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ELEMENTS

OF

CHEMISTRY,

WITH

PRACTICAL EXERCISES,

ILLUSTRATED BY

One Hundred and Forty Engravings on Wood.

FOR THE

USE OF SCHOOLS.

BY FRANCIS J. GRUND,

Author of "Elements of Natural Philosophy," "Elements of Plane and
Solid Geometry," "Popular Lessons in Astronomy,"
"Exercises in Algebra," "Arithmetic," etc.

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PREFACE.

In preparing the following Elementary Treatise of Chemistry, it has been the author's particular study to form a proper scientific arrangement, which shall enable the learner to see the connexions which exist between the different branches of the natural sciences, and to conduct him gradually from a knowledge of the simple bodies, or elements of nature, to a correct understanding of their more complex combinations.

The divisions of the work, it is believed, will be found natural, and such as will prove a strong assistance to the memory.

The Introduction contains the outlines of General Chemistry, treating separately,

I. Of the definition and object of Chemistry.
II. Of Chemical action.
III. Of the Chemical apparatus, and
Of the Chemical composition of bodies.

The first four chapters may be considered as containing the elements of inorganic chemistry. The first treats of the gaseous elements and their binary combinations; the second, of the thirteen non-metallic elements and their binary combinations; the third chapter treats separately of the *metals,* and the fourth of the salts.

To the description of each element is annexed a short table, exhibiting its principal combinations with other substances, and each chapter is followed by questions for recapitulation, which are numbered to correspond with the sections of the book.

The fifth and sixth chapters treat respectively of vegetable and organic chemistry, and the seventh chapter explains the three principal processes of fermentation, or the spontaneous decomposition of organized matter. Each of these chapters is again followed by questions for review, numbered to correspond with the sections of the text. The appendix contains a brief description of the steam engine, with questions for the learner. Numerous engravings are introduced for illustrating the experiments, and indeed no expense and labor spared to render the work intelligible even to ordinary capacities.

It is hardly necessary to add that on his tour to Europe the author has had an opportunity to embody in his work the latest discoveries in chemistry, and that it may therefore be reasonable in him to hope that in this respect his book is not inferior to any similar work published in this country.

Boston, October 1st, 1833.

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CHEMISTRY.

INTRODUCTION.

I. DEFINITION AND OBJECT OF CHEMISTRY.

I. ALL natural sciences, that is, all human knowledge about created nature, may be divided into two great classes — *Natural History*, and *Natural Philosophy.*

II. *Natural History* has for its object the systematic description of animate and inanimate (living and lifeless) bodies, and is again divided into *Zoölogy, Botany,* and *Mineralogy ;* according as the bodies described are *Animals, Plants,* or *Minerals.*

III. The object of *Natural Philosophy* is to explain the various phenomena which occur in the material world, by finding out their mutual relation and connection with certain invariable principles, called *Laws of Nature.* The phenomena, themselves, may have their origin in the general properties of matter ; such as gravity, attraction, elasticity, &c,* and consist, then, principally in *motion ;* or they may be occasioned also by certain powers which are *inherent* in bodies, by virtue of which one body *changes the form and properties of another with which it comes in contact.* On this account Natural Philosophy has been divided into two great branches ; one which treats of the *Mechanical properties of matter* — Natural Philosophy

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* See Grund's Elements of Natural Philosophy.

This double composition is exhibited by the following table.

Saltpetre.

nitric acid, alkali.

nitrogen, oxygen, potassium, oxygen.

Query. — Which, in this example, are the *nearer*, and which the *more remote* ingredients of saltpetre ? *Ans.* — In this example nitric acid and alkali are the *nearer ; nitrogen, potassium,* and *oxygen,* the *more remote* ingredients of saltpetre.

VIII. Those substances which have not as yet been decomposed by any means in our power are called *Elements* ; but it does not follow that all substances which are *now* considered as elements, are really incapable of chemical analysis.

Query. — What then does the word *Element* express in chemistry ? *Ans.* — The word Element indicates only *the degree of our knowledge* with regard to a certain substance, and shows that we have not, as yet, been capable to decompose this substance.

II. Chemical Action.

IX. It has been observed that each chemical composition or decomposition, in other words, all chemical action, is effected by a peculiar kind of attraction, called *affinity. This, therefore must be considered as the principal cause of all chemical phenomena.*

The changes produced on bodies which are subjected to it, are principally the following.

a. A change in temperature.

Example. — Oil of vitriol and water suddenly mixed, produce a temperature of 212° Fahrenheit : — Again, Salammoniac and snow mixed together, produce a cold equal to zero of Fahrenheit's thermometer.

Hence chemical affinity changes the capacity for heat, or the specific caloric of bodies. (Nat. Phil. Chap. VI.)

b. A change in the physical properties of bodies.

EXAMPLE. — Sulphur and oxygen are both destitute of smell, taste, or action on vegetable color; but when combined together they form a powerful *acid*, of a strong smell, which changes blue vegetable colors into red.

ANOTHER EXAMPLE. — Quicksilver, which is of a bright tin-color, unites with sulphur, which is yellow, and forms a substance called cinnaber, distinguished by its beautiful *red* color.

*c. Change in the aggregate form of bodies.**

EXAMPLE. — Oxygen and hydrogen are both aeriform,† or *gaseous*, but when combined in the ratio of about 1 to 8, form the well-known *liquid*, water.

It is not unfrequent to see chemical action accompanied by light. The intensity of this light increases with the degree of affinity which exists between the two combining bodies, and the circumstances which favor their combination. This phenomenon will be explained in Chap. I, when treating of oxygen.

X. It becomes us to speak separately of the great influence which *heat* has upon all chemical phenomena. And this is not only so far true, *that no chemical action takes place without a change of temperature; but is founded also on the fact that some combinations or decompositions are effected only through the influence of higher degrees of temperature* (when one or the other body has previously been heated.) Heat, therefore is a powerful chemical agent, which, in most cases, favors the chemical affinity of one body for another; although there are instances in which heat seems to produce a different effect.

EXAMPLE. — The process of fermentation and putrefaction (see Chapter VII) requires at least 32 degrees Fahrenheit.

Again — Quicksilver combines with oxygen only when heated to 212 degrees; and the result of this combination, which is *the oxide of quicksilver*, separates again into quicksilver and oxygen, when submitted to a *red* heat.

ANOTHER EXAMPLE. — The *Chlorates*, a class of salts with which we shall hereafter become acquainted, are decomposed

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* See Natural Philosophy, Chapter I.

† See Natural Philosophy.

and give off the oxygen which they contain, when thrown upon live coals.

XI. The greatest *obstacle* to chemical action is the cohesive attraction of bodies; — that is, (as has been explained in Natural Philosophy) the attraction by which their particles are kept together and in their relative positions.* This is the reason why bodies combine readiest with each other, when one or the other has been reduced to the *fluid* state; because the cohesive attraction is less in liquids than in solid substances. It also explains why heat increases the action of chemical affinity; because heat, by expanding all bodies (Natural Philosophy, Chap. VI,) lessens their cohesive attraction, and predisposes them for the fluid state. From this the general inference has been drawn, *that no chemical action takes place, except one of the two bodies is in the fluid state.* This rule, however, is not without exceptions.

Query — What would take place if there were no cohesive attraction to counteract the chemical affinities of bodies? *Ans.* — Without the cohesive attraction of the particles of bodies, all substances would combine and unite with each other to one huge mass.

Query — How, then, must chemical affinity and cohesive attraction be considered in reference to each other? *Ans.* — They must be considered as two opposite powers in nature whose effects, by a wise distribution of Providence, are wonderfully balanced.

XII. Bodies frequently combine with each other in such a way that each of them loses its physical properties in the combination. They are then said to be *neutralized.*

In the above example, the *oxygen* and the *sulphur* are *neutralized* in sulphuric acid.

ANOTHER EXAMPLE. — *Alkali* (potash) and *sulphuric acid* are each distinguished by a peculiar taste; potash changes blue vegetable colors into green, and sulphuric acid turns them into red. By mixing these substances in the proper proportion, we obtain a salt destitute of either acid or alkaline qualities; its taste being bitter, and the salt itself being without any effect on vegetable colors.

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* See Natural Philosophy, Chapter I.

Query — In what state are the potash and the sulphuric acid, in this case, contained in the salt? *Ans.* — They are *neutralized* in it.

It may be well to observe here, that in order to effect a complete neutralization, the two bodies must combine in a certain fixed proportion, before or beyond which no such phenomenon takes place.

XIII. Some bodies combine with each other in all proportions, and preserve still a portion of their original properties. Such a combination is more properly called a *mixture*.

EXAMPLE. — If wine and water be poured together, a *mixture* is obtained in which the fluidity of both liquids, as well as some of the taste and color of the wine is preserved. The same is the case when vinegar and water, alcohol and water, alcohol and wine, &c, are poured together.

XIV. Whenever we wish to decompose a chemical compound into its constituent parts, we must have recourse to a *third* substance, with which one of these parts is to combine, by which means the other becomes *disengaged* or *free*. This kind of chemical attraction, in consequence of which a body *quits* a combination already existing, for the sake of forming a *new* one, is called *Elective affinity;* because the body seems, as it were, to *elect* one combination in preference to another, which it has already formed.

EXAMPLE. — Muriate of lime is a compound of muriatic acid and lime; but when potash is added to the solution the muriatic acid combines with the potash, and the lime being now disengaged falls to the bottom, and forms what is called a *precipitate*. This process may be represented to the eye by the following figure.

$$\text{Muriate of Lime.}\left\{\begin{array}{l}\overbrace{\text{Muriatic acid.}\qquad\qquad\qquad\text{Potash.}}^{\text{Muriate of Potash.}}\\ \text{Lime.}\end{array}\right.$$

The original compound (Muriate of Lime) is composed of Muriatic acid and lime. As soon as potash is added, the muriatic acid combines with the potash, and forms muriate of potash; and the lime becomes free.

Query — What substance, in this example, shows an elective affinity for Potash? *Ans.* — The muriatic acid. *Query* — Why? *Ans.* — Because it quits its combination with lime, and unites, as it were, in preference with the potash.

XV. When a solid body combines with a fluid, the product is called a *solution*. In this case the affinity between the two substances continues to act only to a certain point, that is, the liquid is only capable to dissolve a *certain portion* of the solid — so that if we wished to have a greater quantity of the solid dissolved, we should have to add more of the liquid. The point beyond which the affinity of the liquid ceases to act upon the solid, is called the point of *saturation;* and the solution itself, when arrived at this point, is said to be *saturated.*

Example — Water will dissolve only a certain quantity of sugar or salt, until it becomes saturated. A fresh quantity of sugar or salt being then added will remain unchanged at the bottom of the vessel. But if a new quantity of water be added to the solution, then a new quantity of sugar or salt will be dissolved.

XVI. The saturation of liquids depends principally —

1. Upon the temperature of the liquid.

2. Upon the degree of affinity which exists between the liquid and the solid; and

3. Upon the purity of the liquid.

The warmer the liquid is, the more can it generally dissolve of a given solid. To this rule, however, there are several exceptions.

Example. — Water of the temperature of 212° Fahrenheit, will dissolve no more common salt, than water of the temperature near the freezing point. Water of the temperature of 212° dissolves even less magnesia, than water of the common temperature of the atmosphere. But with regard to most salts the solving power of water increases with the temperature.

XVII. It frequently occurs that a compound of two substances cannot be decomposed without the assistance of a third *and fourth* substance. The affinity of the third substance for any *one* of the constituent parts of the compound, is then, of itself, not sufficient to produce a separation. This kind of affinity is called *Double* or *Complex* affinity. It will be best understood from the following EXAMPLE.

Zinc decomposes water (which is a compound of oxygen and hydrogen) only when an acid is added. The hydrogen of the water then becomes free, while the zinc and oxygen combine together with the acid to form a salt.— The zinc, of itself, is not capable of separating the oxygen from the hydrogen; but the acid having a strong affinity for a combination of zinc and oxygen, predisposes the oxygen to quit its combination with water and to combine with the zinc. For an illustration, see the following table:

$$\text{Water, }\left\{\begin{array}{l}\text{hydrogen,}\\ \\ \left.\begin{array}{l}\text{oxygen,}\\ \\ \text{zinc,}\end{array}\right\}\left.\begin{array}{l}\text{oxide of zinc,}\\ \\ \text{acid}\end{array}\right\}\text{salt.}\end{array}\right.$$

Zinc alone does not separate the oxygen from the hydrogen; but when the acid is added, which has a strong affinity for the *oxide of zinc*, this latter substance (oxide of zinc) is formed, and combines with the acid to salt.

Some philosophers ascribe these phenomena to a *predisposing* affinity; because the acid, in our first example, seems to *predispose* the oxygen for a combination with the zinc.

Query — What substance, in this example, has exercised a predisposing affinity upon oxygen? *Ans.* — The acid. *Query* — Why? *Ans.* — Because it has disposed it for a combination with the zinc. *Query* — But by what means does the acid predispose the oxygen for a combination with the zinc? *Ans.* — By the strong affinity which it has for the oxide of zinc, which is a combination of the oxygen with zinc.

XVIII. If two compounds be brought together in a state of solution, it frequently happens that a double decomposition, and two new compositions take place. Both the original compounds are then decomposed, and two new compositions are formed by a mutual interchange of ingredients. Such a compound action is said to be caused by *double elective affinity*.

EXAMPLE. — The well known substance, *sugar of lead,* (which is used as a paint) is composed of acetic acid (vinegar) and lead. *White vitriol* is a compound of sulphuric acid and zinc. Now if a solution of sugar of lead be mixed with a solution of white vitriol, the acetic acid will quit its combination with lead, and unite with the zinc; while, at the same time, the sulphuric acid which is set free, unites with the lead and forms an insoluble hard powder (sulphate of lead) which is precipitated. For an illustration see the following diagram.

$$\text{Sugar of Lead,}\left\{\begin{array}{l}\overbrace{\text{Acetic acid,}\qquad\text{Zinc,}}^{\text{Acetate of zinc,}}\\ \underbrace{\text{Lead,}\qquad\text{Sulphuric acid,}}_{\text{Sulphate of lead.}}\end{array}\right\}\text{White Vitriol,}$$

The original compounds, sugar of lead and white vitriol, are placed at the extremities of the two brackets; their respective ingredients, acetic acid and lead, and zinc and sulphuric acid, are placed inside of the brackets; the new compounds, acetate of zinc, which is formed by the combination of the acetic acid with the zinc is placed above the upper, and the second compound, sulphate of lead, formed by the combination of the lead with the sulphuric acid, is placed under the lower bracket.

Query — Which substance does the acetic acid, in this example elect in preference to the lead with which it was combined? *Ans.* — The zinc, with which it combines, setting lead free. *Query* — And which substance does the sulphuric acid elect in preference to the zinc? *Ans.* — The Lead, giving off the zinc with which it was united. *Query* — And why is this action called double elective affinity? *Ans.* — Because two distinct elections took place, viz. the acetic acid elects the zinc, and the sulphuric acid the lead, for a new combination.

This kind of affinity often effects the decomposition of a substance which would have resisted the action of *single elective* or *predisposing affinity.*

XIX. It has been said that while some bodies combine with each other in all proportions and form *mixtures,* others have a *limit* to their combination, which is the point of SATURATION. But there are substances which combine with each other *only in certain fixed proportions,* that is, so many parts or weights of one substance, with a definite number of parts or weights of another. The product of such a combination is always a compound in which the properties of the constituent parts are completely neutralized. (See XII.)

Example. — Sulphur and oxygen are apparently heterogeneous substances; oxygen is a gas, and sulphur a solid body. These two substances however unite with each other in the proportion of 16 weights of sulphur with 24 weights of oxygen, in which case they form a compound which is known by the name of sulphuric acid ; and whose properties are totally different from those of the sulphur or oxygen ; these are therefore neutralized by the combination.

Some bodies combine with each other only in one proportion ; others combine in two, three, four and more fixed ratios.

Example. — *Zinc* and *oxygen* combine with each other only in *one proportion*, forming what is called *oxide of zinc ;* but the two gases, known by the name of oxygen and nitrogen, combine with each other in five distinct ratios, viz.

1 volume of nitrogen with 1 volume of oxygen,
1 " " " " 2 " " "
1 " " " " 3 " " "
1 " " " " 4 " " "
and 1 " " " " 5 " " "

the five resulting combinations being two oxides and three acids of nitrogen, and there are no other combinations of these two substances known.

Similar *fixed* ratios have been discovered in the combination of other bodies to definite compounds, and it has been observed that in *these combinations the original properties of the ingredients are always completely neutralized,* so that we are able to lay down the general principle : *No two bodies combine with each other to neutralization, except in a fixed determined proportion, which remains always the same, for the same two substances.*

Now it has been remarked and proved by numerous experiments, that *if a body, A, combines with another body, B, for instance, in the ratio of* 1 *weight of A with* 2 *weights of B ; and the same body A, combines with a third body, C, in the ratio, say of* 1 *weight of A, to* 3 *of C, then the body, B, will, if it have any neutralizing affinity for* *the body C, combine with it in the ratio of 2 to 3, or at least in a multiple of this ratio by a whole number; that is in 2, 3, 4, 5 or 6 times this ratio; so that the ratio in which one and the same body, A, combines to neutralization with different bodies, B, C, D, &c, being once known, the neutralizing ratio in which these bodies combine with each other are also determined* This will be better understood by the following EXAMPLE.

$$\text{Supposing 1 lb. of a substance A, combines with} \left\{\begin{array}{l}\text{2 lbs. of B,}\\ \text{3 lbs. of C,}\\ \text{4 lbs. of D,}\\ \text{5 lbs. of E;}\end{array}\right.$$

then the relation of the substance, A, to the bodies, B, C, D, E, determines also that of the bodies B, C, D, and E to each other; viz. if the body, B, has a neutralizing affinity for C, D, and E, it will combine with them in the ratio of

$$\text{2 lbs of B} \left\{\begin{array}{l}\text{with 3 lbs. of C,}\\ \text{with 4 lbs. of D,}\\ \text{with 5 lbs. of E.}\end{array}\right.$$

Further, if C, has any neutralizing affinity for C, D, and E, it will combine with them in the ratio of

$$\text{3 lbs. of C with} \left\{\begin{array}{l}\text{2 lbs. of B,}\\ \text{4 lbs. of D,}\\ \text{5 lbs. of E.}\end{array}\right.$$

If D have any such affinity for B, C, and E, it will combine with them in the ratio of

$$\text{4 lbs. of D with} \left\{\begin{array}{l}\text{2 lbs. of B,}\\ \text{3 lbs. of C,}\\ \text{5 lbs. of E,}\end{array}\right.$$

And lastly if E have this affinity for B, C, and D, it will combine with them in the ratio of

$$\text{5 lbs. of E with} \left\{\begin{array}{l}\text{2 lbs. of B,}\\ \text{3 lbs. of C,}\\ \text{4 lbs. of D.}\end{array}\right.$$

Thus a single table expressing the fixed proportions in which the body A, combines respectively with B, C, D and E, has given us at once the fixed proportions in which B, C, D, and E combine with each other.

The learner will now be able to understand the following example, which is taken from nature:

We know from experience that

37 weights of Muriatic acid combine with 28 of Lime,
40 " " Sulphuric acid " " 48 " Potass,
54 " " Nitric acid " " 32 " Soda,
28 " " Phosphoric acid " " 17 " Ammonia.

These ratios give not only the proportions in which each of these substances combines with that which is placed on the same line with it; but also the proportion in which each of these substances combines with all others. Thus,

37 weights of muriatic acid combine to saturation	with	28 weights of Lime, 48 " " Potass, 32 " " Soda, 17 " " Ammonia,

40 weights of Sulphuric acid combine to saturation	with	28 weights of Lime, 48 " " Potass, 32 " " Soda, 17 " " Ammonia,

54 weights of Nitric acid combine to saturation	with	28 weights of Lime, 48 " " Potass, 32 " " Soda, 17 " " Ammonia.

&c

Or we could also take any of the four substances, Lime, Potass, Soda, or Ammonia; say soda, and write the four acid substances after it, viz.

32 weights of Soda combine to saturation	with	37 weights of Muriatic acid, 40 " " Sulphuric acid, 54 " " Nitric acid, 28 " " Phosphoric acid,

and so on.

Now as 37 weights of muriatic acid combine in the same proportions with Lime, Potass, Soda, and Ammonia, in which 40 weights of sulphuric acid combine with these substances, 37 weights of the first acid are said to be *equivalent* to 40 weights of the second; and accordingly, also to 54 weights of Nitric, and to 28 weights of Phosphoric acid. In like manner are 28 weights of lime equivalent to 48 weights of potass, 32 of Soda, 17 of ammonia. Or we may also say that 37 weights of muriatic acid are equivalent to 28 weights of lime, 48 of potass, 32 of soda, &c, or that 28 weights of lime are equivalent to 37 weights of muriatic, 40 of sulphuric, 54 of nitric, and 28 of phosphoric acid, and so on.

We shall show in the body of the following work that similar equivalent numbers have been found for a great many substances in the chemical catalogue; and it is by these numbers that we are able to express *the definite proportions in which one substance combines with all others, for which it has a strong chemical affinity. — The smallest number of weights of one substance which in this manner combines with other substances, is said to be a* CHEMICAL EQUIVALENT *for all other substances with which it is capable of entering into combination.*

Now it has been found by experiments that in all cases where a body is composed of two elements, the sum of the equivalents of the elements is equal to the equivalent of the body itself. Knowing therefore the equivalent of the elements of a body, we also know that of the compound; and the reverse, if the equivalent of the compound and the elements of its composition are known, the equivalents of its elements may be inferred from it. This will be better understood from the following

EXAMPLE. — 1 weight of hydrogen combines with about 8 weights of oxygen to water. Consequently if 1 weight of hydrogen gas is taken for unity of comparison, the equivalent of oxygen will be 8; whence that of water will be 1 added to 8, equal to 9. And the reverse; suppose we know that the chemical equivalent of water is 9; and that it is composed of 1 equivalent of water and 1 of oxygen. Knowing the equivalent of water to be = 9, we should at once infer that of the oxygen, which must be equal to 8.

ANOTHER EXAMPLE. — One weight of *hydrogen* combines with 16 weights of *sulphur*, to *sulphuretted hydrogen*; consequently the weight of hydrogen taken for unity, the chemical equivalent of sulphur is 16. Now the chemical equivalent of oxygen being 8, it is known that 2 equivalents of oxygen combine with 1 equivalent of *sulphur* to

sulphurous acid. *Query* — What is the equivalent number of sulphurous acid? *Ans.* — 32. *Query* — Why? *Ans.* — Because it is composed of 1 equivalent of sulphur = 16
and of 2 equivalents of oxygen (each equal to 8) = 16

Consequently, Chemical equivalent of sulphurous acid = 32

Again — Supposing we know the chemical equivalents of sulphurous acid = 32, and also that it is composed of 1 equivalent of sulphur, and 2 equivalents of oxygen, (each equal to 8.) Required the chemical equivalent of sulphur. *Ans.* — The equivalent of sulphurous acid being = 32
Subtract from it 2 equivalents of oxygen (each equal to 8) = 16

The remainder will be the equivalent of sulphur = 16.

These few examples will be sufficient to show the beauty and harmony of the theory of chemical equivalents; as well as the advantages which the *practical chemist* may derive from it.

Were the chemical equivalents of all bodies unchangeable, and as correctly determined as those we have mentioned in our last examples, then it would indeed be possible to introduce mathematical precision and certainty into the science of chemistry, which would then in no respect yield to any of the exact sciences. A single experiment which should show the relation of an unknown substance to one with whose properties we are already acquainted, would suffice to determine the relation of that substance to all other bodies; which relation would, in most cases, be found by a mere addition or subtraction, as has been shown in the last two examples. But this is far from being universally true. The same limits with which the human understanding invariably meets in all sciences, await us also in chemistry. For the proportion in which bodies combine are not always as definitely pronounced as we could wish them to be. In some bodies they are less perceptible than in others, and there are substances whose composition is so vague and indefinite that thus far, it has been impossible, even by the nicest experiments, to fix upon any of their supposed definite equivalents. We know farther, from experience, that 1 equivalent of one body, does not always combine again with 1 equivalent of another; on the contrary it has been found that 1 equivalent of one body frequently combines with 1, $1\frac{1}{2}$, 2, 3, or 5 equivalents of another; and there are experiments and facts, which have induced some of the best chemists now living to suppose that one equivalent of one substance may also combine with $\frac{1}{2}$, $\frac{1}{3}$, $\frac{2}{3}$, $\frac{1}{4}$, $\frac{1}{8}$, and even $\frac{1}{6}$ equivalent of another substance. Hence the universal advantage which it was hoped would be obtained from a *numerical* computation of chemical equivalents has, thus far, *not* been realized. For although we may be able to investigate by experiment the proportion of matter or weight in which two substances combine with each other, yet will this investigation not always lead us to a precise result as regards the chemical equivalent of the compound; because we do not always know whether 1, $\frac{1}{2}$, 2, or one fourth, one third, two thirds, one eighth, or one sixth equivalent of either substance is combined with one equivalent of the other. But as far as the whole theory of Chemical proportions is supported by *actual experiments*, it not only serves to facilitate the labors and to assist the memory of the practical chemist; but deserves also, on account of its harmony with other laws of nature, to be ranked among the most brilliant discoveries of the human mind.

