wood of equal size, on which depend the dimensions of the machine. The bellows used for the lamp of the glass-blower are 2 feet long and 1 broad; but for a strong smelting fire they should be from 5 to 6 feet long, and 2½ broad. The upper piece of wood, *c*, is connected with the middle piece, *b*, and this again with the lower one, *a*, by means of six thin pieces of wood; where these and the former four come in contact with each other, very thin leather is glued between them. Four of these pieces are equal, and form triangular

Fig. 102.

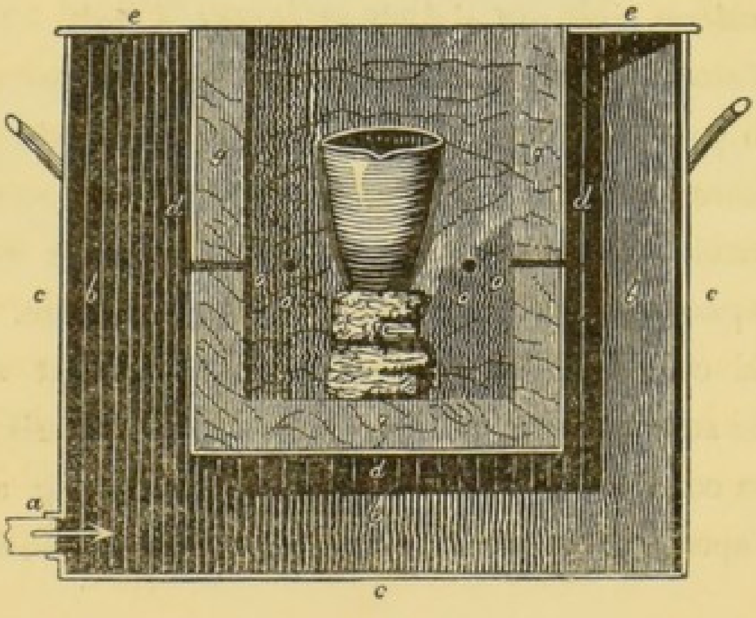


spaces, *h*, *i*, *g*; two others are also equal, and form right angles, *g*, *i*, *s*, *o*. (Fig. 102.) The angle at *i*, both in the triangles and right angles, is so obtuse that the triangular and quadrangular pieces of wood can be applied to the other pieces without coming in contact. The middle piece, *b*, and the lowest, *a*, have flaps, *n* and *m*, which open very easily, and in order to close completely are covered with cloth. The middle piece is fastened all around a frame, and is fixed at both ends to two transverse bars; this middle piece, if the bellows be small that are employed, is either attached underneath a table, or if they be large, is fixed to a permanent stand. The upper board is loaded with a weight in proportion to the quantity of air required. Underneath the under board is affixed a weight also, which draws down the board. By means of a cord which passes over the roller, *u*, communicating with a pedal in small bellows, and in large with a handle, or with a stirrup, the lower board may be lifted by the hand, or by the whole weight of the body pressing on the stirrup. By raising up the board, *a*, the air between it and *b* is found in a state of compression, the flap, *m*, is lifted, and the air rushes in between the middle and upper boards, which are raised in consequence. By allowing the under board to sink again, then the flap, *m*, closes by its own weight, and the flap, *n*, becomes opened; the atmospheric air enters between the under and middle boards. By raising again the upper board, fresh quantities of air are admitted between the two upper boards.

In the frame of the middle board a hole, *u*, is made, into which a tube is fixed, and one of copper is usually employed for this purpose. From this tube the air is conducted wherever we please, by merely lengthening the tube. Caution, however, should be observed lest the tube be bent at right angles; the wind, however, loses its force by being carried too far.

The highest temperature is found in a stove, by introducing air by a pair of bellows from different points towards the centre. This is effected in the easiest manner

Fig. 103.



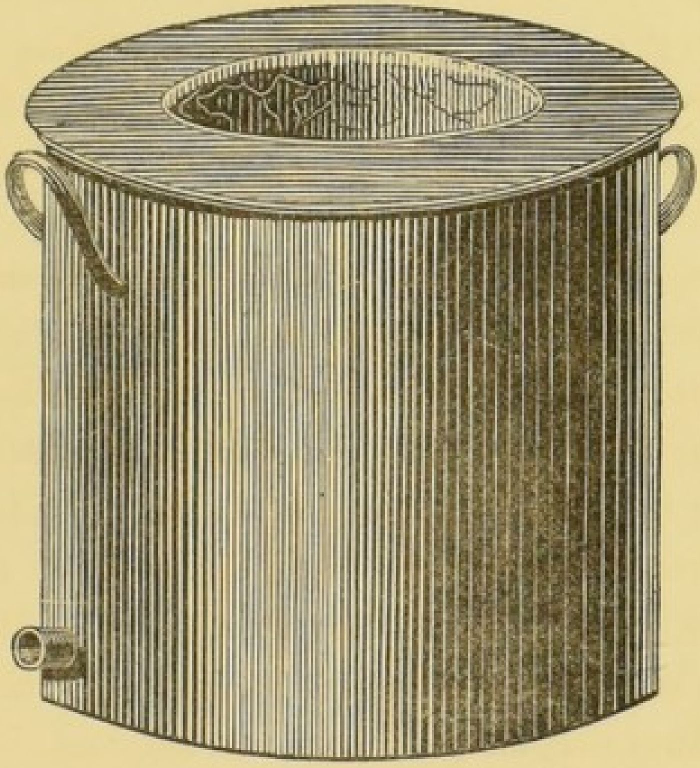
by means of two cylinders, *c, c,* and *d, d, d,* made of plate iron, (Fig. 103) each of which is provided with a bottom, and are so placed one within the other, that the inner cylinder at the bottom is as far distant from the outer one as at the side, and both are hermetically connected with each other.

Through the inner cylinder, which is coated with fire-proof clay, *g, g, g,* as well as through the coating of clay, 8 holes pass, which are made at equal distances from the bottom. In the centre either a larger or smaller crucible may be placed on a stone. Into the tube, *a,* passes another pipe, communicating with a pair of bellows; the air is then driven into the space, *b,* and passes through the openings, *d, d, d,* into the smelting chamber, producing such a heat, that if the furnace be constructed on this scale, in 20 minutes, ½ lb. of fluor spar may be reduced to a complete liquid. Iron and other substances, that are with difficulty fusible, are reduced with the greatest facility. It is important to remark, that the pieces of charcoal should be all of an uniform size, namely, about a square inch. This is easily effected, if they are cut to about the necessary size, and then passed through two sieves: the first having holes of a square inch in size, keeps back the larger pieces; the second having smaller holes allows only such as are too small to pass, and retains those of the requisite size.

Should coke be used instead of charcoal, that variety should be selected which yields least ashes. Hessian crucibles are commonly used in experiments requiring a very high temperature; they become soft, however, and fuse.

Even crucibles formed of graphite and other substances with difficulty fusible, cannot withstand the strong heat of this furnace; so that a higher temperature is obtained in it, than crucibles formed of varieties of clay up to this time known, are capable of resisting.

Fig. 104.



This figure represents the two cylinders, when prepared for use, the former (Fig. 103) being laid open to show its internal parts.

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THE END.

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