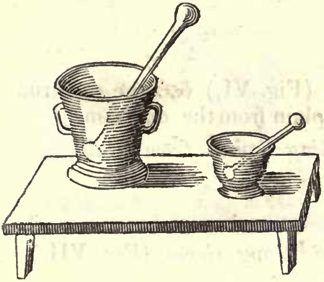
The chemical equivalents of a great number of substances, as far as we have been able to determine them by actual experiments (but in most cases unfortunately only by arithmetical computation), have been arranged in tables, of which one is attached to the end of the book. From what we have said it will easily be seen that they are not in all cases to be relied upon with mathematical certainty, although many authors speak of them as established facts, or consider the whole theory established beyond any reasonable doubt. In most of these tables the weight of 1 equivalent of hydrogen gas is taken for unity of comparison. The same is done in our table, for reasons which we shall explain hereafter when treating of hydrogen gas. The full development of the theory of chemical equivalent cannot be given here (in the introduction to chemistry); nor can it be expected that the pupil shall have an *adequate* idea of it from the few statements of facts which we have made in this section. But we shall revert to this subject again, and give a more complete exposition of it, as we go along, treating separately of the most important substances of the chemical catalogue.

III. Chemical Apparatus.

[It is to be understood that only the most useful and essential apparatus, which may be easily procured, can find a place in an elementary treatise for schools. A complete description of it is found in Berzelius's Chemistry, Vol. 1.]

XX. *a. Apparatus for dividing bodies.*

Fig. I.



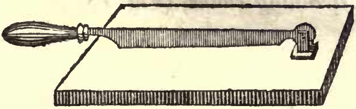
These consist of *mortars* and *pestle*, (Fig. I.)

Fig. II.

hammer and *anvil*, (Fig. II.)

Fig. III.

Fig. IV.



knives, (Figs. III, IV and V.)

Fig. V.

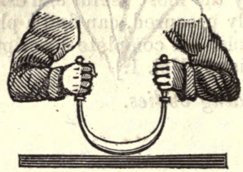
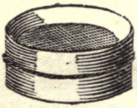


Fig. VI.

files, (Fig. VI,) &c, the construction of which is sufficiently plain from the diagrams.

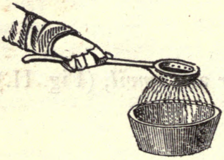
b. Apparatus for separating liquids from solids.

Fig. VII.



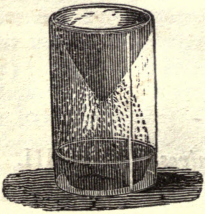
To these belong *sieves*, (Fig. VII.)

Fig. VIII.



cullenders, (Fig VIII.)

Fig. IX.



straining cloths, (Fig. IX.)

Fig. X,

Fig. XI.

Fig. XII·

funnels, (Fig. X, XI, and XII.); &c.

Fig. XIII.

Fig. XIV.

The *decanting jar* is represented in Figs. XIII and XIV. Its shape is sufficiently plain from the figure, and its application in the pouring of liquids, easily understood.

Fig. XV.

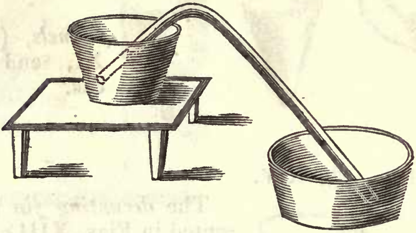
Fig. XVI.

A spherical or common glass bottle, (Figs. XV and XVI,) with a small cylindrical tube, fixed air-tight in the cork, serves to separate a liquid from a solid by the process of evaporation (explained in Natural Philosophy).

Fig. XVII.

To separate a lighter fluid from a specific heavier one, the *separatory funnel* (Fig. XVII) is used, which opens upwards and downwards. When the lighter fluid is decanted through the upper aperture the specific heavier descends through the lower.

Fig. XVIII.



The operations of the syphon has already been described in Natural Philosophy, Chapter V.

c. Apparatus for the liquefaction of solids.

Fig. XIX.

Fig. XX.

These consist of *melting pots*, (Fig. XIX,) or *crucibles*, (Fig. XX,) made of earthen ware, silver or platinum ;

Fig. XXI.

of glass vessels called *matrasses*, of which one is represented in Fig. XXI.

Fig. XXII.

of porcelain saucers and spoons, (Figs. XXII,) for stirring acids which would effect metal or glass, &c.

d. *Apparatus for evaporation and crystalization.*

Both processes have been described in Natural Philosophy.

XXI. For this purpose we make use of what are called evaporating dishes, made of porcelain, glass, or silver. (See Fig. XXIII.) Their form must be *flat*, to present the greatest possible surface to the atmosphere. When the process of evaporation takes place under the influence of heat it is called a steam-bath. For this purpose a flat vessel, made of wedgewood ware, is bedded in hot sand or ashes. (See Fig. XXIV.)

Fig. XXIII.

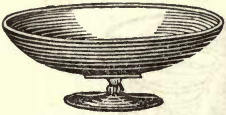
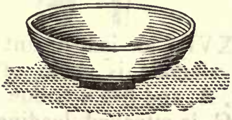


Fig. XXIV.

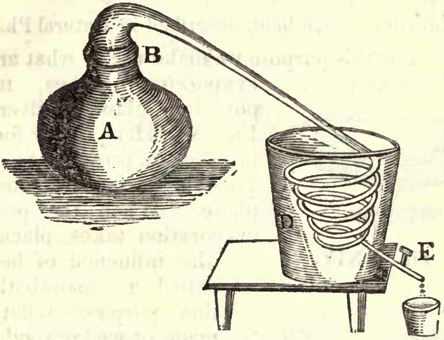


e. *Apparatus for distillation.*

XXII. This is a contrivance for collecting the volatile portion of a body which escapes through the process of evaporation. The most common is an *alembic*, (Fig. XXV,) composed of a flask, (which may be bedded in sand) the head of which fits air-tight in the neck of the pipe, which is destined to carry the rising gas from the flask into the receiver.

Fig. XXV.

Fig. XXVI.



The *common still*, (Fig. XXVI,) an instrument similar in its construction to an alembic, is made of copper. It is shaped like a kettle, A, and has a hollow movable head, B, to which a pipe, C, is attached, leading to a spirally formed tube, commonly called the *worm*, which for the purpose of cooling, may be immersed in water. The vapours then contained in it are, by this means, condensed, and descend in drops when the cock, E, is opened.

Fig. XXVII.

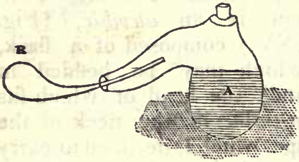
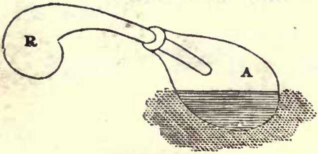
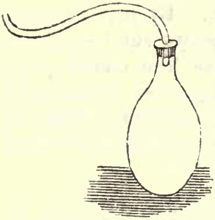


Fig. XXVIII.



The instrument more generally employed for distillation is a *retort.* It may be made of glass, porcelain, or metal; and is either as shaped in Fig. XXVII, or as represented in Fig. XXVIII. There is always a receiver, R, connected with it, which in some instances is again provided with a pipe and stop-cock, to let off the distilled liquid at different periods. The operation of this apparatus is easily understood. When the liquid which is heated in the retort, A, evaporates, the volatile parts are collected by the receiver, R.

Fig. XXIX.



A Florence flask (Fig. XXIX,) with a pipe fixed air-tight through its cork, is a cheap apparatus, answering most purposes for which retorts are used. The pipe, A, may be connected with a receiver, as in Figs. XXVII, and XXVIII.

f. Apparatus for heating Chemical substances.

X XIII. These consist in lamps and furnaces.

Fig. XXX.

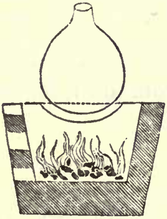
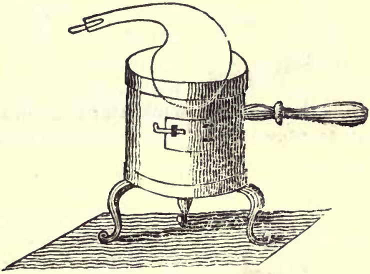
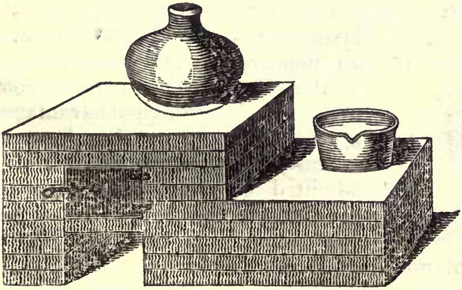


Fig. XXXI.



The latter are either *portable air furnaces* with crucible stands (Figs. XXX, and XXXI) ; or they are fixed wind-furnaces of which one is represented in Fig. XXXII.

Fig. XXXII.



Both kinds of furnaces are so constructed that the air has free access to the fire from below. By this means a continued draught is created, which, as we shall see hereafter, is necessary for a brisk flame or free combustion. For the heated air in the furnace becomes specifically lighter and escapes through the upper opening, while the outer air rushes from below in its place. (See Natural Philosophy, Chap. V.)

Fig. XXXIII.

Figs. XXXIII, XXXIV, and XXXV, represent the three principal kinds of lamps used for chemical purposes. Fig. XXXIII represents the common lamp. A combustible substance, usually made of cotton, called the wick, is immersed in oil, with which the whole apparatus is filled, and is then lighted. The flame, nourished by the oil, which ascends through the wick and is gradually consumed, throws out heat and light at the same time.

Fig. XXXIV.

Fig. XXXIV represents a spirit lamp. The main difference between this lamp and the one just described, consists in spirit of wine being employed instead of oil, — the heat of the flame of this substance being much more intense than that produced by the flame of a common oil lamp.

Fig. XXXV.

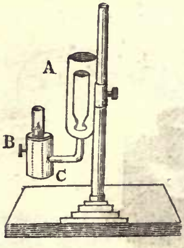
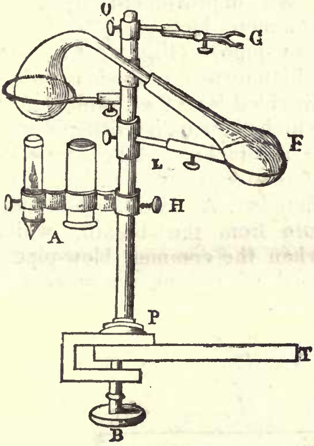


Fig. XXXV represents an Argand lamp, with its stand. This is as great an improvement upon common lamps as the wind-furnace upon a common fire-place. Its principal advantage over a common lamp consists in a round hollow wick through which the air is admitted by an opening from below, causing thereby a much more perfect combustion, and throwing out much more light and heat than is done by a common lamp, where the air comes only in contact with the exterior part of the flame. The flame of the Argand lamp is moreover covered by a round open glass, which serves it in the office of a chimney, through which the heated air ascends and is replaced by the air which enters from below; the draft thereby created tending not a little to increase the intensity and heat of the flame.

Fig. XXXVI.

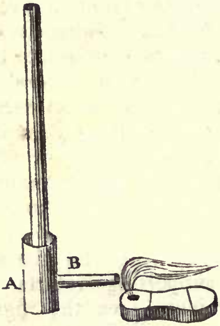


A convenient contrivance for heating bodies in a retort, is *Guiton's Lamp-furnace.* It consists of an iron or brass rod, O P, with several sliding sockets, which serve to support the lamp, A, and the arms, LF, OG, of which there may be as many as may be thought expedient. The arms terminate in iron or brass rings for the sake of supporting retorts and receivers, (see the figure) or in small forceps to hold the body which is to be exposed to the heat of the lamp. These arms may, by means of sockets, be moved up and down the rod, O P, or turned sideways, and then screwed fast to any particular part of it, as the experiment may require; and the same may be done with the lamp, in order to regulate the heat. The whole apparatus is best fastened to a table, T, by means of a screw, B, in order to give more steadiness and security to the experiment.

Fig. XXXVII.

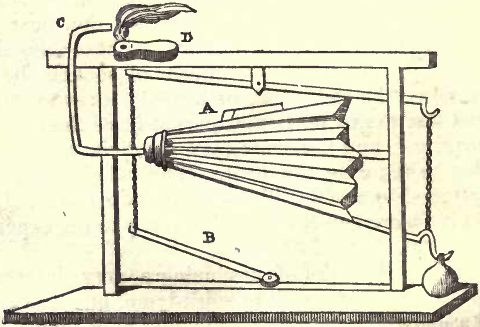
For the sake of producing a very intense heat with a common oil or spirit-lamp, an instrument is used which is called a common blow-pipe. It consists of a bent brass tube, whose upper end is from one third to one half inch in diameter; but is gradually tapering to a point, as is represented in figure XXXVII. When the lower (bent) end is placed in the flame of the lamp and the upper is applied to the mouth or nostrils, a stream of air may be applied to the jet of the flame for the double purpose of giving it a horizontal direction, and making it gradually taper to a point, to which the body that is to be heated must then be exposed. The body must be placed upon a piece of charcoal, which may be held by small forceps. (See fig. L. page 32.)

Fig. XXXVIII.



An improvement upon the common blow-pipe, is Gahn's blow-pipe, (Fig. XXXVIII.) which instead of the bent tube is provided with the chamber A, to which the smaller orificed pipe, B, is attached. The advantage of this apparatus consists in the chamber, A, retaining the moisture from the breath, which, when the common blow-pipe is used, often stops the process, or diminishes the flame.

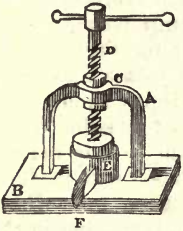
Fig. XXXIX.



A more convenient contrivance than either is that represented in Fig. XXXIX. where the blow pipe C, communicates with a bellows A, which may be moved with the foot by placing it upon the board, B, and by which means a constant stream of air is sent through the jet of the flame, D. This apparatus is particularly used for closing the tubes of barometers and thermometers, and such similar purposes.

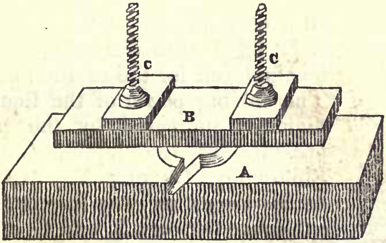
g. *Apparatus for compressing bodies, or extracting liquids from bodies in which they are contained.*

Fig. XL.



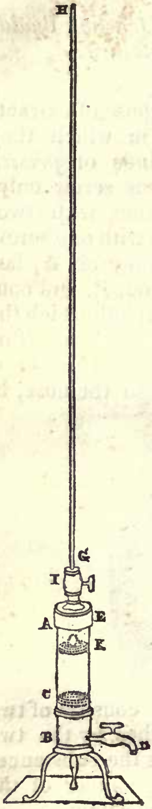
XXIV. For the purpose of extracting liquids from solids in which they are contained, two kinds of *presses* are used; one with *one* screw only, (Fig. XL.) and the other with two, (Fig. XLI.) The press with one screw consists chiefly of an iron arch, A, fastened to a block of wood, B, and containing in C the *nut* through which the screw, D, moves up and down. The substances contained in the basin, E, are by this screw compressed, and the liquid descends through the nose, F.

Fig. XLI.



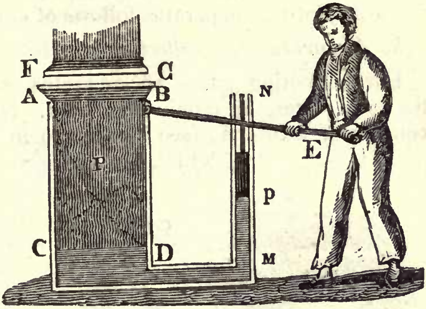
The press with two screws (Fig. XLI.) consists of two boards, A and B, which are brought together by the two screws, C, C, and by this means compress the substances which are placed between them. The remainder of the construction is similar to the press with one screw.

Fig. XLII.



When a solid substance is to be dissolved in a liquid, an instrument is often used, which is called the hydrostatic, or, from its inventor, Count Real's press. It consists of a strong tin barrel, A B, which in C is provided with a fine sieve, and in D, with a discharging spout. The upper part screws into a metallic cover E, which terminates in a long narrow tube, and is, in I, provided with a stopcock. The solid substance from which an extract is to be made, is first put in the barrel and placed upon the sieve C; on top of it is placed a tin plate, K, which like the sieve, C, is provided with a great many fine holes; the cover is then screwed upon the barrel, and the narrow tube, G H, filled with the liquid which is to be employed for the solution of the solid. The solving power of the liquid is prodigiously increased by the hydrostatic pressure of the liquid, (see Natural Philosophy, Chapter VI) which by this means forces its way through the solid substance between K and C, and collects in the lower part, B, of the barrel, whence it may be drawn off by the discharging spout, D.

Fig. XLIII.



The pressure of liquids is also taken advantage of in the construction of Brahma's hydraulic press. It consists of a large pump barrel, A, B, C, D, which communicates with a small forcing pump, M N. The two pistons, P, P, work water tight in their respective barrels. The whole space between the two pistons is filled with water. The substance to be pressed is placed upon the top, A B, of the large piston, above which a strong fixed surface, F G, is made to meet the pressure. When the small piston is forced down by means of the lever, E, the water exercises a pressure upon the lower end, C D, of the large piston, P, which will be as many times greater than the force with which the small piston is worked down, as the surface of the larger piston is larger than the surface of the smaller one. Thus, if the surface of the smaller piston be one square inch, and that of the larger one square foot, then the pressure on the upper piston will be 144 times greater than the force which pressed the smaller piston down. Hence one man working on the lever, E, may exercise pressure upon the piston, P, equal to that which it would take 144 men of the same strength to produce, if directly working upon C D. If the surface of the smaller piston were only one fourth of a square inch, then the pressure upon C D upwards would be 4 times 144, or 576 times greater; and so on. Now it is easily seen that the greater the power is, which presses the piston P, upwards, the greater will be the pressure exercised upon the body which is placed between the two surfaces, A B, and F G; whence the utility of this apparatus follows of course.

h. Apparatus for collecting gases.

XXV. For collecting gases an apparatus called the Pneumatic tub, water, or quicksilver bath, is employed. It consists of a tub, A, (see the figure) in which a shelf is fixed in such a manner, that the liquid, commonly water or quicksilver, may rise two or three inches above it. A jar or receiver, B, filled with the same liquid is placed upon this shelf, (which for this purpose must be provided with several holes) with its mouth downward. The pipe, C, conducts the gas which is forming in the retort, D, to the jar, B, in which it rises in little bubbles, expelling thereby the liquid of which it takes the place.

Fig. XLIV.

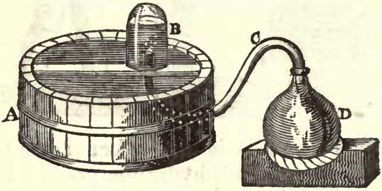


Fig. XLV.

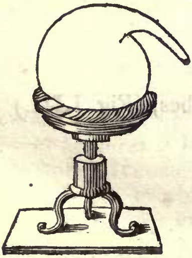
Another apparatus for collecting gases is Priestley's bell-glass. (Fig. XLV.) This useful apparatus consists of a bell glass, A, the neck, B, of which may be closed or opened by means of the stop-cock, C. This contrivance is very convenient for the collecting of gases, because in order to fill it with water or quicksilver, it is only necessary to open the stop-cock, C, and immerse the glass perpendicularly in the liquid. As the glass fills with the liquid, the air escapes through the neck, B D. Its principal use however consists in transferring gases from one vessel to another; for which purpose the gas which escapes through the neck, B D, need only be collected by a receiver.

Fig. XLVI.

Another application of this apparatus is made by filling a bladder (Fig. XLVI.) with a particular gas that may be contained in the bell-glass. This, as we shall see hereafter, is very desirable for the sake of certain experiments. The bladder, L, (Fig. XLVI.) must for this purpose be tied air-tight to a brass tube, G H, which by means of the stop-cock, F, may be closed or opened at pleasure, and in G is made to screw to the extremity, D, of the neck of the bell-glass. When this is done, and the two cocks, G and F, are opened, the bell-glass (Fig. XLV.) needs only be perpendicularly immersed in quicksilver or water, and the gas will escape through the neck into the bladder. When the bladder is filled, the stop-cock F, is closed, and the barrel G H, unscrewed from the bell-glass. It is also common to provide the bell, A, with a scale S, (see the last figure) in order to estimate the volume of gas which escapes by the rise of the quicksilver or water in the bell-glass.

i. Apparatus necessary for various chemical purposes.

Fig. XLVII.

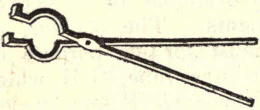


XXVI. To these we reckon stands, (Fig. XLVII.)

Fig. XLVIII.

shears, (Fig. XLIII.)

Fig. XLIX.



pincers, (Fig. XLIX.)

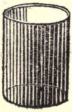
Fig. L.

forceps, (Fig. L.)

Fig. LI.

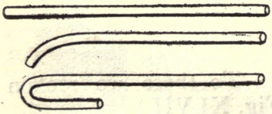
plates, (Fig. LI.)

Fig. LII.



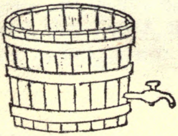
cylindrical glasses, (Fig. LII.)

Fig. LIII.



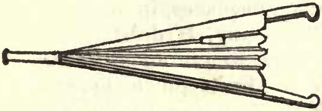
glass tubes, (Fig. LIII.)

Fig. LIV.



tubs, (Fig. LIV.)

Fig. LV.



bellows, (Fig. LV.)

Fig. LVI.

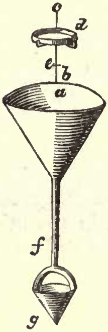
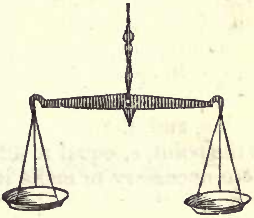


Fig. LVII.

Fig. LVIII.



and especially accurate beams and scales (Figs. LVI, LVII, and LVIII.)

The principle of the common balance, (Fig. LVIII.) has already been described in Natural Philosophy. It remains for us to say a few words on the construction of beams, or portable balances (Figs. LVI and LVII.) These are insturments of great utility to the practical chemist, and serve either for the determination of the specific gravity of substances, or to show at once the proportion of their chemical compositions. In the latter case they are called *per-cent balances*. Fig. LVI represents Nicholson's portable balance. It consists of a hollow body, *a*, made of silver or tinned iron, to which is fastened a piece of thin wire, *b*, which at its upper extremity supports a small plate or cup, *d*. To the lower extremity of the body, *a*, is attached another piece of wire, *f*, stronger than the one above, carrying a metallic cone, *g*, the lower point of which is filled out with lead to give the apparatus a perpendicular direction, when immersed in water. The weight of the whole must be less than the water which it displaces, in order that it may swim, (see Natural Philosophy, Hydrostatics,) and be able to bear a small additional weight upon the cup, *d*, before it sinks to the point, *e*, marked upon the upper wire. The use of this apparatus in determining the specific gravities of bodies is exceedingly simple. When the body whose specific gravity is to be determined is a liquid, then immerse the apparatus first in water, and then in the proposed liquid; placing in each case as many weights in the cup, *d*, as is necessary to make it sink to the point, *e*. The weight of the apparatus added to the weight placed in the cup, *d*, will in each case give the weight of equal volumes of both liquids, which, divided by one another, will give the specific gravity of the liquid in question. To give an

EXAMPLE: Suppose the weight of the apparatus is 180 grains, and the weight required to make it sink in water to the point, *e*, equal to 42 grains more. Suppose 80 grains were necessary to make it sink to the point, *e*, in the other fluid; then 42 added to 180 gives 222 grains for the weight of the water; and 80 added to 180 gives 260 grains for the weight of the liquid; and dividing 260 by 222, we obtain 1, 17 for the specific gravity of the liquid.

If the body whose specific gravity we wish to know is a solid, then place it in the cup, *d*, and add to it as many weights as will sink the apparatus to the point, *e*. By this means you find the *absolute* weight of the body. For if the apparatus requires 42 grains of itself to sink to the point *e*, and now that the body is in the cup, *d*, it requires but 30 grains, the body itself must evidently weigh 12 grains. Hence the *absolute* weight of a body is found by subtracting the weights added to it when in the cup, *d*, from the weight which is required to sink the balance alone to the point *e*. Remove the body now from the cup, *d*, to the hollow cone, *g*, and the apparatus will immediately rise; for it will lose as much of its weight as the water weighs, which the body now displaces. (Natural Philosophy.) Adding therefore as many weights to the cup, *d*, as will make the apparatus again sink to the point *e*, we determine the absolute weight of an equal volume of water; and dividing the absolute weight of the body by the weight of an equal volume of water, we obtain its specific gravity. To give an EXAMPLE: Suppose the balance requires of itself 42 grains to sink to the point *e*, but when the body is in the cup it requires but 12 grains; and if the body be now removed from the cup, *d*, to the cone, *g*, 5 further grains are necessary to sink the apparatus to the point, *e;* required the specific gravity of the body? *Ans.* — By the first supposition it is evident that the body must weigh 30 grains; and by the second it is plain that an equal volume of water weighs 5 grains; hence 30 divided by 5, equal to 6, is the specific gravity of the body. (See Natural Philosophy, Chap. IV.)

The per cent balance Fig. LVII, is an instrument by which the degree of mixture of two liquids, or of a liquid with a solid substance is ascertained. It consists of a hollow body, *a*, made of silver or tinned iron, bearing upon its upper extremity a scale, *a b*, and on its lower end some heavy substance to give the apparatus a perpendicular direction when immersed in the liquid. The scale is generally divided into 100 degrees, each degree marking the existence of 1 portion of one liquid in another, or of a solid substance in a liquid. But such a scale will only serve for one particular kind of mixture, and must be altered or changed if applied to another. Such are the beer, brandy or spirit scales, which by the degree of their immersion in these respective liquids, show the quantity of alcohol contained in them. The deeper they immerse, the less water, and consequently the more alcohol is contained in these liquids; alcohol being specifically lighter than water. (See Natural Philosophy, Chap. IV.) But the scale used for brandy would not answer for beer or wine, and vice versa.

k. Lutes.

XXVII. These are employed to join together the parts of vessels which are used in distillation, to prevent the escape of vapors. A mixture of China clay with a solution of borax will do for metallic vessels. When the liquid which is to be distilled is not corrosive, slips of bladder or paper spread with gum arabic or flour-paste will answer the purpose; 8 parts of yellow wax mixed with one part of turpentine oil, forms a very good resinous lute.

IV. CHEMICAL COMPOSITION OF BODIES.

XXVIII. All bodies in nature are either *animate* or *inanimate.* The former, to which belong the plants and animals, are composed of a variety of exceedingly delicate vessels, filled with liquids, of which each has a particular office, and the assemblage of which forms what is called their *organization.* Hence it is also customary to call plants and animals *organized* or *organic* bodies, in opposition to dead or inanimate substances, which being merely composed of particles kept together by the power of cohesion, are said to be *unorganized* or *inorganic.*

XXIX. With regard to chemistry, all unorganized or inorganic bodies are,

1. Either simple or compound; that is, either as yet not known to contain other ingredients, or composed of two or more heterogeneous substances.

2. The compounds of unorganized bodies are most always formed by a *binary* combination (combinations of two and two substances). Thus water is composed of *two* elements, oxygen and hydrogen; *Saltpetre* of *two* substances, *nitric acid* and *alkali,* of which *each* is again a compound of *two* other substances: (nitric acid is a compound of nitrogen and oxygen, and alkali a compound of Potassium and oxygen.) See introduction, VII.

3. The compounds of unorganized bodies can, in most cases, be produced by the combination of their elements. Thus, water may be produced, as we shall see hereafter, by combining oxygen and hydrogen in the proper proportions; saltpetre may be produced by a combination of nitric acid and alkali, &c.

Organized bodies, on the contrary, are

1. Generally composed of *more than two* elements.

2. They cannot be produced by art, through a combination of their chemical ingredients; because they all contain a certain *vivifying principle,* totally unknown to us; and which will probably forever escape all our anatomical and chemical researches.

XXX. A vast number of organized and unorganized bodies have been subjected to chemical analysis, and, by means of art, been decomposed into their ingredients; but there are fiftyfour substances, which, thus far, have resisted all attempts to decompose them, and, on that account, are called elements. Of these, 4 are gaseous or aeriform bodies; 9 are solid, non-metallic substances; and 41 are metals. We shall here annex their names, and propose to treat separately of the properties and combinations of each in the course of this book.

NOMENCLATURE OF ELEMENTS.

a. Gaseous Elements.

1. Oxygen,
2. Hydrogen,
3. Nitrogen,
4. Chlorine.

b. Solid Substances.

5. Carbon,
6. Sulphur,
7. Selenium,
8. Phosphorus,
9. Boron,
10. Iodine,
11. Bromine,
12. Silicon,
13. Fluorine.

c. Metals.

14. Potassium,
15. Sodium,
16. Lithium,
17. Calcium,
18. Barium,
19. Strontium,
20. Magnesium,
21. Glacinum, or Berillium,
22. Yttrium,
23. Allumium,
24. Zirconium,
25. Thorium,
26. Mercury,
27. Silver,
28. Gold,
29. Platinum,
30. Palladium,
31. Rhodium,
32. Iridium,
33. Osmium,
34. Nickel,
35. Iron,
36. Lead,
37. Tin,
38. Copper,
39. Zinc,
40. Bismuth,
41. Cobalt,
42. Antimony,
43. Arsenic,
44. Manganese,
45. Tellurium,
46. Titanium,
47. Cerium,
48. Uranium,
49. Columbium,

50. Tungsten, (Wolfram,)
51. Cadmium,
52. Chromium,
53. Molybdenum,
54. Vanadium.

And of these 54 elements the whole infinite variety of bodies is composed ! !

XXXI. The various chemical compositions arising from the combination of these elements may again be arranged under six different heads :

1. *Oxides.* This name is applied to all combinations of oxygen with another element. Thus, the combination of oxygen with iron is called *oxide of iron ;* that of oxygen with manganese, *oxide of manganese,* &c.

2. *Acids.* These are combinations of certain substances with acidifying (acid-producing) principles, commonly oxygen or hydrogen, and distinguish themselves by the following properties :

a. They have generally (not always) a sour taste.

b. Most of them are soluble in water ; and change blue vegetable colors into red.

c. They are all negatively electric ; (Natural Philosophy, Chap. IX.) *that is, they adhere to the positive or zinc pole of the voltaic pile.* (To understand this more completely see the remark on the following page.)

d. Combined with solid substances they form salts, or at least substances which bear a great resemblance to salts. The last mentioned properties are, by modern chemists, considered the most characterizing and essential qualities of acids.

3. *Bases.* To this class belong all substances remarkable for the following two properties :

a. When combined with acids they form salts ; and

b. When separated from a combination with an acid by the action of a voltaic battery, they adhere to the negative pole. *They are consequently positively electric.*

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[*] Not all acids have a sour taste ; neither do all acids necessarily contain oxygen, as it was once believed. *Prussic acid,* for instance, has a bitter taste, and contains no oxygen in its composition.

The learner ought to direct his attention particularly to the distinguishing characteristic between acids and salts; viz. that the acids are negatively, and the bases positively electric.

4. *Salts.* So are termed the almost innumerable combinations of the bases with the acids.

5. *Sulphides* and *Chlorides.* These are combinations of sulphur or chlorine with an element, commonly a metal.

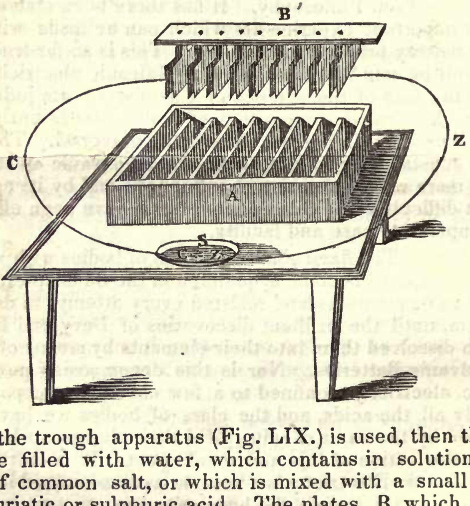
6. *Alloys of Metals.* These are combinations of one metal with another. The combinations of quicksilver with other metals have received the special name of *Amalgams.*

The theory of Galvanic electricity, as well as that of the voltaic pile or battery, has already been given in the ninth chapter of Natural Philosophy. It has there been stated, that the most important experiments which can be made with the galvanic battery belong to chemistry. This is so far true that it may well be said that the theory of Galvanic electricity has changed the face of the science of Chemistry. Its influence upon the chemical decomposition of bodies stands unrivalled by any other agent in nature, and is truly universal. There is hardly a substance in nature, upon which galvanic electricity does not more or less exercise its influence; and by its agency the most difficult chemical decompositions have been effected with comparative ease and facility.

Example. — The fixed alkalies, a class of bodies with whose properties we shall become acquainted in the 3d chapter, were believed to be elements, and resisted every attempt to decompose them, until the brilliant discoveries of Davy and Berzelius, who dissolved them into their elements by means of powerful Galvanic Batteries. Nor is this decomposing power of Galvanic electricity confined to a few chemical compounds; for nearly all the acids, and the class of bodies we have distinguished by the name of salts, yield their elements when exposed to the action of this universal agent. It is on this account, Galvanic Electricity has become a criterion (and indeed, as we have said before, the best criterion we have) of the basic or acid nature of a chemical substance. For whenever a salt is decomposed into its two principal constituents, the acid and the basis, the acid adheres invariably to the *positive*, and the basis to the *negative* pole of the galvanic battery. Now as the positive or zinc pole of the battery attracts only negative electric bodies, (see Natural Philosophy, Chap. IX.) and the negative or copper pole attracts positively electric substances, we conclude that all acids are in reference to the class of bodies which are called bases, negatively, and all bases in reference to the acids, positively electric substances. But it does not follow from this that a *basis* cannot of *itself* be attracted by either of the two poles, or that an acid cannot be composed of two elements, which evince again opposite electricities to each other. This as we shall soon see, occurs frequently enough; but it is sufficient for us at present, to understand the difference between an acid and a basis, as we shall revert to this subject again in the fourth Chapter.

We shall now describe the manner in which the combinations of the almost innumerable class of bodies which are characterized by the names of *salts* and *acids*, is effected by galvanic electricity. (See Natural Philosophy, Chapter IX.)

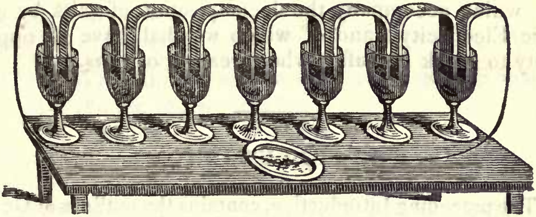
Fig. LIX.



If the trough apparatus (Fig. LIX.) is used, then the cells, A, are filled with water, which contains in solution a quantity of common salt, or which is mixed with a small portion of muriatic or sulphuric acid. The plates, B, which are fitted to these cells and connected by a slip of wood, are then let down into the cells, and the two conducting wires, Z and C, (of which Z is connected with the positive, or zinc pole, and C with the negative or copper pole) are brought in contact with the substance, S, which is to be submitted to the agency of the battery. Now if this happens to be a salt, it has been found that the acid of which it is composed adheres invariably to the positive or zinc pole, Z, and the basis to the negative, or copper pole, C, of the battery.

A very convenient apparatus of this kind, which may be at pleasure increased or diminished, is Count Stadion's *Couronne des Tasses*, or cup-battery. It consists of a number of cups of glass or wedgewood, (see Fig. LX.) In each cup is placed a plate of zinc, and another of copper, in such a manner that the metals do not touch each other in the cups; but are without connected with each other by slips of metal. The same order of plates zinc, copper, zinc, copper, &c, is of course preserved throughout the apparatus. When the cups are filled with a solution of salt or muriatic acid, then the effect is the same as that produced by the trough-battery. It is easily perceived that the strength of such an apparatus may be increased or diminished by employing a greater or smaller number of cups.

Fig. LX.



To account for the chemical decomposition of bodies by Galvanic Electricity, several ingenious theories have been invented, among which that of Sir Humphrey Davy deserves decidedly the preference. He supposes the elements of all chemical compounds to be originally possessed of opposite electricities. These opposite electricities are, by the chemical affinity which these elements have for one another, kept in a perfect state of equilibrium. But when such a compound is exposed to the agency of a galvanic battery, then the *attractive* and *repulsive force* of the two opposite poles, effect a separation of its elements; the *negatively electric* element flies to the *positive* or *zinc pole*, and the *positively electric* ingredient, to the negative pole of the battery. Those substances which adhere to the negative pole are then said to be *positively electric;* and those which adhere to the positive pole of the battery are called *negatively electric bodies.* Thus according to what we have said *all acids are, in reference to those substances which we call bases, negatively electric; and all bases are, in reference to the acids, positively electric substances.*

This theory, although there are several objections to it, is strongly corroborated by some very prominent phenomena, which accompany the decomposition of salts by galvanic Electricity; and of which we shall have an opportunity to speak hereafter when treating of salts.

RECAPITULATION.

[The preceding Introduction, contains the outlines of General Chemistry. It will therefore be well for the teacher to go over it a number of times — until he is perfectly satisfied that his pupils have understood the definition of chemistry, and can give a tolerably good account of the laws of affinity and chemical action. Not until then ought they to commence the study of the first chapter.]

I. Questions on Definitions.

[I.] Into how many classes are all natural sciences divided? What are these?

[II.] What is the object of Natural History? Which are the three great branches of Natural History?

[III.] What is the object of Natural Philosophy? Into what two branches has Natural Philosophy been divided? How do you define Chemistry?

[IV.] What do you call the peculiar kind of attraction which is only manifest in *contact*, and which is the cause of a change in the properties of bodies?

Give an example.

[V.] In how many different ways does the chemical affinity which one body has for another manifest itself? What are these two ways? What is the first of these processes called? What the second?

Give an example of chemical composition or synthesis.

Give an example of chemical analysis.

What is the difference between mechanical and chemical separation? Give instances of mechanical and chemical division.

[VI.] What are the parts obtained by a chemical separation or analysis called? What is the body called from which they are derived?

Give an example.

[VII.] When do you call a body composed of nearer and more remote ingredients?

Give an example.

Which, in your example are the nearer, and which the more remote ingredients?

[VIII.] What are those substances called which are not, as yet, decomposed by any means in our power? Does it follow from this that all substances which are *now* considered as elements are really incapable of analysis?

What then does the word element express in chemistry?

II. Questions on Chemical Action.

[IX.] What kind of attraction must be considered as the principal cause of all chemical phenomena? What changes does chemical affinity produce on bodies which are subjected to its action?

[In the answer to this question the pupil ought only to enumerate the three principal changes, *a*, *b*, *c*, printed in italics.]

Give examples of changes produced in the temperature; of changes produced in the physical properties of bodies; and of changes produced in aggregate form of bodies.

[X.] Does chemical action ever take place without a change of temperature? What important fact do you know respecting it? Does heat generally favor or counteract chemical affinity?

Give examples.

[XI.] What is the greatest obstacle to chemical affinity? Why do bodies combine readiest with each other, when one or the other has been reduced to the fluid state? Why does heat increase the action of chemical affinity?

What general inference has been drawn from this? Is this rule without exception?

What would take place if there were no cohesive attraction to counteract the chemical affinities of bodies? How must chemical affinity and cohesive attraction be considered in reference to each other?

[XII.] When are two bodies said to be *neutralized*? *Give examples of neutralization.*

In what state are potash and sulphuric acid contained in the salt which is formed by their combination? What is necessary in order to effect a complete neutralization?

[XIII.] What are those combinations called, in which the ingredients still preserve a portion of their original properties?
Give an example of such a combination.

[XIV.] To what must we have recourse in order to decompose a chemical compound into its constituent parts? What is that kind of chemical attraction called, in consequence of which a body quits a combination already existing, for the sake of forming a new one? Why is this attraction called *elective* affinity?
Give an example of the action of elective affinity. (Explain the figure, page 7.)

What substance, in your example, shows an elective affinity for potash? Why?

[XV.] What is the product of the combination of a solid body with a fluid called? Does the affinity between a solid and a liquid substance continue forever, or is it limited to a certain point? How is that point called, beyond which the solving power of the liquid ceases to operate upon the solid? What is the solution itself said to be, when arrived at this point?
Give an example.

[XVI.] Upon what three things does the saturation of liquids principally depend? Is there no exception to the general rule, that heat increases the solving power of liquids?
Give examples.

[XVII.] What do some compounds of two substances require for their decomposition? When is this the case? What do you call this kind of affinity?

Give an example. (Explain the table on page 9.)

To what do some philosophers ascribe these phenomena? Why?

What substance in your example (page 9) exercises a predisposing affinity upon oxygen? Why? By what means does the acid predispose the oxygen for a combination with the zinc?

[XVIII.] What does frequently happen when two compounds are brought together in a state of solution? What is this compound action said to be caused by?

Give an example. (Explain the table on page 10.)

Which substance, in your example, does the acetic acid elect in preference to the lead, with which it was combined? Which substance does the sulphuric acid elect in preference to the zinc? And why is this action called *double* elective affinity?

[XIX.] In what other manner do bodies combine, besides forming mixtures, or dissolving others to saturation? What sort of compound do we always obtain from a combination in fixed proportions?

Give an example.

Do bodies always combine with each other in only one fixed proportion? *Give an example* where one substance combines with another in several fixed proportions?

Have similar fixed substances been discovered in the combinations of other bodies? And what has been observed in reference to these combinations? *What general principle are we enabled to lay down, from these observations?*

If the remainder of this section should be found too difficult for the beginner, it may be omitted until reviewing the first four chapters of the book. But it would be better for him if he could explain the example on page 12. If he has understood it well, let him take the substance B, in reference to A, C, D, E, and F, and determine from that the relation of A to C, to D, E, and F, &c. The better he understands this example, the better will he be able to comprehend the one which is taken from nature, and which consists of larger proportions.

Let the pupils now explain the table on page 13. — The teacher may also let them copy that table, and then ask the following questions: *Ques.* — Why are 37 weights of muriatic acid said to be an *equivalent* to 40 weights of sulphuric acid? Why are 40 weights of sulphuric acid an equivalent to 54 of nitric acid, or to 28 of phosphoric acid? Why are 28 weights of lime equivalent to 48 weights of Potass, or to 32 of soda?

What is the smallest number of weights of one substance called which combines to saturation with all other substances for which it has a strong chemical affinity? By what means is the chemical equivalent of a compound substance found, when the chemical equivalents of its elements are known?

Explain example I. *Explain example* II. *Explain example* III.

III. QUESTIONS ON CHEMICAL APPARATUS.

[XX.] *a.* What instruments are principally used for dividing bodies?

b. What instruments are used for separating liquids from solids. Explain the separatory funnel, (Fig. XVII, page 19) and its operation.

c. What apparatus is used for the liquefaction of solids.

[XXI.] *d.* What apparatus is used for evaporation and crystallization? Why must the form of evaporating dishes be flat? What is the process of evaporation called, when it takes place under the influence of heat? What apparatus is used for this purpose?

[XXII.] *e.* What is the most common apparatus used for collecting the volatile portion of a body which escapes through the process of evaporation? Describe Fig. XXV. Describe the *common still*, (Fig. XXVI.) What is the name of the instrument most commonly employed in distillation? Explain Figs. XXVII and XXVIII. What other apparatus answers most purposes for which retorts are used?

f. In what consists the apparatus for heating chemical substances? On what principle are both, the portable air-furnace with crucible stands, and the fixed wind-furnace constructed? What is the construction of the common lamp? What is the difference between a common lamp and a spirit lamp? In what consists the principal advantage of an Argand's lamp over a common lamp? For what purpose is the flame of an Argand's lamp covered with a cylindrical open glass?

How is Guiton's lamp furnace constructed? (Explain Fig. XXXVI, page 25.)

What is the name of the instrument which is used for producing a very intense heat with a common oil or spirit lamp? Of what does it consist? Explain its operation and the manner in which it is used.

What is the difference between Gahn's blow-pipe and the common blow-pipe? Explain Fig. XXXVIII. In what does the advantage of this apparatus consist?

What other still more convenient contrivance is there, than either the common or Gahn's blow-pipe. Explain Fig. XXXIX.

[XXIII.] How many different kinds of presses are used for extracting liquids from solid substances. Explain Fig. XL. Explain Fig. XLI.

What apparatus is frequently used when a solid substance is to be dissolved in a liquid? Describe Fig. XLII.

How is Brahma's Hydraulic press constructed? Explain Fig. XLIII.

[XXIV.] What apparatus is used for collecting gases? Describe Fig. XLIV. What other apparatus is used for collecting gases? Explain Fig. XLV. What application is made of Priestley's bell glass? Explain Fig. XLVI.

[XXV.] What other *apparatus* is used for various other chemical purposes? Explain Nicholson's portable balance Fig LVII. How is the specific gravity of a liquid determined by means of Nicholson's portable balance? (Explain the example, page 34.) How is Nicholson's balance to be used when the body whose specific gravity we wish to determine is a solid? (Explain the example on page 35.)

What sort of an instrument is the per-cent balance? How is it constructed? (explain Fig. LVII.) Can the scale which is used for one mixture of liquids be employed also for another?

[XXVI.] For what purpose are lutes employed? What kind of lute will answer for metallic vessels? What sort of lute will answer for liquids which are not corrosive? What composition makes a good resinous lute?

IV. QUESTIONS ON THE CHEMICAL COMPOSITION OF BODIES.

[XXVII.] To what class of bodies belong plants and animals? Of what are plants and animals composed? What are all inanimate substances merely composed of?

[XXVIII.] What characterizing properties have all inanimate bodies in reference to chemistry? (The answer to this question consists in the recitation of the three heads, 1, 2, 3, printed in italics.) Give an example of *binary* combinations of bodies. What characteristics, on the contrary, distinguish all organized bodies? How many different substances are there, which have thus far resisted all attempts to decompose them? What are they therefore called? How many of these elements are gaseous? How many are non-metallic solid substances? How many are metals?

If the teacher thinks fit, the pupils might now commit their names to memory, or they may also omit this, until the reviewing of the book.

[XXIX.] Under how many different heads may the various chemical compositions, arising from the combination of these elements be arranged? What are they? (The answer to this question consists in the enumeration of the six heads, Oxides, Acids, Bases, &c.

What substances are called oxides?

Give examples.

What substances are called acids? What are the characterizing properties of the Acids?

By what properties are those bodies distinguished which are called Bases?

What are salts?

What are sulphides and chlorides?

What do you understand by *alloys* of metals?

[Upon the remainder of this section the teacher need ask but a few questions, as the same subject occurs again in the 4th chapter.]

What becomes of all salts when exposed to the action of Galvanic Electricity? Why is galvanic electricity the best criterion of a salt or an acid? Describe the manner in which salts are decomposed by galvanic electricity? (Explain Fig. LIX.)

Of what does Count Stadion's Cup-battery (Couronne des Tasses) consist? (Explain Fig. LX.)

What is Sir Humphrey Davy's theory with regard to the electrical phenomena exhibited by all chemical compounds? What, according to this theory, are all those substances called which adhere to the negative pole of the galvanic pile? What, those which adhere to the positive pole?

What are all acids in reference to that class of bodies, which are called bases? What, all bases with regard to those substances called acids?

CHAPTER I.

OF THE PROPERTIES AND COMBINATIONS OF THE FOUR GASEOUS ELEMENTS, OXYGEN, HYDROGEN, NITROGEN, AND CHLORINE.

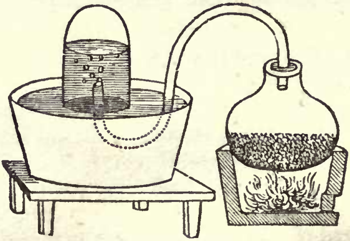
A. Oxygen.[*]

§ 1. *Properties of oxygen.* By the name of *oxygen* we distinguish a gas contained in our atmosphere, of which it constitutes about 21 per cent; (being the $\frac{21}{100}$ part of the whole atmosphere). It is also a component part of water, forming nearly $\frac{88}{100}$ of its whole weight. It is colorless, a little heavier than atmospheric air, and insoluble in water, and is destitute of either smell or taste. Its presence is absolutely necessary to the continuance of animal life; but breathed in its pure state it is injurious, because it affects the lungs.

§ 2. *Mode of obtaining oxygen.* Oxygen is obtained in a variety of ways, of which it will suffice to mention the following four:

1. From a substance called Chlorate of potash; by heating it in a retort and collecting the gas which is given off by means of the pneumatic tub.

Fig. LXI.



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[*] From a Greek word, signifying *formation* of acid.

When the Chlorate of Potash is heated it fuses, and gives off the oxygen in a very pure state, which is then, through the pipe, conveyed to the receiver, in the manner explained in the Introduction, page 30, Fig. XLIV.

2. From a substance called Red Oxide of quicksilver. The process is nearly the same as that just described.

3. From a substance called Black Oxide of manganese.

4. From a variety of *growing* vegetables when exposed to solar light, and from the green matter formed in stagnant pools, when immersed in water. This is an experiment requiring no other apparatus than a tumbler filled with water; if at hand, Priestley's bell-glass is best adapted for it, having a contrivance at the neck, by which means the gas may be introduced into another vessel or a bladder. (See Fig. XLV, page 30.)

§ 3. *Combinations of oxygen. Oxygen combines with nearly all simple and compound bodies.* The process by which this combination is effected is called the *oxygenation* of bodies. This oxygenation is sometimes accompanied by the phenomenon of fire, (by light and heat) in which case it is termed *combustion.* The products of the different combinations of oxygen with other elements are either *oxides* or *acids;* according to the different proportions in which the oxygen combines with them.

Example. — Carbon combined with oxygen gives 1 oxide and 3 different acids. Sulphur combined with oxygen gives 4 different acids. Iron forms with it 2 different oxides, &c.

§ 4. The different oxides and acids arising from the various combinations of oxygen with other substances, have each received a particular name, indicative of the proportion of oxygen contained in the combination. The oxides are termed ***Protoxides*, *Deutoxides*** and ***Peroxides*.** The name of Protoxide is given to the smallest quantity of oxygen combined with another substance; that of Deutoxide denotes the next greater quantity of oxygen combined with it; and the name of ***Peroxide*** is applied to the greatest proportion of oxygen which an oxide is capable of holding. With regard to the acids, we are in the habit of distinguishing them by their terminations, in *ic* or *ous;* or by putting the Greek preposition *hypo* (signifying *under)* before the name of the acid. The name of the acid ending in *ic* indicates the highest degree of oxygenation; that terminating in *ous* indicates the next lower degree; a still lower degree, if there be any, is expressed by the preposition *hypo.*

EXAMPLE. — The gas called nitrogen forms with oxgyen three different acids, which, according to the degree of oxygenation (the quantity of oxygen contained in their composition) are called nitr*ic* acid; nitr*ous* acid, and *hypo*-nitrous acid. Nitric acid indicates the highest degree of oxygenation; nitrous acid the next lower, and hypo-nitrous acid the lowest degree.

Theory of Combustion.

§ 5. It has been said before (§ 3) that the combination of some bodies with oxygen is accompanied by fire — in which case it is called the *combustion*, or *burning* of bodies. *The combustion or burning of bodies, therefore consists in their sudden combination with oxygen.** Every body capable of such a combination is called *a combustible* substance.

Phlogiston of the ancients. — The ancient chemists ascribed the process of combustion, or the phenomenon of fire, to a particular substance which they called phlogiston. But this theory has long ago been exploded; and it is now generally taken as an established fact that this phenomenon is produced, as we have said before, by the sudden union of oxygen with a combustible body.

§ 6. *Degree of temperature necessary for combustion.* There are bodies which combine with oxygen to combustion without being previously heated (as is, for instance, the case with a substance called sulphuretted hydrogen); *most bodies, however, require for this purpose a certain high degree of temperature.*

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* We shall see hereafter that the gas termed chlorine is in a certain measure capable of producing similar phenomena.

Example. — Sulphur, wood, coal, phosphorus, &c, must first be heated to a certain degree of temperature before they exhibit the phenomenon of fire. But when these bodies are once heated, they generally give out sufficient heat to keep up the degree of temperature necessary for their combustion.

Fig. LXII.

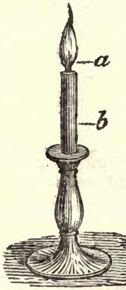
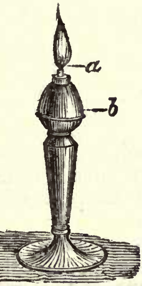


Fig. LXIII.



The chemical process of a burning candle (Fig. LXII,) or lamp, (Fig. LXIII,) is this: The wick *a*, is lighted by a piece of burning paper or wood. By this means the surrounding particles of fat or oil are heated to the boiling point, (Natural Philosophy, Chap. VI,) and thereby decomposed as all animal substances, into inflammable gases. These combine with the oxygen of the atmosphere and produce the phenomenon of light, commonly called the *flame* of the candle. This flame gives out sufficient heat to keep the degree of temperature necessary for the decomposition of another portion of the fat or oil; and so does this process continue until the whole candle or oil is exhausted.

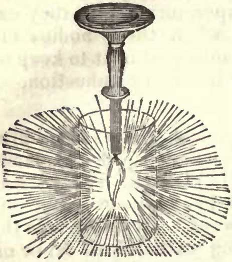
§ 7. *Light given out by the combustion of bodies.* The light which is given out by different substances during the process of combustion is subject to variation in intensity and color.

Examples. — Phosphorus, zinc, and arsenic give out a *white* light; the flame of sulphur is *blue;* that of selenium *azure;* &c.

The color of the flame does not only depend on the burning substance, but also upon the degree of heat produced by its combustion. Most combustible bodies when *moderately* heated burn with a yellow or blue flame; particularly if there be no draft to supply the flame with fresh quantities of oxygen.

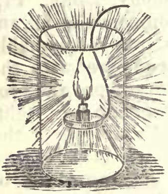
§ 8. *Combustion in oxygen. All combustible bodies burn in oxygen with increased splendor.*

Fig. LXIV.



Example. — A small piece of wax taper with its flame blown out, but its snuff still red hot, when immersed into a vessel filled with oxygen, is instantly rekindled, and throws out a most vivid light. (See Fig. LXIV.)

Fig. LXV.



A piece of sulphur or phosphorus, let down into a jar filled with the same gas will burn with indescribable brilliancy. (See Fig. LXV.)

In order to perform these experiments a common bottle or jar may be filled with the gas by means of the pneumatic tub. (Intr. page 30.) Through the cork of the bottle a piece of wire may be made to pass, containing at its lower end the body which is to be immersed. (See the next figure.)

Another Example. — Iron, which only burns at very elevated temperatures, needs but a red heat to burn in oxygen gas with a light which is almost as dazzling and insufferable to the eye as the sun itself.

Fig. LXVI.

A faint representation of it is given in Fig. LXIV. A piece of piano-wire spirally twisted, is introduced air-tight through the cork, *a*, of a bell-glass or receiver filled with oxygen gas. To the lower end of this wire is attached a piece of thread, touched with sulphur or wax, to ignite the wire in the first instance. As the gas is a little heavier than atmospheric air, its escape or mixing with the atmosphere is prevented by placing the receiver in a basin filled with water. If we were to employ a common jar for the same experiment, then the little globulæ of melted wire which drop during the process of combustion, would melt the glass, or if the bottom of the vessel be thin, fuse a hole through it, without breaking the glass.

Query — What do all these examples prove, in reference to the heat produced by the burning of substances in oxygen gas? *Ans.* — These examples prove that the heat given out by the combustion in oxygen gas is incomparably more intense than that thrown out by combustion of the same substances in atmospheric air. *Query* — And what would become of our grates, stoves, or iron forges, in short, of all the labors of the blacksmith, if our globe was surrounded by pure oxygen? *Ans.* — Our grates and stoves would burn and melt the moment they would get red hot; and as to the labors of the black smith, they would be entirely out of the question; — for in order to shape iron, it must first be made red hot (it being exceedingly hard in its natural state); and the moment it would get red hot it would begin to burn and melt into balls.

§ 9. *If the whole product of combustion is weighed it is always found to be heavier than the substance was before the combustion.* Thus, when a piece of wire is burnt in oxygen its weight is found to increase by 40 per cent, — that is, 100 grains of iron before the combustion, weigh 140 grains after it. The reason of this change in the weight of iron, is because 40 grains of oxygen gas combined with it during the combustion. A similar increase of weight is noticed in all bodies which are burnt in oxygen gas, and corresponding changes take place at every combustion in atmospheric air. To this general rule it cannot be objected that the ashes obtained from burning wood, straw or other substances weigh generally much less than these substances did before they were burned; because when these bodies are burnt in the open air, we do not obtain the whole product of their combustion. A great quantity of inflammable gas which is always given off during their combustion, escapes through the chimney or in the air. But when these are collected and their weight added to that of the ashes, then the sum of these united weights is always greater than that of the wood, straw, or other substance before the combustion.

§ 10. *No combustion can take place without the pres-*

ence of oxygen; the process of combustion, therefore, can only be continued as long as there is a sufficient quantity of oxygen to support it.* This follows immediately from what we have said in § 5. For if every combustion consists in the combination of oxygen with a combustible substance, it is self-evident that no such process can take place unless a sufficient quantity of oxygen is present. Moreover we can mark the actual consumption of oxygen gas during combustion by a very easy

Fig. LXVII.

Experiment. — Take a common bell-glass or receiver, through the cork of which introduce a piece of bent wire, supporting at its lower end a small lighted candle, *a*, and place the whole over a basin of water. As the candle is burning, the water of the basin will rise in the receiver, so that if a small scale be introduced into the latter, the rising of the water will indicate the quantity of oxygen consumed.

Query — What does the rising of the water in the receiver prove? *Ans.* — It proves that a portion of the gas in the receiver is consumed by the flame of the candle. *Query* — Why? *Ans.* — Because without such a consumption of the gas no vacuum could be created in the receiver, into which the water could be forced by the external air.

Another Experiment. — Instead of oxygen, fill the receiver (in the last figure) only with common atmospheric air. The burning of the candle, although less vivid, will still consume a portion of air; the water will still rise in the receiver, although not so rapidly nor so high as when pure oxygen is employed; and the candle, after burning more and more faint, will finally become extinguished. When the quantity of air then remaining in the receiver is examined, it is found to have lost just $\frac{21}{100}$ of its volume, which is exactly the proportion in which oxygen is contained in atmos-

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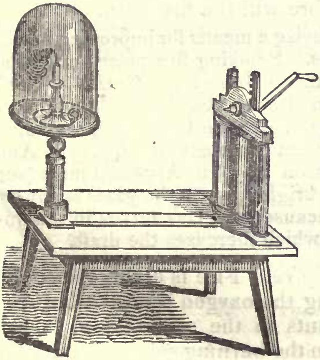
* We shall see in future that a few substances burn faintly in chlorine; but this can hardly be considered an exception to the general rule.

pheric air. (See § 1.) A burning candle now introduced into this air is instantly extinguished; small animals, birds, frogs, &c, introduced into it speedily die; in short, the remainder of the air in the receiver is totally unfit either to support combustion or the process of respiration of living animals.

Query — What does the slower burning of the candle in common atmospheric air prove? *Ans.* — It proves that the vividness and splendor of the combustion depend on the greater or less quantity of oxygen which is consumed? *Ques.* — But why does not the water rise as high in the receiver as when pure oxygen is employed? *Ans.* — Because the whole quantity of air in the receiver is not consumed by the burning of the candle; but only that portion of it which is pure oxygen. *Ques.* — And why does the candle become extinguished, when $\frac{21}{100}$ of the whole air originally contained in the receiver are consumed? *Ans.* — Because the air which then remains in the receiver is destitute of oxygen gas, and is on that account incapable of supporting either combustion or respiration. *Ques.* — What, therefore, is necessary in order that a complete combustion of bodies shall take place in atmospheric air or oxygen? *Ans.* — It is necessary that a fresh quantity of atmospheric air or oxygen should be supplied, while the process of combustion is going on.

Fig. LXVIII.



Another Example. — A burning candle introduced into the receiver of an air-pump (Fig. LXVIII,) burns slower and slower as the air in the receiver becomes more and more exhausted, (Natural Philosophy, Chap. V,) until finally it becomes wholly extinguished. A small animal or a bird introduced instead of the candle will be thrown into convulsions and expire. Gunpowder, phosphorus, and sulphur will cease to burn in the vacuum. An improper mixture of gases, in which the oxygen is not contained in a sufficient proportion, produces the same effect; because it is then unfit to support the process of combustion or respiration.

Query — What remarkable coincidence do you here observe between the process of respiration and combustion? *Ans.* — That oxygen is alike indispensable to the one and the other; for whenever the process of combustion discontinues from want of oxygen, that of respiration ceases also. *Ques.* -- What mode, therefore, may be devised for finding out whether a certain mixture of gases is respirable or not? *Ans.* — A burning candle may be introduced in it; when it continues to burn the gas will be respirable; when it is extinguished, or burns but dimly, then the gas will not be fit for respiration.

This is a convenient way for trying the air in old wells or in caverns, and cannot be too urgently recommended; many lives having been lost by omitting this caution.

§ 11. The quantity of air or oxygen necessary for the continuance of the process of combustion is supplied either by a draft or by means of bellows. We know from Natural Philosophy, (Chap. V,) that when a body is burning, the heated air which surrounds it becomes specific, lighter, and ascends, while a fresh portion of external air rushes in its place. This is called a *draft.* To facilitate it we build fire-places and chimneys. The higher the chimney is, or the greater the difference between the temperature of the air ascending in the chimney, and that of the surrounding atmosphere, the greater is the draft, and the better therefore will the fire burn.

Query — Could you now devise a means for improving smoking fire-places? *Ans.* — Yes. Smoking fire-places might be improved by heightening the chimneys. *Ques.* — Why? *Ans.* — Because this would create a better draft, adding thereby continually a new quantity of oxygen to the fire, and causing by that means a more perfect combustion. *Query* — And can you now explain the reason why an Argand's lamp (see Fig. XXXV, page 24,) burns brighter when the glass is put on, than without it? *Ans.* — Because the glass serves in this instance as a sort of chimney, which increases the draft.

§ 12. *Extinguishing of fire.* Fire is extinguished, as we have seen, by abstracting the oxygen from the burning substance, or, which amounts to the same thing, by excluding the atmosphere from the burning substance. This is effected by covering the combustible substance with another substance, through which the oxygen of the atmosphere cannot penetrate. For this purpose we commonly employ water, merely because it is readiest procured; but then it is necessary to use a sufficient quantity to cover the whole surface of the burning body.

Small quantities of water are of little or no use in conflagrations; but, on the contrary, rather contribute to increase them; because red hot coal, as we shall see hereafter, decomposes water into hydrogen and oxygen; the latter of which substances adds necessarily to the rapidity of the flames. (§ 7.) It is for this reason blacksmiths are in the habit of wetting their coal before using it.

§ 13. It has already been observed that some substances combined with oxygen without the phenomenon of fire. This is the case when the combination takes place *very slowly*.

It is in this manner many of the metals combine with oxygen at the mean temperature of the atmosphere. Sodium, potassium, iron, lead, tin and manganese are oxidized without giving out any observable degree of heat or light. Another substance, (which we shall become acquainted with in the course of this work) termed nitric oxid, combines with oxygen at the greatest cold; while carbon unites with it at a temperature exceeding 656 degrees Fahrenheit, without the phenomenon of fire.

§ 14. It remains for us to speak of the process of *desoxidation*, which consists in *separating* the oxygen from a body with which it is combined. It is effected two ways:

1. *By heat.* This is the case with the oxides of the precious metals, silver, gold, platinum, &c.

2. By the admixture of a third substance, commonly potassium, for which oxygen has a great affinity. (See Art. Potassium, Chap. III.)

The different combinations of oxygen with other substances will be spoken of when treating of these substances.

B. Hydrogen.

§ 15. When water is subjected to the action of Galvanic Electricity, it is, as we have had occasion to remark before, decomposed into two distinct gases, whose properties are in every respect directly opposite to each other. These two gases are *Hydrogen** and *Oxygen.*

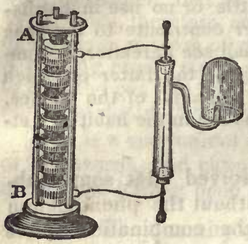


Fig. LXIX.

The *experiment* may be made either by means of a voltaic pile, (Fig. LXIX,) or by a trough battery (see Fig. LIX, page 40). When the voltaic pile is employed, the apparatus represented in Fig. LXIX, in which the two poles A, B, are introduced into a cylindrical tube filled with water, is very convenient.

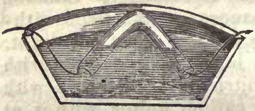


Fig. LXX.

When the trough-battery is used, the two poles of the battery are introduced into a bent glass tube, shaped like a V,(see Fig. LXX.) This tube is first filled with water and then inverted and held over a basin filled with the same liquid, which in this case answers the purpose as a pneumatic tub. The two gases, hydrogen and oxygen, into which the water is decomposed, rise in little bubbles to the top, but are in both instances obtained in a state of mixture.

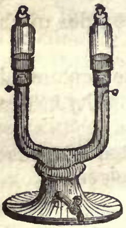


Fig. LXXI.

To obviate this we make use of an apparatus represented in Fig. LXXI. The two poles of the galvanic battery are brought in contact with two brass knobs, A and B, which by means of thin platina wires melt into the glass, communicate with the water in the bent tube. Each of the extremities of the tube is fitted to a small jar, closed with a stopper, and the whole apparatus is filled with water. When the battery is set in motion, the water in the tube becomes decomposed,

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* From a Greek word, signifying formation of water.

and forms two distinct gases; but by a fixed law of electrical attraction (mentioned before in Intr. page 41,) one of these gases, the hydrogen, always collects about the negative or copper pole, and on that account rises in little bubbles in the jar which is connected with that pole; while the oxygen follows the electric attraction of the positive or zinc pole, and collects in the other jar. By the aid of this apparatus the two gases are obtained separately, and may be examined for the sake of various chemical purposes. What is most remarkable about this decomposition of water is, that the volume of hydrogen gas thence obtained, is always exactly double that of the oxygen, from which we infer that in water *two* volumes of hydrogen are combined with *one* volume of oxygen. But about this we shall soon have occasion to say more.

Properties of Hydrogen Gas.

§ 16. When hydrogen gas is examined in its pure state (as obtained from the decomposition of water by galvanic electricity), it is found to be destitute of color, taste, or smell. It is much lighter than atmospheric air, only one sixteenth as heavy as oxygen — and indeed the lightest ponderable substance in nature.* It is highly combustible (§ 5), and when ignited (kindled) by a burning substance, or an electric spark, burns with a yellowish flame and gives out great heat. It is unfit for respiration, although it may be breathed for a short time with impunity. It is equally unfit to support the process of combustion, although it is, itself, a highly combustible substance. A burning substance immersed in it, is instantly extinguished.

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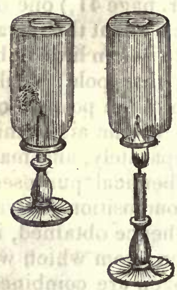
* In speaking of the specific gravity of bodies, we always suppose the pressure of the atmosphere equal to 30 inches of quicksilver, and its temperature equal to 60 degrees of Fahrenheit's thermometer.— (See Grund's Natural Philosophy, article Gravity.)

Fig. LXXII.



Experiment. — If a lighted candle or wax taper is brought near the mouth of a bottle or jar filled with hydrogen gas, the gas will instantly ignite at the mouth of the bottle; but the taper itself, when deeper immersed, will be extinguished. When the taper is drawn out, it will again be ignited by the burning hydrogen at the mouth of the bottle. This experiment may be repeated a number of times, until the gas is entirely exhausted.

Query — What does the inflammation (ignition) of the gas at the mouth of the bottle prove? *Ans.* — It proves that hydrogen is a highly combustible substance. *Query* — And what does the extinguishing of the candle when *immersed* in hydrogen, show? *Ans.* — It shows that although hydrogen is, itself, a highly inflammable gas, it is not capable to support the combustion of other substances.

Fig. LXXIII.

Another experiment, which shows that the specific gravity of hydrogen is much less than that of atmospheric air, may be performed by filling two common beer or wine glasses (Fig. LXXIII,) with this gas, and placing them, one with its open mouth up, and the other down. In a few minutes the gas will have entirely escaped from the glass B, which is placed with its mouth up — but it will still be found in the one, A, which has its mouth turned downwards. This may be easily ascertained by applying the flame of a candle to the mouth of each glass. The hydrogen contained in the glass, A, will burn; but in B there will be nothing but atmospheric air, which of course will not ignite.

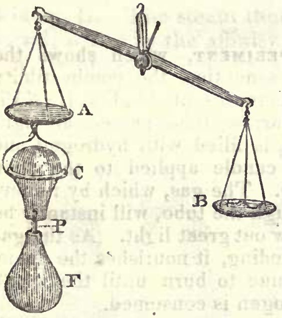
Query — Why has the gas escaped from the glass which has its mouth up? *Ans.* — Because hydrogen being much lighter than atmospheric air, would naturally ascend as a piece of wood does, when placed under water. *Query* — But why does the gas remain in the glass with its mouth down? *Ans.* — Because a vessel filled with hydrogen, having its mouth turned downwards, may be considered as closed; for the escape of the gas is prevented from above, and the pressure of the heavier atmosphere does not permit it to descend below.

Fig. LXXIV.

Query— In what manner then can you transfer hydrogen gas from one vessel to another? *Ans.*— It is only necessary to place the mouth of an open vessel or receiver, B, (Fig. LXXIV,) over the open neck or mouth of another vessel or jar, A, filled with the gas. The gas will, on account of its levity, escape thrrough the neck of the vessel, A (through which, for convenience sake, an open tube may be made to pass), and ascend in the receiver B, from which it will expel the atmospheric air.

Another Experiment, which shows the levity of hydrogen gas, and at the same time enables us to find its specific gravity is the following.

Fig. LXXV.



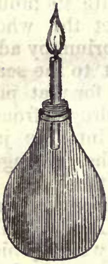
Take an open jar or phial, C, which attach to one scale of a common balance with its mouth downwards, and set the whole apparatus in equilibrium by adding as much weight to the scale B, as is necessary for that purpose. Conduct hydrogen from a Florence flask, F, into the jar. In proportion as the hydrogen ascends through the pipe, P, and expels the atmospheric air from C, the scale B will sink; and by marking the weight which it is finally necessary to place upon A, in order to restore the equilibrium, we determine the difference between the weight of atmospheric air previously contained in it, and that of an equal volume of hydrogen gas.

This will enable us to find the specific gravity of hydrogen. For when the weight of the atmospheric air in the jar A is known, (which may be easily obtained by finding what the jar weighs when the air is exhausted from it) it is only necessary to find the weight of an equal volume of hydrogen; which we obtain by subtracting the loss of the jar when filled with that gas, from the weight of the atmospheric air contained in it. The weight of the gas thus found, divided by that of atmospheric air, gives the specific gravity of hydrogen. This you will probably better understand from an

Example. — Supposing the jar, when the air is exhausted from it, loses $14\frac{4}{10}$ grains; supposing further, that by introducing the hydrogen, instead of the atmospheric air, the jar loses $13\frac{4}{10}$ grains. *Query.* — What is the specific gravity of hydrogen? *Ans.* — By the first supposition it is evident that the atmospheric air which is contained in the jar weighs $14\frac{4}{10}$ grains; by the second it is plain that the weight of an equal volume of hydrogen is only 1 grain; because 1 grain and $13\frac{4}{10}$ grains (the difference) make $14\frac{4}{10}$ grains; consequently the specific gravity of atmospheric air is to that of hydrogen as $14\frac{4}{10}$ is to 1; or in other words, atmospheric air is more than 14 times heavier than hydrogen.

Dividing 1 by $14\frac{4}{10}$, or, which is the same, $\frac{10}{10}$ by $\frac{144}{10}$, we obtain $\frac{10}{144} = 0{,}069$ for the specific gravity of hydrogen expressed in decimals.

Fig. LXXVI.

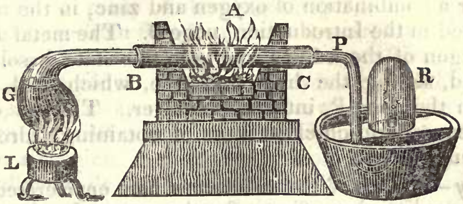


Another Experiment, which shows the levity, and at the same time the combustiblity of hydrogen gas, is represented in Fig. LXXVI. A jar with a narrow tube passed air-tight through its cork, is filled with hydrogen, and the flame of a candle applied to the open end of the tube. The gas, which by its levity escapes through the tube, will instantly be kindled and throw out great light. As the gas is gradually ascending, it nourishes the flame, which will continue to burn until the whole quantity of hydrogen is consumed.

§ 17. The decomposition of water by galvanic electricity is not the only means of obtaining hydrogen gas, for in this manner it is only obtained in small quantities; although in its purest state. There are yet two principal ways of procuring this gas, which we shall now explain.

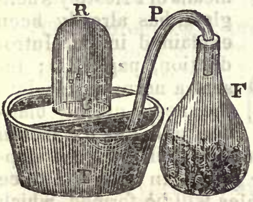
The first is by suffering the hot vapors from boiling water to pass through an iron gun-barrel; by which means the steam becomes decomposed into hydrogen and oxygen gas; the oxygen combines with the iron and the hydrogen is

Fig. LXXVII.



given off. This is the commonest way of obtaining it. Fig. LXXVII represents the apparatus used for this purpose. B C represents the gun-barrel, which contains in its centre a piece of coiled iron-wire, and is placed across a portable wind-furnace, for the purpose of heating it red hot. The retort, G, the neck B, of which fits air-tight into the barrel, B C, is partly filled with water which is heated and converted into steam by means of an Argand's or spirit lamp, L. The steam thus formed is conducted into the barrel, where by the affinity of the red hot iron for oxygen, it is decomposed into its gaseous elements, oxygen and hydrogen; the former combining with the iron, and the hydrogen passing through the pipe P, and the pneumatic tub, into the receiver, R.

Fig. LXXVIII.



A still more convenient way of obtaining hydrogen gas in great quantities is the second, represented in the adjoining figure LXXVIII. It consists in decomposing water by means of zinc* and sulphuric acid. For this purpose a few small pieces of zinc, and about a gill of water with nearly one fifth as much sulphuric acid, are placed in a common Florence flask F, through the neck of which a small pipe, P, leads to the receiver, R. The hydrogen is in this case formed by the decomposition of water by the joint action of the zinc and the sulphuric

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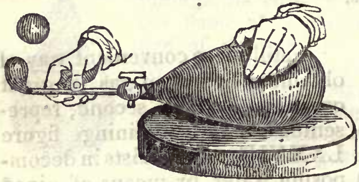
* Iron filings, nails, or tacks, are also frequently used for the same experiment, instead of the zinc.

acid. This is effected by a *predisposing affinity* of the acid for a combination of oxygen and zinc, in the manner explained in the Introduction, page 9. The metal attracts the oxygen of the water; and is in this state dissolved by the acid, setting the hydrogen free, which will escape through the pipe P, into the receiver. This is one of the cheapest and quickest ways of obtaining hydrogen in large quantities.

Query — Which of the substances here enumerated exercises a predisposing affinity for the oxygen? *Ans.* — The acid; because it predisposes it for a combination with the zinc.

§ 18. *Application of hydrogen gas to Aerostatics.* The great levity of hydrogen gas has given rise to one of the boldest undertakings which ever characterized human intrepidity — that of attempting to navigate the atmosphere. A small ball filled with hydrogen, provided it be not made of too heavy a material, will be lighter than the atmospheric air which surrounds it, and will therefore be forced upwards by the pressure of the atmosphere. This you may see from the following

Fig. LXXIX.

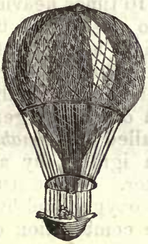


Experiment. — Fill a bladder with hydrogen gas (how this is done by means of Priestley's bell-glass, has already been explained in the Introduction, page 31); insert a narrow pipe into the neck of the bladder, and dip its mouth in a solution of soap and water; you may then open the stop-cock and by squeezing the bladder gently, in order to force the gas into the solution, small bubbles will be formed, which will rapidly ascend in the air.

Upon this experiment is founded the construction of balloons for ascending in the air. The whole consists in confining hydrogen gas in a spherical cover, which must be sufficiently thin and light, in order that with the hydrogen gas which it contains, it shall weigh less than the quantity of atmospheric air which it displaces (Natural

Philosophy, Chap. IV). For small experiments, a balloon may be made of thin letter-paper; but then it must at least have from 6 to 7 inches diameter, otherwise it will not rise. Such a balloon may weigh from 35 to 36 grains, and contain about 5 grains of hydrogen. This will be sufficient for its ascent, because its whole weight will only be little over 40 grains, whereas the quantity of atmospheric air which it displaces is more than 50 grains. If the balloon is destined to draw up other heavy bodies, then it requires, of course, a much larger diameter. The cover is then made of varnished silk, in order that the exterior air may be completely excluded from it. A balloon of 20 feet in diameter may contain 4190 cubic feet of hydrogen gas, and will be capable, in addition to its own tegument, to carry with it 255 lbs. of other substances, such as ropes, and a small boat in which a man may be seated without inconvenience. If the balloon is 30 feet in diameter then it may contain 14,142 cubic feet of hydrogen gas, and carry a burthen of nearly 1000 lbs. Several persons may then be seated in the boat, or basket, attached to the balloon, and ascend several thousand feet in the atmosphere with astonishing rapidity.

Fig. LXXX.



The hydrogen gas prepared for this purpose, is generally obtained from a mixture of iron or zinc (commonly the former) with sulphuric acid and water — 12 oz. of iron and as much sulphuric acid, with 2 lbs. of water are supposed to yield 1 cubic foot of the gas.

Mixture of Hydrogen with Oxygen — Inflammable gas.

§ 19. Hydrogen mixes with oxygen in all proportions; and such is the affinity between these two substances that although hydrogen is 16 times lighter than oxygen, it remains throughout equally diffused in oxygen, contrary to the laws of aerostatics (see Natural Philosophy, Chap. IV). This may easily be shown by the following

Fig. LXXXI.

Experiment. — Take two glass phials, *a*, *b*, into the corks of which insert a narrow glass tube, several inches long. Fill one of these phials with oxygen and the other with hydrogen. Place that which is filled with oxygen with its mouth upwards and insert in it the cork with the tube; the second cork at the other end of the tube, fit to the mouth of the phial filled with hydrogen gas, which must be placed with its mouth downward. Now according to the laws of gravity, the oxygen, which is the specific heavier body, ought to remain in the lower phial, and the hydrogen ought to remain in the upper; but quite the reverse takes place. The hydrogen decends, and the oxygen ascends, although oxygen is 16 times heavier than hydrogen. After several hours the two gases will be equally diffused in both phials; and when a light is applied to either of them an explosion will take place, which will be strongest and loudest when the two gases are mixed in the proportion of two volumes of hydrogen with one of oxygen. Such a mixture of hydrogen and oxygen is called *inflammable gas.* The product of its combustion, when ignited by an electric spark, or the flame of a candle, is water. Hence it is not only in our power to *decompose* water into oxygen and hydrogen, but we can also *reproduce* it by the combination of hydrogen with oxygen in a proper proportion.

Several chemists have attempted to account for the explosion which accompanies the combustion of inflammable air. A very plausible reason on this subject is given by Mr Schubert, Professor of Chemistry in Berlin. He attributes the explosion to the steam which, in his opinion, is forming during the combustion. For the heat which is given off when the gas is ignited is so great that the water which is formed is instantly converted into steam; this expands itself suddenly; but upon being brought in contact with the colder air is suddenly condensed and creates a vacuum, into which the surrounding air rushes with great violence.

§ 20. When one volume of hydrogen gas is mixed with two volumes of atmospheric air, another inflammable gas is formed, whose effects, however are much inferior to those of the mixture we have just spoken of.

Fig. LXXXII.

Experiment. — Take a hollow tin vessel, shaped as represented in figure LXXXII, and fill it with hydrogen gas. Fit a cork to its mouth, and provide it in T with a touch-hole. When the flame of a candle or an electric spark is applied to the touch-hole T, the cork will be driven out with considerable force and with a loud report. This apparatus has received the name of the *Hydrogen-gun.*

Query. — What is the probable reason of the cork being so violently thrown out, by the combustion of the inflammable gas in the gun? *Ans.* — Because by the combustion of the hydrogen gas, water is formed; which, owing to the great heat given out, is instantly converted into steam; and probably expanded to such a degree as not only to make up for the condensation of the gases, (which have been consolidated into water) but also to exercise a considerable pressure upon the cork, which is by that means expelled.

From what we have said of the combustibility of hydrogen gas, and its inflammable mixture with atmospheric air — we may perhaps be able to explain the following

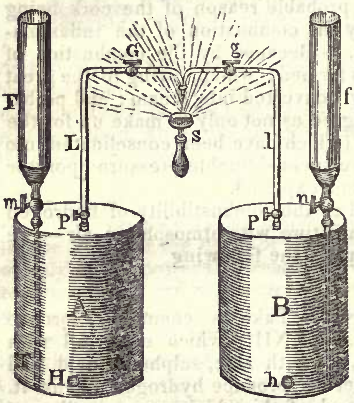
Fig. LXXXIII.

Experiment. — Take a common Florence flask (see Fig. LXXXIII,) which either fill with hydrogen gas, or with zinc, sulphuric acid and water, in order to produce hydrogen gas in it. Through the cork of this phial pass a small, narrow tube, through which the gas is allowed to escape; light the gas at the mouth of the pipe, and introduce the flame in a glass tube of sufficient diameter. As the hydrogen is burning in the tube musical sounds will be produced which will be grave or acute, according as the tube is long or short, or as the flame is deeper immersed in it. Some philosophers consider these sounds as a continued series of explosions in the tube; others consider them occasioned by currents of atmospheric air which are partly produced by the consumption of oxygen, and partly by the expansion and contraction of the heated air and steam in the tube.

Great caution must be used not to light the gas too soon, but to wait until the ascending hydrogen has expelled all the atmospheric air in the tube, otherwise inflammable air would be formed which would explode and burst the tube, and perhaps injure the experimenter.

When soap bubbles are blown with inflammable air (a mixture of hydrogen and oxygen) instead of hydrogen, (see fig. LXXIX, page 66,) and when floating in the air are touched by the flame of a candle, they give a report as loud as a gun, and sometimes even more loud and stunning.

Fig. LXXXIV.



§ 21. A most important application of the properties of inflammable air to chemical purposes is Hare's* oxy-hydrogen blow-pipe. It consists of two air or gas-holders, A, B, of which one is filled with oxygen, and the other with hydrogen. The two tubes, L and l, communicate with these gas-holders, have a common opening, and are each provided with a turn-cock, G, g, to regulate the discharge of the gases, either jointly or separately, and in any proportion we please. The substance, which is to be exposed to the action of this apparatus, is commonly placed upon a piece of charcoal directly under the common opening. The way of using this appa-

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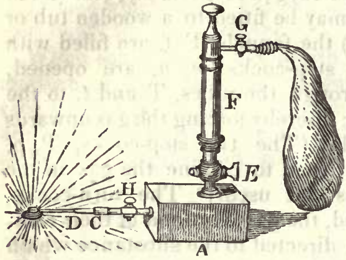
* Dr R. Hare, of Philadelphia, was the first who suggested the idea of constructing a blow-pipe with a mixture of hydrogen and oxygen. Long after him, in 1816, (Hare published his discovery in 1802,) Newman, an English chemist, constructed the compound blow-pipe, described on page 72, Fig. LXXXV. But Prof. Hare's apparatus has the vast advantage of being safe, convenient, and much less liable to the dreadful accidents which have already but too frequently occurred with Newman's apparatus.

ratus is this. When the two gas-holders, A and B, are filled with hydrogen and oxygen respectively, (for which purpose both gas-holders may be fitted to a wooden tub or cistern, filled with water) the funnels, F f, are filled with water, which, when the stop-cocks, *m*, *n*, are opened, is suffered to descend through the tubes, T and *t*, to the bottom of the gas-holders; thereby forcing the gas upwards into the pipes, L, and l. (The two stop-cocks, P, p, serve for no other purpose than to confine the gas in the holder when the pipe is not used.) The turn-cocks, G and g, being now opened, the gas is ignited at their common opening, and the jet directed to the substance which is to be exposed to its heat.

The effects of this apparatus surpass really the most sanguine imagination — the heat produced by it being in some instances even superior to that produced by galvanic electricity. Common iron wire exposed to the flame does not only instantaneously melt, but actually boils like liquid water; platinum wire melts so fast that it runs down in drops from 3 to 5 grains in weight! Incombustible substances, such as flint, crystal, opal, jaspis, sapphire, emerald, &c, are almost instantaneously converted into a glassy mass. Gold is totally vaporised — and even diamonds, which require for their ignition the most powerful galvanic batteries, are in a very short time wholly evaporated, when exposed to the burning jet of the compound blow-pipe. In short, the results obtained by this apparatus are so brilliant, and of so much importance to chemical investigation, that it must be classed among the most important and beautiful inventions, that have been made in the science of chemistry.

§ 22. The *Blow-pipe with condensed oxygen and hydrogen gases*, although not an original invention of John Newman (see the note on page 70,) is yet a highly useful and powerful apparatus, and one for whose improved construction we are indebted to this distinguished philosopher.

Fig. LXXXV.



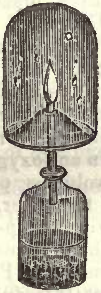
It consists of a strong gas-holder, A, commonly made of copper, which communicates by means of a turn-cock E, with a strong copper barrel, F, which is used as a compression pump. To the gas-holder, A, is fitted an extremely narrow pipe (about three inches long, and only one eighteenth of an inch bore), which, in H, is provided with a discharging-cock. The compression pump F, communicates by the turn-cock G, with a bladder filled with inflammable air — (1 volume of hydrogen mixed with two volumes of oxygen, see § 19).

When the apparatus is to be used, the two cocks, E and G, are opened, and the piston of the compression pump moved upwards. By this means the air from the bladder rushes into the barrel and thence into the gas-holder, from which the atmospheric air must previously be exhausted. The cock E is now closed and the piston of the compression pump moved down to compress the air in the gas-holder. When this is done, the cock E is closed, and G opened, when by raising the piston another portion of inflammable air rushes into the vacuum created in the barrel, which by a fresh stroke downwards is again forced into the gas-holder; and so can this operation be continued until the inflammable air in the gas-holder is sufficiently condensed for the purpose in view. The cocks, E and G are now closed, and the discharging-cock opened, and the gas, which rushes with great violence through the orifice of the pipe B C, ignited.

The effect of this apparatus on various substances which have been submitted to the heat produced by the burning jet, is in every respect equal, if not superior, to those produced by Hare's oxy-hydrogen blow-pipe; but the apparatus is an exceedingly dangerous one. For should the flame at the mouth of the pipe, C D, be by some means or other propagated to the gas-holder, then a dreadful explosion would take place, which would shatter the whole apparatus into fragments, and may be connected with the most distressing consequences to the experimenter. Prof. Hare's apparatus, on the contrary, is perfectly safe, produces nearly the same effects, and may be made equally powerful, if not more so, by providing each of the gas-holders with a compression pump, similar to that employed in Newman's blow-pipe.

Combination of Hydrogen with Oxygen — Water.

Fig. LXXXVI.



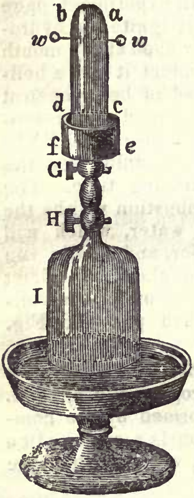
§ 23. **Experiment.** — Take a glass bottle filled with hydrogen, or in which introduce some zinc, with a proper quantity of sulphuric acid and water (as in experiment, page 65, Fig. LXXVIII); ignite the hydrogen which is then evolved at the mouth of the pipe, and conduct it into a bell-glass, which, instead of being open at the bottom, must be shaped as represented in the adjoining figure (LXXXVI,) having but a small opening for the mouth of the conducting tube. The product of the combustion will be the well-known liquid water, which will first appear as vapor, and finally run down the sides of the glass, and collect in small quantities in the cavities at the bottom of the bell-glass. (Compare the experiment described page 63, Fig. LXXIV.)

Query. — What do you infer from this experiment? *Ans.* — That the water is a compound of hydrogen and oxygen. *Query* — Why? *Ans.* — Because it is formed by the combustion of hydrogen: and every combustion is a combination of oxygen with the combustible substance, which in this case is the hydrogen.

§ 24. We have had occasion to remark before that hydrogen and oxygen are *evolved* by the decomposition of water (§ 15); we have now seen that water is *re-produced* from hydrogen and oxygen. It remains for us therefore only to ascertain *in what proportion* hydrogen and oxygen combine to water. We have stated in the Introduction, (page 11) that all definite compounds are formed by the combination in definite proportions of their elements —

and we have already observed from the experiment described on page 60, fig. LXXI, that a definite proportion of hydrogen and oxygen is obtained from the *decomposition* of water, which is *one volume* of oxygen to *two volumes* of hydrogen. If we are now able to show that the same proportion (two volumes of hydrogen to one volume of oxygen) is also preserved in the *combination* of these gases to water, then the chemical equivalent of water would be established beyond any doubt or controversy. This we are actually enabled to show by the following

Fig. LXXXVII.



Experiment. — Procure a very strong glass tube, *abcd*, fitted to a brass cap, *cdef*, and provided in G with a stop-cock. Two small holes must be drilled in the upper part of this tube, into which two small wires, *w*, *w*, must be cemented in such a manner that their points nearly touch each other on the inside. Provide a mixture of pure hydrogen and oxygen in the proportion of two volumes of the former to one volume of the latter, with which fill a jar, I, fitted with a stop-cock, H, to which the cock of the tube may be screwed, in a manner similar to Priestley's bell glass and bladder (Introduction, pages 30 and 31). Extract the air from the tube by an exhausting syringe or an air-pump, and screw it tight to the jar. When the two cocks are opened a portion of the mixed gases will rush into the tube; this it is best to extract again from the tube to make sure of the exhaustion of any remaining air. Place the tube again upon the jar, and by opening again both cocks, fill it another time with the mixture of the gases; and take great care to close both stop-cocks. Now pass an electric spark through the wires, and the gases in the tube will explode (2 0, page, 69). Allow the tubes to cool; after which let in a fresh portion of the mixture, which, when the cocks are closed may again be inflamed — and continue this process until a strong dew is seen upon the interior of the tube This upon examination you will find to be pure water.

If the two gases are mixed in the exact proportion of two volumes of hydrogen to one volume of oxygen, then the whole mixture will be consumed; but if the mixture be made in any other proportion, the excess of either gas will be left; because they combine in no other.

Query — Why must the glass tube in this experiment be stronger than in others? *Ans.* — Because it must resist the explosion of the gases when an electric spark is applied to them. *Query* — Why must the two stop-cocks be carefully closed before the electric spark is passed through the wire? *Ans.* — Because one volume of oxygen and two volumes of hydrogen form a highly explosive mixture (§ 20, page 69); consequently if the cocks were not closed the inflammation of the gases in the tube would communicate itself to the jar, and cause an explosion which would destroy the jar, and endanger the safety of the experimenter. *Query* — And what fact does this experiment tend to establish? *Ans.* — It establishes the indisputable fact that water consists of two volumes of hydrogen combined with one volume of oxygen, and that these gases combine in no other proportion to water than in that of two volumes of hydrogen with one volume of oxygen.

§ 25. The law which we have just found respecting the combination of hydrogen and oxygen corroborates what we have stated in the Introduction (page 11) in reference to the composition of all definite compounds. Now as hydrogen is the lightest ponderable substance in nature, it will combine in the smallest proportion by weight with all other substances; consequently, if the weight of hydrogen which combines with oxygen is taken for unity of comparison, the chemical equivalent of oxygen is 8; because 1 volume of oxygen weighs 8 times as much as the two volumes of hydrogen with which it combines; hydrogen being 16 times lighter than oxygen.* But the chemical equivalent of oxygen and hydrogen being known, that of water follows of course. This is composed of

1 equivalent of hydrogen equal to	1
and 1 equivalent of oxygen, equal to	8
consequently chemical equivalent of water equal to	9.

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* Two sixteenths is the same as one eighth; consequently the weight of the two volumes of hydrogen is only one eighth of the weight of one volume of oxygen; or, which is the same, the weight of the hydrogen employed is to that of the oxygen as 1 to 8.

In a similar manner have the chemical equivalents of other substances been determined in reference to hydrogen ; and we shall make it a rule for the remainder of this treatise, to write at the head of each substance, its equivalent number ; and if the body we treat of is a compound, then we shall besides this, affix the chemical equivalents of its elements.

Some philosophers have assumed oxygen as the standard of comparison, which being supposed equal to 100, the chemical equivalent of hydrogen is one eighth part of 100, or 12,5. Most English and American chemists however prefer the former method, on which account we have adopted it throughout this treatise.

§ 26. The composition and decomposition of gases follow a still more simple law, which is that of combining in *definite volumes*, instead of *definite weights*. Thus, when one gas combines with another, 1 volume of the one, combines always with 1, 2, 3, 4, &c, volumes of the other, and in no intermediate proportions.

§ 27. *Properties of water.* Water, in its pure state, is destitute of color, taste, or smell, and is on this account most admirably fit to be the natural drink of man. It is the most universal solvent in nature, (dissolves most solid substances) and absorbs many of the gases, such as hydrogen, oxygen, nitrogen, &c. A cubic inch of distilled (purified) water weighs about $252\frac{1}{2}$ grains. Its greatest density is at the temperature of 40 degrees ; it freezes at 32°, and becomes converted into steam at the temperature of 212° Fahrenheit. According to the nicest experiments, it is composed of $28\frac{6}{100}$ grains of hydrogen, and $224\frac{46}{100}$ of oxygen ; the volume of hydrogen is 1325 cubic inches, and that of oxygen 662 ; so that the condensation of these gases in the act of forming water, is nearly 2000 volumes into one !

Query — From what has just been observed respecting the enormous condensation of the volumes of the gases which are employed in the formation of water, can you now account for the great heat given off during the combustion of hydrogen ? *Ans.* — When hydrogen is burnt nearly 2000 volumes of gas (hydrogen and oxygen) are condensed into one ; by which means the heat which was hidden in the gas becomes sensible, and produces the astonishing effects of the compound blow-pipe, and the *explosive* mixture of hydrogen and oxygen.

We have said that the greatest density of water is at about 40° of Fahrenheit's thermometer. In this respect it makes an exception to all other liquids, which are known to contract as they cool down to their freezing points. (Natural Philosophy, Chap. VI.) This peculiarity of water is of the greatest influence upon the economy of nature. The water which nearly covers one third of the earth, becomes a most efficient means of equalizing its temperature, making those parts habitable which would otherwise be buried in perpetual frost, or scorched with insufferable heat. The cold air from the polar regions absorbs the heat from the great waters or lakes until they are cooled down to 40 degrees Fahrenheit. At this point the refrigerating influence of the atmosphere nearly ceases; because the uppermost stratum of water, by further cooling, becomes lighter (loses its density) and instead of sinking to the bottom, remains in a cake of ice suspended at the surface, preventing thereby the water below from being further exposed to the influence of the colder air. Without this peculiar property of water, the cold air would continue to rob it of its heat until the whole should be cooled down to 32 degrees, when it would at once settle into a solid mass. Every living creature in it would perish; the ice in the northern regions would never be liquefied, and navigation finally made impossible.*

§ 28. *Ice.* Water in the act of freezing or congealing (see Natural Philosophy, Chap. VI,) expands by nearly $\frac{1}{8}$ of its volume, and so great and violent is this expansion, that it bursts tubs, casks, water-pipes, &c, in which water is suffered to freeze. It also explains why trees and plants are destroyed in hard frosts, and such similar phenomena. The specific gravity of ice is less than that of water, viz, only $\frac{92}{100}$, or 0.92, that of water being 1. This is the reason why the ice remains at the surface of the water, and explains the phenomena alluded to in the preceding paragraph.

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* Library of Useful Knowledge, treatise on Chemistry.

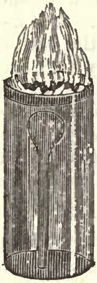
§ 29. *Rain, River, and Pump-water.* We distinguish yet between *Rain, River*, and *Pump* water. The purest of these is rain-water, because descending through the atmosphere, it is least exposed to the influence of other substances. Next to it comes River water, which however is often known to contain certain salts of soda, lime, and magnesia, of which we shall speak in the 4th Chapter. These two kinds of water are called soft water, in opposition to the *hard* pump-water, which contains always a greater or less quantity of carbonic acid. *Mineral waters* contain gases and salts in such proportions that they are only used as physics in medicine. *Sea water* contains a variety of salts. Among these are common salt, Glauber's salt, muriate of lime and of magnesia. The two last-mentioned ingredients give it that disagreeable taste and smell, which causes nausea and vomiting when taken into the stomach.

§ 30. All kinds of water contain atmospheric air (generally from 3 to 4 per cent), not indeed as a chemical ingredient, but mechanically mingled with their particles. From this water may be freed either by the air-pump, or by boiling. The latter method is preferable.

When water is brought under the receiver of an air-pump and the air is exhausted in the receiver, the particles of atmospheric air which are mechanically intangled in the water, rise in little bubbles to the surface and expand themselves in the vacuum created over the water, according to the laws of elastic fluids (Natural Philosophy, Chap. IV). The *boiling* of water consists in heating it until it becomes converted into steam. Just before this takes place the water is thrown into a violent agitation, partly occasioned by the expansion of the atmospheric air contained in it; little bubbles of air rise to the surface and escape along with the steam which is forming during the process of ebullition.

§ 31. Water, although a tolerably good conducter of Electricity, (Natural Philosophy, Chap. VIII), is a very bad conductor of heat. Of this we can easily convince ourselves by the following

Fig. LXXXVIII.



Experiment. — Place a small air-thermometer capable of showing very minute alteration of temperature, in a jar filled with water, so that the bulb of the thermometer may be a little below the surface. Upon this pour a small quantity of ether, which being specifically lighter than water, will remain on top and may be inflamed. The ether will burn for a considerable time without affecting the thermometer in any sensible degree.

It will indeed be quite a different case when the heat is applied to the water from below. In this case the thermometer is soon affected. But then it is not the conducting power of water which transfers the heat from the bottom of the jar to the surface and the thermometer; it is because the heated particles of water themselves are expanded and rise to the surface, while another portion of colder water sinks from the surface to the bottom and occupies their place. This motion can actually be observed by boiling water in which some particles of amber or of some other light substance are diffused, in a glass tube applying the heat from below. The particles of amber will be seen to rise from the bottom of the tube, being carried along by the particles of water to which they adhere, while those near the surface will be observed to descend with the colder particles of water. The same experiment may be made with other liquids, all of them being bad conducters of heat, and capable of being heated only in consequence of the mobility of their particles. (See Natural Philosophy, Chap. VI.)

Fig. LXXXIX.

Query — Could water be very well heated without the mobility of its particles, which enables those which are heated to ascend, making thereby room for the colder ones to descend and become heated? *Ans.* — No; because the conducting power of water in itself is very bad, as we have seen from the experiment described in Fig. LXXXVIII. *Ques.* — And what is the reason that the burning ether on the surface of the water in that experiment, does not materially affect the thermometer? *Ans.* — Because the heated particles on the surface of water, becoming specifically lighter, must of course, from hydrostatic principles, remain on top, and prevent thereby the next lower particles from ascending. And in this consists the whole difference between heating a liquid from below and above — (applying the heat at the bottom or at the surface).

§ 32. It has been stated in Natural Philosophy, Chap. VI, that the pressure of the atmosphere, or of steam, is an obstacle to the boiling of liquids and consequently also to the boiling of water. This has been stated as a reason why water boils sooner under the receiver of an air-pump, from which the air has been exhausted, or on the top of high mountains, where the pressure of the atmosphere is less than on the plain, &c; but we can illustrate this law still more strikingly and satisfactorily by the following

Fig. XC.

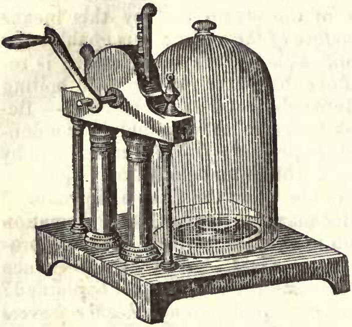
EXPERIMENT — Adapt a cork covered with a thick coating of sealing wax, to a glass flask, into which put water to the depth of about one inch. Place it over a lamp until it boils, and suffer the boiling to continue for a short time, after which introduce the cork air-tight and remove the flask from the lamp. The water will boil a little while after the heat ceases to be applied; but on plunging the flask into a jar filled with cold water or ice, the boiling recommences with great violence and continues until the water in the flask is nearly cold. If the flask is taken out before the boiling ceases, and is plunged into hot water, the boiling immediately stops; but upon being again introduced into cold water the boiling recommences with violence.

Query. — Why is the cork in this experiment introduced during the boiling of the water in the flask? *Ans.* — It is done in order to exclude the atmospheric air, and to prevent the escape of the steam with which the flask becomes filled when the water boils in it. *Ques.* — Why does the water continue to boil for a little while after the heat ceases to be applied to it? *Ans.* — Because when the flask is removed from the lamp, its sides come in contact with the cold atmospheric air, which condenses part of the steam, and by this means *lessens the pressure on the surface of the water*; this enables the water to boil for a short time, although its temperature is reduced. *Ques.* — But why does the water recommence boiling when the flask is plunged into cold water or ice? *Ans.* — Because the steam in the flask becomes then suddenly condensed, *removing thereby the whole pressure from the water*, and by that means throws it into a state of violent ebullition. *Ques.* — And why does the boiling cease when the flask is introduced into hot water? *Ans.* — Because this leads to the formation of a fresh quantity of steam in the flask, whose pressure prevents the boiling of the water. *Ques.* — And what inference should you draw from the experiment you have just explained? *Ans.* — *That water* (and all other liquids) *require higher degrees of temperature to boil under a heavy pressure of air or steam; and considerably lower degrees of temperature to boil when this pressure is removed from them.*

§ 33. Water absorbs constantly a portion of heat, with which it either combines, or through the medium of which it becomes converted into vapor. The quantities of heat or caloric thus absorbed by the large waters on our globe, tend in no small degree to moderate the temperature of the torrid regions, and to create an agreeable freshness near the banks of rivers and on the seacoast. This continued formation of vapors from the surface of water is called the process of *evaporation*, and it serves some of the most important purposes of nature. The vapors of water contained in the atmosphere form mists or clouds, which when brought in contact with the higher, and consequently colder strata of air, are condensed and descend again as dew, rain, or snow, to moisten our fields in summer, or to protect them during the winter; assisting thereby the vegetation of trees and plants, without which animal life itself would soon become extinct. (See Natural Philosophy, Chap. VI.)

The *refrigerating influence* of forming vapors of liquids may be illustrated on a small scale by the following

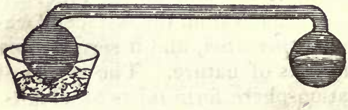
Fig. XCI.



Experiment. — Provide a watch-glass filled with water and place it over a shallow vessel filled with sulphuric acid, and bring the whole under the receiver of an air-pump. As the air is exhausted from the receiver vapors will abundantly rise from the water, which being speedily absorbed by the sulphuric acid (which has a great affinity for water) creates such a degree of cold as to freeze the water in a very short time. If instead of sulphuric acid we employ ether, the same effect will be produced ; but in this case the ether becomes vaporized, and absorbs such a quantity of heat from the water as to congeal it.

A still better illustration of the cold produced by the rapid process of evaporation may be given by means of an instrument invented by Dr Wollaston, and which has received the name of *Cryophorus* or *Frost-bearer*.

Fig XCII.



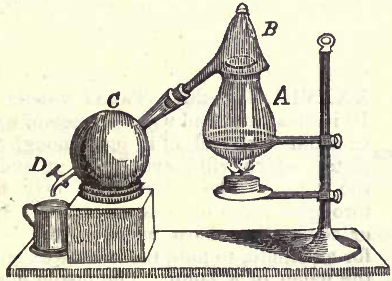
It consists of a narrow glass tube of from 18 inches to 2 feet in length, bent towards the end at right angles (see Fig. XCII,) and terminating on both sides in bulbs. One of these bulbs is about half filled with water ; this being made to boil expels the atmospheric air from the tube and the other bulb which remains filled with steam. The open bulb is then closed by means of a blow-pipe (see Fig. XXXIX, page 26). When the empty bulb of the instrument is now immersed in a mixture of salt and snow, the vapors contained in it are suddenly condensed, by which means a vacuum is created, which removing the pressure upon the surface of the water in the other bulb, produces such a rapid evaporation as to freeze the water in it although at a distance of 24 inches from the ice, and notwithstanding the slow conducting power of water.

The effects of evaporation are also happily illustrated in the process of perspiration. The natural temperature of the human body is from 96 to 98 degrees Fahrenheit; but when taking active exercise, or exposed to a fire, or the heat of a hot summer's day, this temperature would naturally be heightened to a degree which would be injurious to health. This, however, is prevented by the appearance of a watery fluid on the skin, which by its evaporation exercises a cooling effect on the body and reduces it to its healthy temperature.

Query — But why is it dangerous to be exposed to a current of cold air after the clothes have become moist with perspiration? *Ans.* — Because the rapid process of evaporation may then reduce the temperature of the body to a degree which may be equally injurious to health.

§ 34. *Distillation of water.* In order to obtain water in its pure state it is necessary to distill it. For this purpose we make use of a common still (see Fig. XXVI, page 22). Small quantities may be obtained by heating water in a flask A, over an Argand's lamp, and conveying the steam which is formed, through a pipe, P, fitted air-tight to the neck of the flask, into a receiver C, which for this purpose must be surrounded by water or other means of reducing its temperature. The steam formed by the boiling of the water in the flask is, in the receiver, again condensed, and descends as liquid water through the discharging cock, D, where it may be collected in a

Fig. XCIII.

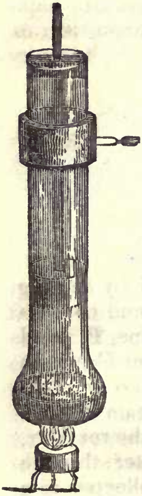


vessel. The water thus obtained is free from all impurities, salts, &c, which remain at the bottom of the flask A, after the water has been converted into steam, and is used for chemical and medicinal purposes.

§ 35. We have learned in Natural Philosophy (Chap. VI), that when water boils it ceases to assume a higher degree of temperature; all the heat further added becoming then hidden or employed in the formation of steam. But if the vessel is closed in such a manner as to prevent the steam from passing off, then the steam may be heated to a much higher degree, and being concentrated in a small space is capable of exercising an immense pressure This is taken advantage of in the construction of steam engines. Water may in this manner be expanded to nearly 1700 times its volume; 1 cubic inch of water giving nearly 1 cubic foot (1728 cubic inches) of steam.

The principal properties of steam may be exhibited by the following

Fig. XCIV.



Experiment. — Provide a glass tube of about three fourths of an inch bore, and from 7 to 8 inches long. Close it at one end, and enlarge it a little by blowing into it when softened by the heat of a blow-pipe (see Introduction, Fig. XXXVIII, page 26). Take a wooden rod about 10 inches long, and wrap a piece of wash-leather about one end of it, just enough to form a piston which will move freely up and down in the tube. The glass tube may be passed through a piece of cork wood, into which a fork or some other sharp instrument may be stuck for a handle, to hold the whole apparatus over the flame of a lamp. The piston must not be introduced in the tube until the air is expelled from it, by the boiling for some time of the water. The remainder of the tube being now filled with steam, introduce the piston a little way, and plunge the tube into water. The piston will instantly be driven down; but by holding the tube again over the flame of the lamp, the piston is again driven upwards, and so may the piston be alternately driven upwards and downwards by repeatedly heating and cooling the water in the bulb of the tube.

Query — Why is the piston in this experiment driven down when the tube is plunged into cold water? *Ans.* — Because by plunging the tube into cold water the steam is suddenly condensed and a vacuum created, into which the piston is forced by the pressure of the atmosphere. *Ques.* -- But why is the piston moved up again when the bulb of the tube is again held over the flame of the lamp? *Ans.* —Because the water in the bulb resuming the process of boiling, is again converted into steam which expands itself in the tube and forces the piston upwards. *Ques.* — What then is the principal cause of the prodigious power of the steam-engine? *Ans.* — The production and sudden annihilation of the steam formed in the boiler. (For the description of the steam engine, see the Appendix).

With regard to the other applications of water to the purposes of common life, we can only say that they are innumerable, as there is none of the arts which can dispense with it, and its presence is absolutely indispensable to the continuance of all animal and vegetable life on our globe.

§ 36. *Modes of ascertaining the purity of water.* Pure water being a great object to the physician, the chemist, and the manufacturer, it may perhaps be desirable to acquaint ourselves with some of the means of ascertaining its purity. Chemically pure water must

1. Not redden Litmus paper, — otherwise it is a sign of its containing an acid;

2. It must not form a precipitate when mixed with a solution of acetate of lead; for in this case it would contain sulphuric acid;

3. Mixed with lime-water it must not become turbid; otherwise it would contain carbonic acid.

4. With a solution of potash it must not form a precipitate, because in this case it would contain earthy salts. (See Chap. IV, Introd. to salts.)

5. It must not become turbid with a solution of Prussiate of iron and potash; otherwise it contains metallic salts, and especially iron, if the precipitate is blue, and copper if the precipitate is brown.

In many cases it is only necessary to know what proportion the solid substances mechanically contained or entangled in the particles of water, bear to the whole volume of the liquid. For this purpose it is sufficient to suffer a measured quantity of water to evaporate slowly over a moderate fire, or from an evaporating dish made of porcelain (see Fig. XXIV, page 21) and bedded in sand. The dry residue, which is generally of a white color, may then be weighed and compared to the volume of water.

Deutoxide of Hydrogen — or Oxygenized water.

Composition: 1 equivalent of hydrogen = 1
2 equivalents of oxygen = 16
Chemical equivalent of oxyg. water = 17.

§ 37. Water was for a long time supposed to be the only compound of hydrogen and oxygen. Another combination of the same elements has, however, been recently discovered, which consists of *equal* volumes of hydrogen and oxygen (water being a combination of 2 volumes of hydrogen with 1 volume of oxygen). It is obtained by an exceedingly tedious and expensive process, from a substance called *Deutoxide* of Barytium, but is nevertheless used in Paris for divers processes in bleaching cambric and calicos. It was discovered by Thénard, a celebrated French Chemist, and consists, as we have stated, of

2 volumes of hydrogen = 1
2 volumes of oxygen (each = 8) = 16
consequently its chemical equivalent is 17.

§ 38. *Properties of oxygenized water.* — It is a colorless liquid, of a metallic bitter taste, a highly disagreeable nauseous smell, bleaches and dries the skin, destroys all vegetable colors (on which account it is used in bleaching) and may be mixed with water in all proportions without being decomposed.

Metals brought in contact with it are speedily oxidized; but silver and platinum thrown into it cause an explosion, without suffering any visible change or oxidation — a phenomenon which has not as yet been satisfactorily explained.

Recapitulation of the Binary Combinations of Hydrogen and Oxygen.

Hydrogen combines with *oxygen* to
- *water*, or *protoxide* of *hydrogen*,
- *Oxygenized water*, or *deutoxide of hydrogen.*

C. Nitrogen, or Azote.

Chemical equivalent = 14.

§ 39. This is an inodorous gas, which is destitute of color or taste, and constitutes about 79 per cent of the whole weight of our atmosphere. It is but sparingly absorbed by water, enters largely into the composition of all animal substances, but is of itself incapable to support animal life. It is not inflammable and extinguishes all burning bodies the moment they are introduced into it. When separated from its combination with oxygen by the influence of galvanic electricity, it adheres to the negative pole, wherefore it is called a positively electric substance. (See introduction, page 41.)

This gas has formerly been called *azote*, from a Greek word signifying destroyer of life. This expression however is not correct, for the gas is no poison — it is merely *incapable of supporting* life, or the process of respiration without the presence of oxygen. It is nevertheless taken into the lungs, as we shall see hereafter, and is probably destined to reduce the injurious effects which would be produced by the respiration of pure oxygen.

§ 40. *Mode of obtaining Nitrogen.* Nitrogen is principally and easiest obtained, by separating it from atmospheric air. This is done by burning phosphorus under a bell-glass or receiver (see Fig LXV, page 54). During the combustion the oxygen of the air in the bell-glass combines with the phosphorus to phosphoric acid, which is rapidly absorbed by the water over which the glass must be placed. The residue of air, after all the oxygen is consumed by the process of combustion, is nitrogen, which may be collected by means of a pneumatic tub, an apparatus already frequently described in the preceding sections (see Introduction, Fig. XLIX, page 30). Nitrogen may also be obtained from a variety of animal substances particularly from meat, as we shall see in the 7th Chapter.

Mixture of Nitrogen with Oxygen — Atmospheric Air.

§ 41. Nitrogen and oxygen may be mixed in all proportions, *but four volumes of nitrogen with one volume of oxygen form a mixture resembling in all essential properties our atmospheric air.*

That nitrogen and oxygen are actually contained in the atmosphere in the proportion of 4 volumes of the former with 1 volume of the latter, is evident from the fact, that when a candle is burnt under a receiver provided with a scale to indicate the diminution of air during the process of combustion, one fifth of the whole volume of air is always consumed by the loss of oxygen, which agrees perfectly with the statement we have just made.* This experiment has already been described in Fig. LXVII, page 56.

§ 42. *Atmospheric air.* The atmosphere of the globe, whose mechanical properties have already been described in Natural Philosophy (Chap. V), contains in addition to nitrogen and oxygen which form its principal ingredients, a greater or less portion of vapors of water and carbonic acid gas — a substance with whose properties we shall become acquainted in the next chapter. The quantity of vapor is continually varying, and depends upon the temperature and situation of the place, whether it is in the neighborhood of large basins of water — or removed from the seacoast and the shores of rivers — upon the season of the year, and upon the particular hour of the day. We know that in the spring and fall of the year the atmosphere is more damp than in summer or winter; and that the mornings and evenings are generally misty or foggy during those seasons. As regards the proportion of carbonic

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* If 4 volumes of nitrogen and 1 volume of oxygen constitute atmospheric air, then the oxygen must be one fifth of the whole volume.

acid gas, it is greater in summer than in winter, and during the night than in day-time.

If we abstract for a moment from the variable portion of vapor of water contained in our atmosphere, we may suppose it to be composed as follows:

21 per cent oxygen,
$78\frac{999}{1000}$ do. nitrogen,
$\frac{1}{1000}$ do. of carbonic acid gas.

§ 43. *The proportion of the principal ingredients of our atmosphere, nitrogen and oxygen, is invariably the same,* viz: 21 weights of oxygen to 79 weights of nitrogen, whether we examine the air on top of the highest mountains, or at the level of the sea, under the equator or in the polar region, in winter or in summer.

Gay Lussac, a celebrated French chemist, found no perceptible difference with regard to this ratio (21 weights of oxygen to 79 of nitrogen) between the air at the height of 24,600 feet above the level of the sea, and that of the most crowded theatre in Paris. What is most wonderful and inexplicable in this ratio, is its permanency, notwithstanding the prodigious consumption of oxygen during combustion and in the various processes of animal and vegetable life.

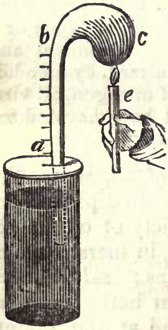
Many trials have been made to see whether no other mixture of gases can support respiration and animal life as well as our atmosphere; but none has succeeded. If the proportion of its mixture were changed, by an addition of nitrogen or a diminution of oxygen, it is highly probable all animal and vegetable life would cease; while, on the contrary, by an additional quantity of oxygen or a diminution of nitrogen, all vital energies, and consequently life itself would be exhausted too rapidly.

§ 44. *Accidental ingredients of our atmosphere.* Besides the gases already enumerated, our atmosphere contains at different times and places, a variety of other substances — such, as *carburetted hydrogen,* in marshy countries and in the vicinity of coal mines; *sulphuretted hydrogen,* in the neighborhood of sulphur baths; *sulphuric acid* gas in the immediate vicinity and at the craters of volcanoes, &c.

All bodies on our globe are continually exposed to the influence of the atmosphere. Most chemical phenomena take place in it. The processes of respiration, combustion, fermentation, and putrefaction (see Chap. VII, on the spontaneous decomposition of vegetable matter), are instances of its continual operation upon all animate and inanimate nature. It has therefore become a matter of great importance to find means of ascertaining its chemical composition at various times and places, and so much has this become a subject of chemical speculation that some chemists treat of it as a separate branch of the science, which they call *Eudiometry*, signifying *measure of the quality* of the atmosphere. We shall now proceed to describe some of the apparatus used or suggested for this purpose.

§ 45. The object of Eudiometry in most cases is to ascertain the quantity of nitrogen or oxygen contained in the atmosphere. Any substance which will absorb or consume all the oxygen from a confined portion of air, will serve this purpose, provided this substance does not itself mix with, or alter the volume of the nitrogen. An apparatus constructed for this purpose is called a Eudiometer. A great variety of them have been suggested, but the following three are the most useful, and commonly employed by practical chemists.

Fig. XCV.



1. *Achard's Eudiometer* by the slow combustion of *phosphorus*. It consists of a glass tube (see Fig. XCV), closed at one end *b*, where it is blown into a bulb *c*. In this small sticks of phosphorus are to be placed, about one third grain to one cubic inch of atmospheric air; the remainder of the tube is then filled with quicksilver, and with its open end downwards, placed into a jar filled with the same metal. Atmospheric air is now allowed to pass through the pneumatic apparatus into the tube (quicksilver being throughout employed instead of water), and the oxidation of the phosphorus, which has a great affinity for oxygen, increased by heating the bulb *c*, by the flame of a candle. The oxygen of the atmospheric air in the tube will unite with the phosphorus, leaving a residue of nitrogen in the gradated tube *a b*, from which, and the whole volume of atmospheric air

employed in the experiment, we are able to judge of the quantity of oxygen consumed; or, which is the same, of the proportion in which oxygen entered in the composition of the atmospheric air employed in the experiment. Thus, if one fifth of the whole volume of atmospheric air should combine with the phosphorus, the remaining nitrogen would be four fifths of the whole volume employed; consequently the proportion of oxygen to nitrogen would be as 1 to 4.

Fig. XCVI.

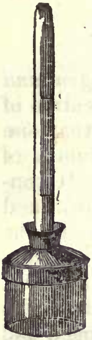
2. *The Eudiometer by detonating Oxygen and Hydrogen gas* (see Fig. XCVI) is an invention of *Volta*, and is founded on the principle that one volume of oxygen combines with two volumes of hydrogen to water (see § 15, page 61). It consists of a strong glass tube *a*, (see the figure) fitted at one end to a brass box, which terminates on the outside in a knob *c*, of the same metal, and is connected with a piece of bent wire in the tube. When the apparatus is to be used, the tube is filled with a mixture of two volumes of hydrogen and one volume of atmospheric air, (which is easily done by means of the pneumatic tub) and an electric spark applied to the knob *c*. The mixture of the gases in the tube will explode (§ 20, page 69) and the hydrogen combine with the oxygen of the atmospheric air to water; the quicksilver or water of the pneumatic tub, over which the experiment must be made, will instantly rise in the tube and show the volume of gas consumed; one third of which is always the oxygen contained in the atmospheric air examined.

Instead of the Eudiometer just described, we may use the apparatus Fig. LXXXVII, page 74. The experiment is nearly the same as that described on that page, with the only difference, that atmospheric air is employed instead of the oxygen.

Query — By what means, in the last experiment, are you able to find the volume of oxygen contained in the atmospheric air. *Ans.* — By the combustion of the hydrogen, which, with the oxygen of the atmospheric air combines to water.

Ques. — But what reason have you to infer that exactly one third of the whole volume of gases consumed, is the quantity of oxygen which was contained in the atmospheric air? *Ans.* — Because two volumes of hydrogen combine with exactly one volume of oxygen to water, consequently of the three volumes consumed, the oxygen constitutes necessarily one third.

Fig. XCVII.



Gay Lussac's Eudiometer, which we are now about to describe, is founded on the property of some liquids to absorb certain gases, contained at different times and places in our atmosphere. It consists of a cylindrical jar, which is fitted to a brass box, terminating in a neck, shaped like that of a bottle, and provided with a cork, through which a gradated tube may be made to communicate with the jar. When the apparatus is to be used the gradated tube is first filled with air, and then fitted to the jar, which must be filled with such liquids as are capable to absorb the gases which we suppose to be contained in the atmospheric air under examination. The whole apparatus is then inverted for some time, so that the air from the tube may ascend into the jar — and afterwards, in its proper position, placed under water or quicksilver; the rise of the liquid in the tube will indicate the quantity of gas absorbed, and thereby enable us to judge of the ingredients contained in the atmosphere.

The various experiments which have been made with these Eudiometers have convinced us that the oxygen contained in the atmosphere is absolutely *invariable*, at all times of the day and year. The great difference therefore which exists between the air of certain places, and the great influence which the atmosphere, at different times, has upon our state of health, cannot be explained from the greater or less quantity of oxygen which it contains, but is owing to certain principles which it is impossible for us to determine with any degree of precision. The different miasmas which at times are contained in the atmosphere, and are supposed to be the cause of the existence or spreading of contagious diseases, escape likewise wholly our observations; their nature being entirely different from any known element in chemistry.

Combinations of Nitrogen with Oxygen.

§ 46. Nitrogen combines with oxygen in five different proportions, forming with it 2 oxides and 3 acids. (See the nomenclature of oxides and acids, § 4, page 51.) Their names, according to their composition, are *Protoxide of nitrogen, Deutoxide of nitrogen*, or *nitric oxide, hyponitrous acid, nitrous acid*, and *nitric acid.*

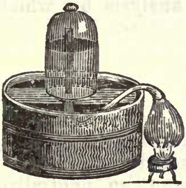
Protoxide of Nitrogen.

Chemical Composition. : 1 Equiv. Nitrogen = 14
1 do. Oxygen = 8

Chemical equiv. of Protoxide of Nitrogen = 22.

§ 47. Protoxide of nitrogen is never found in its simple state. It is altogether a product of art, and is best obtained by the following

Fig. XCVIII.



Experiment. — Fuse a salt called *Nitrate* of ammonia in a retort over an Argand's or spirit lamp; or as this salt is not always readily obtained, prepare it from a solution of carbonate of ammonia (the principal ingredient of common smelling salts) in diluted nitric acid. Evaporate the solution until its consistency is such that a drop taken out with a glass rod concretes on cooling. When this is done, liquefy the salt thus obtained, and keep it simmering by a gentle heat. The gas will be given off in abundance, and may be collected by the pneumatic tub. For this purpose however it is necessary to conduct the pipe to the top of the receiver, as is shown in the figure; because the gas has a strong affinity for water, and would otherwise be absorbed by it in a great proportion.

§ 48. *Properties of Protoxide of Nitrogen.* The Protoxide of nitrogen is a colorless gas of a sweetish taste, and faint, agreeable smell. It becomes liquid by pressure: is not inflammable, but supports combustion with more splendor than common atmospheric air. Animals die in it speedily. When breathed in small quantities it produces an exhilarating effect, similar to that produced by spirituous liquors. It mostly occasions an irresistible propensity to laughter and muscular exertion ; but taken in greater quantities produces swoon and apoplexy.

For the purpose of taking this gas into the lungs, we may take Priestley's bell-glass instead of a receiver, and transfer the gas which is collected in it to a bladder, from which it may be breathed. Sir Humphry Davy is said to have inhaled 12 quarts of this gas. But this is rather a dangerous experiment; the greatest quantity of it inhaled at any one time ought not to exceed 3 or 4 quarts, and even these are known to have produced the most distressing consequences on the particular constitution of individuals.

Protoxide of nitrogen may by electricity be again decomposed into its elements, nitrogen and oxygen. When mixed with hydrogen it becomes inflammable, and on the application of an electric spark detonates with great violence.

Its composition by volumes is one volume of nitrogen with one volume of oxygen. Its chemical proportion or equivalent by weights have been stated in the introduction.

It will however be well to say here a few words on the mode of reasoning, or the species of chemical analysis by which the equivalents of this gas have been determined. Two volumes of hydrogen have been mixed with two volumes of Protoxide of nitrogen, and detonated by means of an electric spark in the apparatus described on fig. LXXXVII, page 74. By this means the protoxide of nitrogen has become completely neutralized, its oxygen combining with the hydrogen to water, and the residue being exactly two volumes of nitrogen.

But we know that two volumes of hydrogen can neutralize neither more nor less than one volume of oxygen, we infer therefore that in protoxide of nitrogen there could not be either more or less than one volume of oxygen, combined with two volumes of nitrogen. If now we wished to determine the proportion in which these substances are combined by *weight*, it would only be necessary to know the weight of a given volume of both gases.

Taking therefore any given volume, say 50 cubic inches, for the standard of comparison, we say,

50 cubic inches of oxygen weigh 16.8 grains
double this volume, or 100 cubic inches of nitrogen weigh 29.7*

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* This has been found by experiment; or the weight of 50 cubic inches of either gas may also be calculated from its specific gravity when compared to the weight of a cubic inch of water (see § 27, page 76.)

consequently the chemical equivalent, or proportion by weight of nitrogen, is to the chemical equivalent of oxygen (which we know is 8 — see page 75) as 29.7 is to 16.8 — or which is the same, we have the proportion.

16.8 : 29.7 :: 8 : Answer = 14, nearly; which is therefore the chemical equivalent of nitrogen, or the proportion in which it combines by weight with all other substances.

$$\begin{array}{r} 29.7 \\ 8 \\ 16.8)\overline{237.6}(13.9 \\ 168 \\ \hline 656 \\ 504 \\ \hline 1520 \\ 1512 \\ \hline 8 \end{array}$$

Now knowing the chemical equivalent of nitrogen and also that of the oxygen, with which it combines to protoxide of nitrogen, it is only required to add them together to obtain the chemical equivalent of that substance, viz.

2 volumes or 1 equivalent of nitrogen = 14
and 1 volume or 1 equivalent of oxygen = 8

hence the chemical equivalent of deutoxide of nitrogen = 22, which was to be proved.

Deutoxide of Nitrogen.

Chemical composition. — 1 Equivalent of Nitrogen = 14
2 Equivalents of Oxygen, (each being 8) = 16

Chemical equivalent of Deutoxide of Nitrogen = 30.

§ 49. The *deutoxide of nitrogen*, like the protoxide of the same gas is not to be found in nature. It is a product of art, and may be obtained by the action of nitric acid (aqua-fortis) on some oxidable metal, commonly copper or quicksilver (the latter is to be preferred). The metal ought to be put into a retort, and the acid poured upon it, when an effervescence will take place, and the gas which is given off may be collected through the pneumatic tub. To understand this process it is necessary to state that nitric acid is a combination of nitrogen with a greater quantity of oxygen than is contained in the deutoxide, and that by pouring it upon copper or mercury, for which oxygen has a strong affinity, part of its oxygen combines with the metal, leaving just enough with the nitrogen to form the deutoxide.

§ 50. *Properties of Deutoxide of nitrogen.* We have already stated at the head of this article that the deutoxide of nitrogen is a combination of nitrogen with a further portion of oxygen. This compound is a colorless gas, whose smell and taste are not known, because as soon as it comes in contact with the atmosphere it combines with a fresh portion of oxygen, and becomes converted into vapors of nitrous acid. It is wholly irrespirable, permanently elastic, sparingly soluble in water, and does not, in its pure state, act upon vegetable colors. It is not inflammable, and a burning body immersed in it, is instantly extinguished; but pieces of charcoal or phosphorus introduced in a state of vivid inflammation burn in it with great splendor, by virtue of the oxygen which it contains. With hydrogen it may be mixed in any proportion without exploding, but when burnt with it in atmospheric air, it changes the yellow flame of the hydrogen into green.

When deutoxide or nitric oxide is mixed with oxygen deep red fumes are generated, which, when the experiment is made over the pneumatic tub, are speedily absorbed by the water, so that if the gases are entirely pure, and mixed in the proper proportion, they will wholly disappear. If instead of pure oxygen common atmospheric air be employed, the effect will be apparently the same; the nitric oxide will combine with the oxygen of the air, and be absorbed by the water over which the mixture is made, *the diminution in the volume of the gases being proportionate to the quantity of oxygen contained in the jar.*

Upon this property of the deutoxide of nitrogen, to combine with the oxygen in atmospheric air, and in this state to be absorbed by water, is founded Gay Lussac's Eudiometer, described on fig. XCVII, page 92. To a measured quantity of atmospheric air in the tube (see that figure) is added a sufficient quantity of deutoxide of nitrogen to combine with all the oxygen contained in the air. The tube is then screwed to the glass jar, filled with water, and the apparatus inverted to allow the gas to ascend in the liquid, and to be absorbed by it. When the apparatus is afterwards placed in its proper position, the diminution of oxygen will be perceived by the rise of the water and its higher stand in the gradated tube.

§ 51. Deutoxide of nitrogen may be decomposed by suffering it to stand over iron-filings. A portion of its oxygen will combine with the filings, and the gas will by this means be converted into a protoxide (see § 47). Its composition (at the head of this article) has been inferred from the fact that burning charcoal absorbs exactly one half of its volume, leaving the other half pure nitrogen. It must therefore consist of equal volumes of nitrogen and oxygen; or, which is the same, of

1 equivalent or proportion by weight of nitrogen = 14
and of 2 equivalents of oxygen (each being 8) = 16

whence Equiv. of Deutoxide of Nitrogen = 30.

Hyponitrous Acid.

Chemical composition: 1 equiv. of Nitrogen = 14
3 do. Oxygen = 28

Chemical equivalent of Hyponitrous acid = 42.

§ 52. *Hyponitrous acid* is a conjectural or hypothetical substance, which it is supposed is formed from a combination of the deutoxide of nitrogen, with a further portion of oxygen. It is said to be produced when 4 volumes of that gas are mixed with one volume of oxygen, making the experiment over mercury, on top of which a few drops of a solution of potash must float. The deutoxide of nitrogen is then supposed to combine with the oxygen to an acid, which immediately unites with the potash, but which afterwards cannot be separated from it without decomposition.

Some chemists* pretend that at the common temperature of the atmosphere it appears as an orange colored vapor, which is exceedingly injurious to the lungs.

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* Prof. Schubert, of Berlin, and Gmehlen, in Heidelberg.

Nitrous Acid.

Chemical composition : 1 equivalent of Nitrogen = 14
4 equivalents of Oxygen (each = 8) = 32
Chemical equivalent of Nitrous acid = 46

§ 53. This gas may be produced like the hyponitrous acid, by adding oxygen to the deutoxide of nitrogen. For this purpose conduct two measures of the deutoxide and one measure of oxygen into a glass retort fitted with a stop-cock, and from which the atmospheric air has previously been extracted, either by an air-pump or an exhausting syringe. (The experiment cannot be made over water or mercury; because these liquids have too great an affinity for the compound, which would thus be generated). The two measures of the deutoxide and one measure of the oxygen will be condensed into half their volume, and form a deep orange colored gas, which is the nitrous acid.

§ 54. The combinations of nitrogen and oxygen afford striking instances of the direct proportions in which gases combine with each other by volumes. We have seen that the protoxide of nitrogen was composed of 2 volumes of nitrogen with 1 volume of oxygen; the deutoxide of nitrogen of 2 volumes of nitrogen with 2 volumes of oxygen; and the hyponitrous acid, being formed by adding 1 volume of oxygen to the deutoxide, is equivalent to 2 volumes of nitrogen with 3 volumes of oxygen; finally the nitrous acid which is formed by adding 2 volumes of oxygen to 2 volumes of the deutoxide is evidently equal to 2 volumes of nitrogen with 4 of oxygen; or, which is the same, to 1 volume of nitrogen with 2 volumes of oxygen.

This verifies what we have stated in § 26, page 76, in reference to the combination of the gases, which is always in the proportion of *whole* numbers by volume, and in no intermediate ratio, affording a striking illustration of the harmony and simplicity of the laws of nature.

§ 55. *Properties of Nitrous acid.* It is, as we have said, a deep orange-colored gas, which is capable, by virtue of its oxygen, to support the process of combustion, and is readily dissolved by water, which acquires by it first a green, then a blue, and finally a yellow tint. The solution tastes sour, reddens litmus-paper, and stains animal substances yellow. No great application has been made of this acid in the arts.

Nitric Acid.

Chemical composition: 1 equivalent of Nitrogen = 14
5 equivalents of Oxygen (each 8) = 40
Chemical equivalent of nitric acid = 54.

§ 56. *Nitric* acid *(aqua-fortis)* is found (in an engaged state) combined with a number of mineral and vegetable bases (Intr. page 38). It is easily obtained by art, when deutoxide of nitrogen is passed very slowly into pure oxygen gas, standing over water. By this operation 4 volumes of the deutoxide combine with 3 volumes of oxygen; consequently, as the deutoxide itself consists of 1 volume of nitrogen and 2 of oxygen, nitric acid will by the addition of 3 volumes of oxygen, be composed of 1 volume of nitrogen and 5 of oxygen; or by weight, of 1 equivalent of nitrogen and 5 of oxygen, as stated at the head of this article. Nitric acid may also be procured from a *mixture* of nitrogen and oxygen placed over water by passing through it a number of electric sparks, (see the apparatus, fig. LXXXVII, page 74).

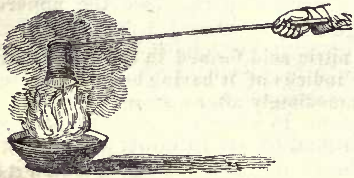
In a similar manner is nitric acid formed in the atmosphere during a thunder storm; indices of it having been discovered in rain-water collected immediately after a storm.

§ 57. Nitric acid formed by art in either manner we have just described, is absorbed by the water over which it is made, by which means it is reduced to the liquid state; and so great is the affinity of this acid for water, that it is doubtful whether it can ever be exhibited in an insolated state.

§ 58. *Liquid nitric acid* is an important article of commerce, large quantities of it being used in the arts. For this particular purpose nitric acid is frequently distilled with concentrated sulphuric acid, by which means a most powerful acid is obtained, containing only little more than twentyfive per cent of water; this being the smallest quantity of water with which it is known to exist. The liquid acid is called *Hydro-nitric acid*, from a Greek word, signifying *water*. But when this acid combines again with those substances called bases, then the water is given off, and is then said to be in an *an-hydrous state.*

§ 59. *Properties of Nitric Acid.* Nitric acid, or aqua-fortis is a highly corrosive fluid, which oxidates most metals, and, with the exception of tin and antimony, dissolves them at a gentle heat. Its specific gravity, when most concentrated, is 1.5, that is, it is about half as heavy again as water. It acts as a powerful caustic on the skin, and destroys instantaneously all organized matter. It is decomposed by all substances which have a great affinity for oxygen. When heated, or brought in contact with hydrogen, it detonates with great violence; but the experiment is somewhat dangerous. When poured upon warm powdered charcoal a combustion takes place, at which the deutoxide of nitrogen is given off in copious fumes. Spirit of turpentine may likewise be inflamed by it, which may be shown by the following pleasing

Fig. XCIX.



Experiment. — Place some spirit of turpentine, or any other essential oil, in a warm saucer, and pour suddenly some nitric acid upon it. The carbon and hydrogen of which turpentine, and in geneal all these oils are principally composed, will unite to combustion with the oxygen of the nitric acid; and so rapid is the inflammation that it is necessary to pour the nitric acid from a vessel attached to a long stick, in order to avoid the danger to which the eyes of the experimenter would inevitably be exposed if standing too near.

§ 60. *Application of Nitric acid to the arts.* Nitric acid is one of the most powerful means of attaining the various ends proposed in chemical investigations, or in the arts. Its great application is founded partly upon its capacity in union with water to dissolve most solid substances and partly upon the small cohesive attraction between its particles, in consequence of which it is easily decomposed and yields its oxygen to other substances with which it is brought in contact. To the *gold* and *silver-smith* it is a means of separating one metal from another. The *dyer* and *cotton printer* use it in the preparation of various metallic salts, for the purpose of producing different shades of colors. The *artificer in bronze* employs its solving power to cleanse the products of his art from various oxides and other impurities; the *engraver* uses it in the process of etching; the *turner* finds it useful in dying ivory and wood; and so might we continue to transcribe a long catalogue of the useful applications which are made of this acid in the arts, were it not inconsistent with the limits proposed in this treatise.

Combination of Nitrogen with Hydrogen —Ammonia.

Chemical composition: 1 equivalent of Nitrogen = 14
3 equivalents of hydrogen (each being 1) = 3

Consequently, Equivalent of Ammonia = 17.

§ 61. *Ammonia*, the compound of nitrogen with hydrogen, is not found in nature in its *free* state; but occurs combined with acids from the mineral and vegetable kingdoms. It is best obtained from a mixture of equal volumes of powdered sal-ammoniac and quicklime, gently heated in a retort. The gas will be given off in great quantities, but must be collected over quicksilver, water absorbing it too fast. When the experiment is made over water, which takes up more than 500 times its own bulk, an *aqueous solution of ammonia* is formed, which is an article of great use, and possesses all the essential qualities of the gas.

This solution of ammonia has received the several appellations of *spirits of sal-ammoniac*, *spirits of hartshorn*, or *liquid ammonia*, and is extensively employed by druggists. The salt contained in smelling bottles is a *carbonate of ammonia* which will be described in the 4th Chapter.

§ 62. *Properties of Ammonia.* Ammonia is a colorless gas of an extremely pungent smell, and a sharp, burning taste. It changes blue vegetable colors into green, and yellow into brown, and is very much lighter than atmospheric air, 100 cubic inches of it weighing only 18 grains. It is totally irrespirable, and when accidentally taken into the lungs causes cramp and suffocation. An animal plunged into it immediately dies. Neither is it fit to support the process of combustion ; nor is it itself combustible in atmospheric air, but in pure oxygen it burns with a yellow flame. It loses its elasticity and becomes liquid at a pressure equal to 195 perpendicular inches of quicksilver, or by a temperature of 40 degrees below zero of Fahrenheit's thermometer.

From the manner in which we have just stated that ammonia affects vegetable colors, and from the remarkable property which it possesses to combine with the acids to salts, it is evident that ammonia belongs to that class of bodies which are called bases (see Intr. page 38). It is therefore called the *volatile alkali*, to designate its *basic* nature, and at the same time to distinguish it from the *vegetable* and *mineral alkalis*, which are likewise capable of neutralizing the acids and form salts with them. (See Chapter VI.)

§ 63. When ammonia is passed through narrow red-hot tubes, especially if some iron wire be coiled up in them, it is again decomposed into its elements, nitrogen and hydrogen ; yielding by volume, three times as much hydrogen gas as nitrogen, which proves the correctness of its chemical composition as before stated. It is also decomposed by a series of electric sparks, and when mixed with oxygen may be ignited like a mixture of oxygen and hydrogen.

Recapitulation of the most important binary combinations of Nitrogen.

Nitrogen combines with
- *Oxygen* to
  - *Protoxide* of nitrogen.
  - *Deutoxide* of nitrogen.
  - *Hypo*-nitrous acid.
  - *Nitrous* acid.
  - *Nitric* acid.
- *Hydrogen* to *Ammonia.*

D. Chlorine.

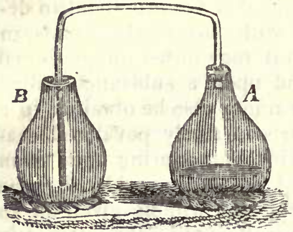
Chemical Equivalent = 36.

§ 64. This is the fourth and last of the gaseous elements which, although not found in its simple state in nature, is easily procured in the manner we are about to describe. It is found combined with most of the metals, or united with hydrogen. By art it may either be produced by the action of muriatic acid upon a substance called *black oxide of manganese;* or it may also be obtained in a cheaper way, by adding 3 parts of finely powdered sea-salt to one part of the same oxide, and pouring upon them in a retort two parts of diluted sulphuric acid. By the application of a gentle heat, chlorine will be given off in great quantities, which may be collected by the pneumatic tub, employing *hot* water or quicksilver for this purpose ; because cold water absorbs the gas too rapidly. The gas obtained in this manner may be preserved in glass-bottles with greased stoppers, taking great care to expel all water from them.

§ 65. *Properties of Chlorine.* Chlorine is a gas of a yellowish green color (whence its name, from a Greek word signifying *green*), which has an astringent (not acid) taste, and a disagreeable, suffocating smell. When inhaled it is exceedingly injurious to the lungs, and may produce instant death. An animal confined in it is almost instantaneously killed. It is not inflammable, but it is capable of supporting the combustion of some substances, such as phosphorus, arsenic, bismuth, antimony, &c. Mixed with vapors of water it becomes liquid, but concentrates again into a yellow solid substance when surrounded by snow or ice. Its specific gravity is 2.5, that of atmospheric air being 1 ; it is consequently two and a half times as heavy as atmospheric air ; 100 cubic inches weighing $76\frac{1}{4}$ grains, while the same quantity of air weighs only $30\frac{1}{2}$ grains. Combined with lime it forms *chloride of lime*, a substance also known by the name of *bleaching powder*, on account of its possessing the remarkable property of destroying all animal and vegetable colors. Of this substance we shall speak more fully in the 4th chapter, in treating of the salts.

Chlorine being specifically heavier than atmospheric air, is one of those gases which may be transferred from one vessel to another without the assistance of the pneumatic tub. Indeed, suppose we had been preparing chlorine in the retort A. It would only be necessary to introduce a pipe through the cork of this retort to conduct the gas into an open vessel, into which it would descend in consequence of its specific gravity. But chlorine collected in this manner combines always with a portion of vapor of water contained in the atmospheric air; it is therefore better to collect it over hot water or quicksilver.

Fig. C.



The property of chlorine to support the combustion or to ignite some, of the metals, may be illustrated by the following pleasing

Experiment. — Fill a long bottle or tube with chlorine, and cover its mouth by a plate of glass. Provide some powdered antimony, which, upon sliding off the cover, pour into the glass. The metal will ignite before it reaches the bottom, and affords a beautiful shower of white flames. Tin, copper, zinc, arsenic, or even gold introduced in a state of minute division, afford the same experiment.

Combinations of Chlorine with Oxygen.

§ 66. Chlorine combines with oxygen in four different proportions, forming with it two oxides and two acids, viz: *Protoxide of Chlorine*, *Peroxide of Chlorine*, *Chloric acid*, and *Perchloric acid.* Neither of these compounds has ever been found in nature, nor has any application been made of them in the arts.

Protoxide of Chlorine

is composed of 1 equivalent of Chlorine = 36
1 do. Oxygen = 8

Consequently, chemical equiv. of Prot. of Chlorine = 44.

It is a deeper colored gas than chlorine; its smell is somewhat like burnt sugar. It is obtained from heated chlorine of potash mixed with very dilute muriatic acid, and consists, by volume, of 2 volumes of chlorine with 1 volume of oxygen.

Peroxide of Chlorine

consists of 1 equivalent of chlorine = 36
and of 4 equivalents of oxygen (each = 8) = 32

Chemical equivalent of Peroxide of Chlorine = 68.

Properties. It is of a yellow color, smells like chlorine, has a very disagreeable astringent taste, and is speedily absorbed by water. It is obtained by the action of sulphuric acid on chlorate of potash, and is composed, by volume, of 2 volumes of chlorine with 4 volumes of oxygen.

Chloric acid

is composed of 1 equivalent of chlorine = 36
5 equivalents of oxygen (each = 8) = 40

Chemical equivalent of Chloric acid = 76.

Properties. It is colorless, always mixed with a small portion of water, consequently liquid, has an astringent taste, and reddens blue vegetable colors. It is obtained from the decomposition of a salt called Chloride of Baryta by means of diluted sulphuric acid, and consists of two volumes of chlorine with 5 volumes of oxygen.

Per-chloric Acid

consists probably of 1 equivalent of chlorine = 36
8 equivalents of oxygen (each = 8) = 64

Chemical equivalent of Per-chloric acid = 100.

It is the fourth and last of the combinatians of chlorine with oxygen, and its chemical composition is not precisely known. It is colorless, inodorous, and has a pure sour taste. It consists of 2 volumes of chlorine with 8 volumes of oxygen.

REMARK.—There exists a difference in the opinions of distinguished chemists with regard to the composition of the two compounds, *peroxide of chlorine* and *per-chloric acid.* We have stated that the peroxide consists of two volumes of chlorine and four volumes of oxygen. This however is doubted, and the composition of this compound stated by some chemists as two volumes of chlorine and three volumes of oxygen. If this be true, its composition is

1 equivalent of chlorine = 36
3 do. of oxygen = 24

Chemical equivalent of peroxide of chlorine = 60.
and not 68 as before stated.

Again, we have stated the chemical equivalent of perchloric acid to be 100. This substance however, is by some chemists believed to be compounded of

1 equivalent of chlorine = 36
7 equivalents of oxygen = 56

consequently, chemical equivalent of per-chloric acid = 92. Compare this with the remark on page 15.

Combinations of Chlorine with Hydrogen — Muriatic Acid.

Chemical composition : 1 equivalent of chlorine = 36
1 do of hydrogen = 1

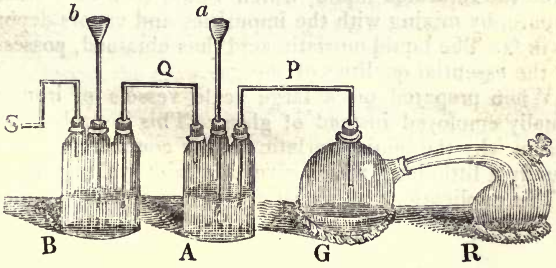
Consequently, Chemical equiv. of muriatic acid = 37.

§ 67. Chlorine and hydrogen combine together to *muriatic acid.* This compound is found in nature in form of vapors, or also in a liquid state, particularly in the neighborhood of volcanos, as for instance in the vicinity of *Rio Vinagre,* in South America. But it may also be obtained by the mysterious influence of solar light. A mixture of hydrogen and oxygen, well secluded from the light, will remain unchanged for any length of time. But if the mixture is made of equal volumes of these gases and exposed to the light of day (in the shade), they gradually combine without *change* of volume to a powerful acid, in which the peculiar smell and odor of chlorine will no longer be perceptible. If the mixture be directly exposed to the light of the sun, then the combination takes place suddenly and is attended by an explosion. (The mixture may also be exploded by an electric spark or the flame of a candle). Muriatic acid gas may also be procured in a much cheaper way by the action of strong sulphuric acid on sea-salt. The gas obtained in either way must be collected over mercury, (by the pneumatic tub filled with mercury instead of water) its affinity for water being so great that an unstopped vessel filled with it and placed under water, will in a few moments be entirely filled with the liquid, the gas being wholly absorbed.

§ 68. *Properties of Muriatic Acid.* It is a colorless gas, of a very pungent smell and strong acid taste. It turns blue vegetable colors into red, and in contact with the atmosphere forms dense white clouds, (in consequence of its combining with the steam or vapor contained in atmospheric air). By a pressure of about 1120 perpendicular inches of quicksilver (equal to about 40 times the pressure of our atmosphere) it becomes liquid, but it is neither combustible nor respirable, nor is it capable of supporting the process of combustion. In contact with the oxides it loses its hydrogen, which combines with the oxygen of the oxide to water, setting the chlorine free. This explains the process by which chlorine is obtained from the operation of muriatic acid on black oxide of manganese. (See § 64, page 103).

§ 69 When muriatic gas is conducted into water, it is rapidly absorbed by this liquid, by which means *liquid muriatic acid* is obtained; a substance similar in properties to the muriatic acid gas, and of great usefulness and application in chemistry and the arts. For this purpose Woulf's apparatus is generally employed. It consists of

Fig. CI.



a number of glass bottles shaped as in figure CI. The bottles A and B, of which there may be any number we please, are each provided with three necks, and contain a quantity of water, which is to be impregnated with the gas. When liquid muriatic acid, or as it is sometimes called, *hydro-muriatic acid*, is to be formed, common salt is put into the retort R, and a small quantity of dilute sulphuric acid poured upon it. When a gentle heat is applied to the retort muriatic acid gas is given off, which passes into the globe G, destined to condense such portions of vapor as would render the gas impure. From the globe the gas passes through the bent tube P, into the first bottle A. The water in this bottle will absorb a portion of the gas, and the remainder will pass through the tube Q, into the next bottle, and so on. The bent tubes P, Q, &c, (see the figure), are a little above the surface of the preceding bottle, and dip below the surface of the liquid in the other, in order to allow the gas to escape from one bottle, and to impregnate the water in the other. The process must be carried on until the water in all the bottles is completely saturated. (See Intr. page 8). To promote the absorption of the gas, the bottles may be placed in ice. The last bottle must be provided with an open tube to allow the escape of atmospheric air, or such other gas as the water will not absorb. The perpendicular tubes *a*, *b*, are safety tubes, to admit atmospheric air into each bottle when the gas ceases to come over from the retort; for in this case a vacuum would be created in the globe G, (from which the gas is absorbed by the water in the first bottle), into which the pressure of atmospheric air, acting through the open tube S, would force the saturated liquid, which would then be rendered impure, by mixing with the impurities and vapors deposited in G. The liquid muriatic acid thus obtained, possesses all the essential qualities of the gas.

When prepared on a large scale vessels of iron are usually employed instead of glass. This is probably the reason why the liquid muriatic acid of commerce contains usually a little iron, which gives it a faint yellow tint.

The applications of muriatic acid are almost as numerous as those of nitric acid. It is used in the art of bleaching, and is able to dissolve most solid substances, particularly metals. It operates very powerfully on metallic oxides and forms with some of them (such as oxides of lead or silver) insoluble compounds. Mixed with nitric acid it forms the well known *aqua regia** the only liquid which dissolves gold, and is on that account useful to the goldsmith. Combined with oxide of tin it is used in the processes of dying and calico-printing. It is also employed in the extraction of animal gluten from the bones, for various medicinal purposes.

Combination of Chlorine with Nitrogen.—Chloride of Nitrogen.

Chemical composition: 4 equivalents Chlorine (each 36) = 144
1 equivalent Nitrogen = 14

Chemical equivalent of Chloride of Nitrogen = 158.

§ 70. This compound of chlorine was discovered by *Dulong*, a celebrated French chemist. Chlorine and nitrogen have but a feeble affinity for each other; but when chlorine is passed through a solution of nitrate of ammonia at a temperature of about 90 degrees Fahrenheit, then the chlorine is rapidly absorbed, and an oily film first appears on the surface of the solution, and finally sinks to the bottom of the vessel. This oily liquid is chloride of nitrogen.

To understand what we have just said, it is necessary to state that nitrate of ammonia is a compound of nitric acid and ammonia, nitric acid being composed of nitrogen and oxygen. The oily globulæ which sink to the bottom are formed by the decomposition of the nitrate of ammonia, the nitrogen combining with the chlorine. If a flat vessel be placed at the bottom of the solution, the compound may be collected in it.

§ 71. *Properties of Chloride of Nitrogen.* Chloride of nitrogen in a yellowish oily liquid, which does not be-

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* Signifying king's water, because it dissolves gold, which by the alchemist was called the king of metals.

come solid by great degrees of artificial cold. Its specific gravity is 1.653 that of water being 1; and it is the most powerfully explosive substance known. It should therefore be handled with great caution, and not be experimented upon in quantities larger than a grain of mustard seed, and even then with great caution.* It explodes at a temperature of about 200 degrees Fahrenheit, but detonates in contact with a combustible substance at the common temperature of the atmosphere. A single drop of it thrown into turpentine or olive oil causes so violent an explosion as to burst the phial.

This phenomenon is explained by the great volume of the two gases, nitrogen and chlorine, which are engaged in the formation of chloride of nitrogen, and which become suddenly free ,and by the expansion of their volume cause the explosion when brought in contact with a combustible substance.

Recapitulation of the principal binary Combinations of Chlorine.†

Chlorine combines with
- *oxygen* to
  - *Protoxide of Chlorine.*
  - *Peroxide of Chlorine.*
  - *Chloric Acid.*
  - *Per-chloric Acid.*
- *Hydrogen* to *Muriatic Acid.*
- *Nitrogen* to *Chloride of Nitrogen.*

RECAPITULATION.

Questions for reviewing some of the most important Principles contained in the 1st Chapter.

A. QUESTIONS ON OXYGEN.

[§ 1.] What are the principal properties of oxygen? Is the presence of oxygen absolutely indispensable to animal life?

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* See Library of Useful Knowledge.

† See article Chlorides, in Chap. IV.

[§ 2.] Describe some of the ways in which oxygen is obtained.

[§ 3.] What is that process called, by which oxygen combines with other simple and compound bodies?

[§ 4.] How many different names are given to the oxides? To what substance is the name of *Protoxide* given? What is a *Deutoxide?* What a *Peroxide?* By what means do we distinguish between the names of the different acids? What does the name of the acid in *ic* indicate? What that, terminating in *ous?* What does the name of *hypo* signify when put before the name of an acid? *Give examples.*

[§ 5.] In what consists the combustion or burning of bodies? What is every body called which is capable of such a combination with oxygen?

What was the phlogiston of the ancients?

[§ 6.] What do most bodies require for their combustion? *Give examples.*

Explain the process of a burning lamp or candle.

[§ 7.] Is the light which is given out during the process of combustion always the same, or is it subject to variation in intensity and color? *Give examples.*

[§ 8.] How do all bodies burn in oxygen? *Give examples.* (Explain Figs. LXIV, LXV, LXVI.)

What do these examples prove with regard to the heat produced by combustions in pure oxygen?

[§ 9.] When the whole product of combustion is weighed, is it found heavier or lighter than the substance was before the combustion? *Give an example.*

But why do the ashes produced by burning wood or straw weigh less than the wood or straw before the combustion? When the inflammable gas which is given off during the combustion of these substances is collected, and its weight added to that of the ashes, is the sum of their weight greater or less than that of the wood or straw before the combustion?

[§ 10.] Can any combustion take place without the presence of oxygen? How long therefore can the combustion of oxygen only be continued?

What *experiment* can you describe to prove your assertion? (Explain Fig. LXVII). What alteration will take place, if in your experiment, you employ atmospheric air instead of pure oxygen? What does the slower burning of the candle in common atmospheric air prove? Why does the water rise higher in the receiver when pure oxygen is used? Why does the candle become extinguished when 21 per cent of the whole air contained in the receiver, are consumed? What is required for a complete combustion of bodies in oxygen or atmospheric air? (Explain Fig. LXVIII). What remarkable coincidence is there between the processes of respiration and combustion?

[§ 11.] By what is the quantity of air necessary for combustion, supplied? What do you call a draft? For what purpose are fire-places and chimneys built?

How are smoking fire-places improved? Why is the flame of an Argand's lamp brighter than that of a common lamp?

[§ 12.] How is fire extinguished? By what means is this effected?

Why are small quantities of water of little use in the extinguishing of conflagrations?

[§ 13.] Is the combination of oxygen with other substances always accompanied by the phenomenon of fire? In what cases is it not?

Give instances of such combinations.

[§ 14.] In what does the process of desoxidation consist? In how many different ways is it effected? What are they?

B. Questions on Hydrogen.

[§ 15.] What becomes of water when subjected to the action of galvanic electricity? Explain Figs. LXIX, LXX, and LXXI. What is most remarkable about this decomposition of water?

[§ 16.] What are the characterizing properties of hydrogen ?

Explain the two experiments represented in Figs. LXXII, and LXXIII (page 62). In what manner can hydrogen gas be transferred from one vessel to another ? Explain the experiment represented in Fig. LXXIV.

By what experiment can you show the levity of hydrogen gas ? Explain Fig. LXXV. How does the experiment you have just described enable us to find the specific gravity of hydrogen ?* Describe the experiment represented in fig. LXXVI, which shows the levity and combustibility of hydrogen.

[§ 17.] Is galvanic electricity the only means of obtaining hydrogen gas ? What other means have we for procuring this gas ? (Explain Figs. LXXVII, and LXXVIII.)

[§ 18.] How is the great levity of hydrogen gas taken advantage of ? (Explain Fig. LXXIX). In what consists the construction of balloons for ascending in the air ? (Explain Fig. LXXX).

[§ 19.] In what proportions may oxygen be mixed with hydrogen ? Is there a strong affinity between the substances ?

By what experiment can you prove this ? Explain the experiment represented in Fig. LXXXI. In what manner does Prof. Schubert account for the explosion accompanying the combustion of inflammable air ?

[§ 20.] What is formed when one volume of hydrogen gas is mixed with two volumes of atmospheric air ?

Explain Fig. LXXXII. Explain the experiment represented in Fig. LXXXIII.

[§ 21.] What is the most important application made of the properties of inflammable air to various chemical purposes ? Explain Fig. LXXXIV. What are the effects of Dr Hare's compound blow-pipe ?

[§ 22.] What is the construction of the blow-pipe

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* This question need not be put to very young pupils.

with *condensed* oxygen and hydrogen? Explain Fig. LXXXV. How is the apparatus used?

[§ 23.] Describe the experiment (represented in Fig. LXXXVI) by which water is formed by the combustion of hydrogen? What inference do you draw from this experiment with regard to the nature of water?

[§ 24.] In what *proportion* do hydrogen and oxygen combine to water? By what experiment can you prove that water consists of two volumes of hydrogen combined with one volume of oxygen? Explain Fig. LXXXVII. What does this experiment serve to establish?

[§ 25.] Of how many equivalents of hydrogen and oxygen does water consist? What is the equivalent number of oxygen? What, that of hydrogen? What, therefore that of water?

[§ 26.] What remarkable law has been discovered in reference to the combinations of the gases?

[§ 27.] What are the most essential properties of water? What is the weight of a cubic inch of distilled water? At what degree of Fahrenheit's scale is the greatest density of water? What is the condensation of oxygen and hydrogen in the act of forming water.

How does the sudden diminution in the volume of the two gases account for the heat given out during the combustion of hydrogen?

What influence has this peculiarity of water — to be most dense at 40 degrees Fahrenheit — have upon the economy of nature? What would become of the waters in the northern regions, if water did not possess this property?

[§ 28.] Does water in the act of freezing or congealing expand or contract in volume? What phenomena does this explain? What is the specific gravity of ice? What is this the reason of?

[§ 29.] Which of the three kinds of water, rain, river, or pump water, is the purest? Why? Which comes next to it? What are the first two kinds called in opposition to pump water? What does pump water always contain? What are the ingredients of mineral waters? What are the principal salts contained in sea-water?

[§ 30.] What do all kinds of water contain? Do they contain atmospheric air as a chemical ingredient, or merely mechanically entangled? By what means may water be freed from it?

[§ 31.] Is water a good conducter of heat? What experiment convinces us that water is a bad conductor of heat?

Describe the experiment represented in Fig. LXXXVIII. Explain the experiment represented in Fig. LXXXIX.

Could water be heated without the mobility of its particles? Why not? What then, is the reason why burning ether on the surface of water does not affect a small thermometer immersed in the water?

[§ 32.] Does the pressure of the atmosphere or of steam promote or hinder the boiling of water and other liquids? What is this the reason of? How can this be illustrated? (Describe the experiment represented in the XCth figure).

What does this experiment prove? What inference can you draw from the experiment just described, with regard to the boiling of water or other liquids?

[§ 33.] What does water constantly absorb? Into what does it thereby become converted? Of what use is the absorption of heat or caloric by the large waters on the surface of our globe? What is the continued formation of vapors from the surface of water called? What do the vapors of water contained in the atmosphere, form? what becomes of these, when brought in contact with colder strata of air?

By what experiment may the refrigerating influence of forming vapors of liquids be illustrated? Describe the experiment represented in Fig. XCI.

What other illustration is there of the cold produced by the rapid process of evaporation?

Describe Dr Wallaston's Cryophorus or Frost-bearer, and its operation. By what other natural processes are the effects of evaporation happily illustrated? How does the process of evaporation operate upon the human body? Why is it dangerous to be exposed to a current of cold air when the clothes have become moist with perspiration?

[§ 34.] What is necessary to obtain water in its pure state? By what process may small quantities of water be distilled? (Explain Fig. XCIII). What properties does the water thus obtained possess?

[§ 35.] What becomes of all the heat or caloric that is added to boiling water? What is steam which is shut up in a vessel capable of exercising? To how many times its volume may water thus be expanded?

By what experiment may the principal properties of steam be illustrated? Describe the experiment represented in fig. XCIV. Why is the piston in your experiment driven down when the tube is plunged into cold water? and why is the piston moved up again, when the bulb of the tube is again held over the flame of the lamp? What is the cause of the power and operation of the steam-engine?

[§ 36.] What properties must chemically pure water possess? When it is only necessary to know the proportion which the *solid* substances, dissolved or contained in water, bear to the whole volume of the liquid, by what means may this be ascertained?

[§ 37.] Is water the only compound of oxygen and hydrogen? What other combination is there of the same elements? What is the name of this compound?

[§ 38.] What are the principal properties of oxygenized water?

Recapitulate the binary combinations of hydrogen and oxygen.

C. QUESTIONS ON NITROGEN.

[§ 39.] What sort of gas is *Nitrogen*, and what are its principal properties?

Why has this gas been called Azote? Is this expression correct? Why not?

[§ 40.] By what means may nitrogen be easiest obtained? How is nitrogen separated from oxygen?

[§ 41.] *What particular mixture of Nitrogen and Oxygen resembles, or constitutes our atmosphere?*

How do we know that nitrogen and oxygen are actually contained in the atmosphere in the proportion of 4 volumes of nitrogen to 1 volume of oxygen.

[§ 42.] Are nitrogen and oxygen the only ingredients of atmospheric air? What other substances are yet contained in it? Upon what does the quantity of vapor depend? Is the proportion of carbonic acid greater in summer or in winter? in the night or in day-time.

What are the exact proportions, by weight, of nitrogen, oxygen, and carbonic acid gas contained in our atmosphere, abstracting for a moment from the variable quantity of vapor?

[§ 43.] *Is the proportion of the principal ingredients of our atmosphere, nitrogen and oxygen, variable?*

At what result did Gay Lussac arrive from examining the air at a height of 24,600 feet above the level of the sea, and that of crowded theatres in Paris?

Has any other mixture of gases been found capable to support the process of respiration and animal life as well as atmospheric air? What would be the probable consequence if the air did contain more nitrogen or less oxygen? What, on the contrary, would take place if the quantity of nitrogen be diminished, or that of oxygen increased?

[§ 44.] What accidental ingredients are yet contained in the atmosphere, besides those you have already enumerated?

[§ 45.] What is the object of Eudiometry? What substance will answer this purpose? What is an apparatus constructed for this purpose called? *Explain the construction of Achard's Eudiometer* (Fig. XCV.) Of what consists Volta's Eudiometer for detonating oxygen and hydrogen gas? (Explain Fig. XCVI). What other Eudiometer may be used for this purpose instead of the one you have just described?

By what means, in the experiment you have now described, are you able to find the volume of oxygen contained in atmospheric air?

Upon what principle is Gay Lussac's eudiometer constructed? Of what does it consist? How is it to be used?

What fact has been established by the various experiments which have been made with Eudiometers? Can the great difference which exists between the air of certain places, and at different times, be explained from the greater or less quantity of oxygen contained in it? Do we know anything about the different miasmas which, at times, are contained in the atmosphere?

[§ 46.] In how many different proportions does nitrogen combine with oxygen? What are the products of these combinations?

[§ 47.] What is the chemical composition of protoxide of nitrogen? Is it a product of nature or of art? How is it best and easiest obtained? (Explain the experiment represented in Fig. XCVIII).

[§ 48.] What are the characterizing properties of protoxide of nitrogen.

What is the average quantity of this gas that can be inhaled without being injurious to the lungs?

What influence has electricity upon the Protoxide of nitrogen? What becomes of this gas when mixed with hydrogen, and an electric spark is applied to it?

(The remainder of this section it is sufficient for the pupil to understand. More advanced pupils may repeat the reasoning.)

[§ 49.] What is the chemical composition of *Deutoxide of Nitrogen*? By what means is it obtained? How is this process explained?

[§ 50.] What are the principal properties of deutoxide of nitrogen? What takes place when deutoxide of nitrogen is mixed with oxygen and the experiment is made over water? What takes place if, instead of oxygen, atmospheric air is employed?

What instrument is founded upon the property of the deutoxide of nitrogen to absorb the oxygen from atmospheric air?

How then do you use the apparatus described on page 92, Fig. XCVII?

[§ 51.] By what means may deutoxide of nitrogen be decomposed ?

[§ 52.] What is the supposed chemical composition of Hypo-nitrous acid? In what manner is it generated? What do some chemists pretend, as regards its appearance at common temperatures?

[§ 53.] What is the chemical composition of nitrous acid? In what way may it be produced?

[§ 54.] What remark can you make respecting the different combinations of oxygen and nitrogen by volumes? What general law does this verify ?

[§ 55.] What are the properties of nitrous acid ?

[§ 56.] What is the chemical composition of nitric acid ? Where is nitric acid found in nature ? In what way is it obtained by art? By what other means may it be procured ?

How is nitric acid produced in the atmosphere ?

[§ 57.) Is nitric acid, found in either way you have just described, obtained in a gaseous or liquid state ?

[§ 58.] In what manner is liquid nitric acid prepared for commerce ? What is the smallest quantity of water with which it is known to exist ? What is the liquid nitric acid sometimes called ? When is nitric acid said to be in an an-hydrous state ?

[§ 59.] What are the characterizing properties of nitric acid ? What is its specific gravity ? How does it act upon the skin and all organized matter ? What takes place when nitric acid is brought in contact with hydrogen ? What when poured upon warm powdered charcoal ? How does it affect spirit of turpentine or any other essential oil ? (Explain the experiment represented in Fig. XCIX.)

[§ 60.] What applications are made of this acid in the arts ?

[§ 61.] What is the chemical composition of Ammonia? Where does ammonia occur? How is it best obtained? What is formed when the experiment is made over water?

What is the aqueous solution of ammonia called? What does the salt contained in smelling-bottles consist of?

[§ 62.] What are the principal properties of ammonia? To what class of bodies does ammonia belong? What is it therefore called?

[§ 63.] What takes place when ammonia is passed through red-hot tubes (particularly if some iron wire be coiled up in them)?

What are the most important binary combinations of nitrogen?

D. Questions on Chlorine.

[§ 64.] In what state is chlorine found in nature? How may it be produced by art?

[§ 65] What are the characterizing properties of chlorine?

In what manner can chlorine be transferred from one vessel to another? (Explain Fig. C.) What other experiment can be made to show the property of chlorine to support combustion and to ignite some of the metals?

[§ 66.] In how many different proportions does chlorine combine with oxygen? What are the compounds? Has any of these compounds been found in nature in its simple state? What is the composition of protoxide of chlorine? What sort of gas is it?

What is the composition of the peroxide of chlorine? What are its properties?

What is the composition of chloric acid? What are its properties?

What is the composition of per-chloric acid? What are its properties?

[§ 67.] What is the name of the compound formed by the combination of chlorine with hydrogen? Where is this compound found? What is the composition of muriatic acid? By what influence is it obtained? In what other way may muriatic acid gas be obtained?

[§ 68.] What are the principal properties of muriatic acid? What does muriatic acid lose in contact with the oxides of metals?

[§ 69.] What takes place when muriatic acid gas is conducted into water? What apparatus is generally employed for this purpose? (Describe the apparatus represented in Fig. CI.)

What sort of vessels are employed when liquid muriatic acid is prepared on a large scale? What is this the cause of?

Are any applications of this acid made in the arts? What are they?

[§ 70.] To what compound does chlorine combine with nitrogen? What is the composition of this compound? By what process is it formed?

[§ 71.] What are the properties of chloride of nitrogen? How is its great explosive power explained?

What are the principal binary combinations of Chlorine?

CHAPTER II.

OF THE REMAINING NINE NON-METALLIC ELEMENTS, AND THEIR COMBINATIONS.

§ 72. Besides the four gases, Oxygen, Hydrogen, Nitrogen and Chlorine, there are yet nine other non-metallic elements which, with the exception of Boron, are all solid at the mean temperature of the atmosphere. Their names are *Carbon*, *Sulphur*, *Selenium*, *Phosphorus*, *Boron*, *Iodine*, *Bromine*, *Silicon*, and *Fluor*. They are, like the gases, bad conductors of electricity and heat,* and become all converted into vapor by the application of a gentle heat.

A. Carbon.

Chemical Equivalent = 6.

§ 73. *Properties of Carbon.* Carbon occurs in nature as the principal ingredient of coal. It is either found in its pure state — as diamond; or mixed with earthy masses — in graphit, anthracite coal, turf, &c, and enters largely into the composition of all animal and vegetable substances.

Diamonds are chiefly found in the East Indies, (in the mines of Golconda) and in Brazil, (in the Province of Serro do Frio). They are generally disseminated in sand or gravel, and frequently mixed with gold. They are considered gems of the highest value. They are found either crystallized (in form of

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* Carbon is a pretty good conductor of both.

octahedrons*) or in grains. They are either colorless, (and are then said to be of the first water) or of a light red, green, blue, and even black color. Diamond is the hardest substance known. Its specific gravity is 3.52. When submitted to the action of heat in close vessels its properties do not change; but in the focus of a large burning-glass, or in pure oxygen it is entirely consumed. The product of the combustion, carbonic acid gas, is precisely the same as that obtained from burning charcoal.

Graphit or *Plumbago* is of a grayish black color (like iron or steel). It is opaque, and has a black, metallic lustre. It resists the action of a common fire, but is consumed by higher degrees of heat, or by the effect of a voltaic battery. It is a compound of carbon and about 4 per cent of iron. Extensive use is made of plumbago in the manufacture of lead-pencils. It is also used in the making of crucibles for the use of gold and silver-smiths. Mixed with fat it a most excellent means to prevent friction in wagons, mills, and other machines.

Anthracite Coal. — *Anthracite Coal* (glance-coal of the English) occurs in irregular forms. Great quantities of it are found in Pennsylvania, and will probably be discovered in other parts of the United States. It is opaque, of a greyish-black color, is rather difficult to kindle, burns without much flame or smoke, and leaves for ashes a mixture of silicious earth, mixed with clay and oxide of iron.

Lehigh Coal. — *Lehigh Coal* has a strong, metallic lustre, and leaves when burnt 13½ per cent white ashes. Although difficult to kindle, it is extensively used in America.

Black and Brown Coal. — *Black and Brown Coal* is found in England Scotland,† and Germany.‡ When burnt it occasions a disagreeable smell, owing to the oily substances which it contains, and which are given off during combustion. It leaves, however, but 3 per cent of ashes.

Turf. — *Turf* is a tissue of vegetable substances, reduced to a compact solid, by a peculiar process of decomposition. When slowly burnt it produces from 26 to 28 per cent of *coal*, but leaves a great deal of ashes.

Vegetable Charcoal is obtained by burning wood, which pro-

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* See Grund's Solid Geometry, Appendix.

† New-Castle, Whitehaven, Dumfrieshire, Derbyshire, Sheffield, Clydesdale, &c.

‡ Silesia, Westphalia, Saxony, Wurtemberg, and Bavaria.

cess, however, must be carefully conducted. It is used as fuel in cupelling furnaces; as a principal ingredient in the manufactory of powder (see Chap. IV), and as a dyeing stuff in the manufactory of blacking. It has the peculiar property of resisting the putrefaction of animal substances, (and may therefore be used for the preservation of meat); but it destroys their color and smell. It is also a great purifyer of water, and is on this account used extensively in the refining of sugar. But the most remarkable property of charcoal consists in its power of resisting destruction. This property of charcoal was even known to the ancients, who were in the habit of charring their piles and posts (burning their surfaces to coal) before driving them into the ground; and so well has this preserved them from decay, that when the piles upon which the foundation of the temple of Ephesus rested, were but of late taken from the ground, the charcoal upon their surface appeared perfectly fresh, and the wood underneath free from rot or putrefaction. Charcoal is also unalterable by heat, if excluded from atmospheric air; but in contact with other substances exercises a powerful influence upon them by combining with the oxygen which enters into their chemical composition. Its mechanical structure (its interstices, or pores) enable it to absorb large quantities of gases, and it is known in one instance to retain more than 90 times its own volume.

Animal Charcoal (bone-black) is obtained from burning animal substances, commonly bones, horns, &c. It is of a deep black color, and is used in the manufactory of printers' ink.

REMARK. — Although carbon abounds in all the three kingdoms of nature, it is rarely found in its pure state — as diamond. All attempts to procure diamonds by art, or, in other words, to extract pure solid carbon from other substances, have hitherto proved ineffectual.

Query — Why is charcoal so different in appearance from diamond, one being black and opaque, the other transparent, brilliant, and the hardest substance known? *Ans.* — Because diamond is *Carbon* in its pure, crystallized state, and the other is mixed with various impurities, and other constituents, adding sometimes more than 10 or 20 per cent to its amount of pure carbon. *Ques.* — But why has it thus far been impossible for us to crystallize carbon, or to make diamonds, as we are able to produce water from the union of its ingredients, hydrogen and oxygen? *Ans.* — The probable reason is that diamond is of *organic* formation as the similarity of its chemical composition to charcoal plainly indicates; and that if this be true, we might as well wish to create plants and animals, because we know their chemical composition, which would evidently be impossible.

Combinations of Carbon with Oxygen.

§ 74. Carbon combines with oxygen in 5 different proportions; but of the compounds thus formed there are but two which deserve special notice, or which are of any application in common life. These are *carbonic oxide,* and *carbonic acid.*

Carbonic Oxide

consists of 1 equivalent of Carbon = 6
and 1 equivalent of Oxygen = 8

Consequently, chem. equiv. of Carbonic Oxide = 14

§ 75. This compound does not occur in nature; but is easily produced by art, by applying heat to a mixture of charcoal and lime, or by heating two parts of chalk and one of iron-filings in a gun-barrel, and collecting the gas which is given off in the usual manner.

Both processes are easily explained. In the first instance, the vapors of carbon produced by the charcoal, combine with the oxygen of the lime (which, as we shall see, is a combination of oxygen with calcium). In the second case, when lime or chalk are heated, carbonic acid is formed (see the next section), which, when the iron is heated, yields again a portion of it to this metal, by which means it becomes reduced to carbonic oxide.

§ 76. *Properties of Carbonic Oxide.* It is a gaseous, colorless substance, which in its pure state is without taste or smell. It is incapable of supporting the process of combustion, but is itself inflammable and burns with a blue flame. When taken into the lungs it causes giddiness, stupor, and fainting, even when mixed with 25 per cent of atmospheric air.

Carbonic Acid— (Fixed Air.)

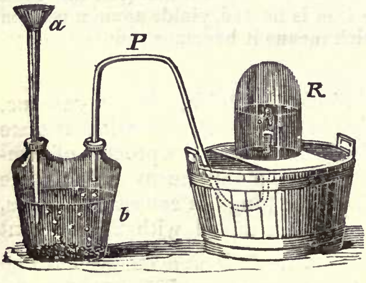
Chemical composition: 1 equivalent Carbon = 6
2 equivalents Oxygen (each 8) = 16

Consequently, chem. equivalent of Carbonic acid = 22.

§ 77. Carbonic acid gas is always contained in small quantities in the atmosphere; particularly in the neighborhood of volcanos; (near mount Vesuvius, in the cave of Pausilippo, near Puzzuoli, in Pyrmont, &c). It is continually produced by the burning of wood or coal, by the respiration of men and animals (see chapter VII), and by every process of fermentation and putrefaction which takes place in nature. It is also found in coal mines, where it occasions the *chalk dampness* of the miners, which in many instances has proved fatal to them. By art it may be produced by dropping fragments of marble or chalk into dilute muriatic or sulphuric acid.

Marble and chalk are compounds of carbonic acid with an oxide of a metal called oxide of calcium, and are composed of about 22 parts of carbonic acid with 28 parts of lime. When exposed to the action of sulphuric or muriatic acid, which have a strong affinity for the lime, this substance combines by elective affinity with the acid, setting the carbonic acid free.

Fig. CII.



For the purpose of making the experiment, introduce some pure white marble in small fragments into a two-necked bottle *b*, shaped like that represented in the adjoining figure, CII. Upon these, through the funnel *a*, pour some dilute sulphuric acid; when a quick effervescence will take place, by which carbonic acid is given off in abundance, which may be conducted through the pipe P, through the pneumatic tub into the receiver R.

Query — By what kind of affinity is the carbonic acid, in this experiment, formed? *Ans.* — By single elective affinity. *Ques.* — Why? *Ans.* — Because marble is a carbonate of lime, consisting of a combination of carbonic acid with oxide of calcium (see the last section); but when sulphuric acid is added, for which the oxide of calcium has a stronger affinity than for carbonic acid, then the oxide quits its combination with the carbonic acid and elects as it were, in preference, a combination with the sulphuric acid, setting the carbonic acid free. This is the cause of the effervescence which takes place when dilute sulphuric acid is poured upon fragments of marble or chalk.

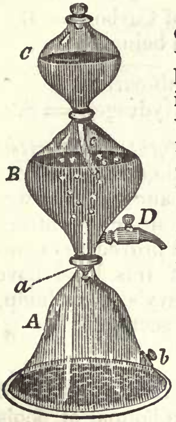
§ 78. *Properties of Carbonic Acid.* Carbonic acid or as it is commonly called, *fixed air*, is a combination of equal volumes of carbon and oxygen. It is a perfectly colorless gas, which has a pungent, half acid taste, and is not inflammable. A burning taper immersed in it is instantly extinguished. When taken into the lungs it proves speedily fatal to life. It is so extremely poisonous that but a small quantity of it, even mixed with atmospheric air is sufficient to produce dimness, difficulty of respiration, swoon, apoplexy, and death. Hence the danger arising from burning charcoal in a room that is not well ventilated; because during combustion a considerable quantity of this gas is given off.

The danger of burning charcoal in a confined room is twofold. 1st. From the fact that during the process of combustion a considerable quantity of oxygen is consumed, which, if no draft be created to supply fresh quantities of it, must finally terminate in a complete exhaustion of that principle which alone can support animal life. 2d. By the combination of oxygen with charcoal a considerable quantity of carbonic acid is formed, which from the stupor and swoon which it causes, deprives the person thus exposed to its injurious influence, soon of the means of rescuing himself from this deadly poison. It is needless to dwell on the many fatal accidents that have occurred either from ignorance, or from a disregard of this property of carbonic acid.

§ 79. Carbonic acid gas is quickly absorbed by water and other liquids. In this manner (mechanically entangled between the particles of liquids) it is contained in a variety of mineral waters, and in all *sparkling*, fermenting liquors, such as beer, cider, champaigne, &c, causing that agreeable pungent taste, which these liquids lose after being for some time exposed to the atmosphere. Our common Soda and Seltzer waters are charged with carbonic acid by means of forcing pumps. The pleasant fresh taste of common pump water is in a great measure owing to the carbonic acid which collects at the bottom of the wells. From river water the carbonic acid is continually absorbed by the atmosphere. This constitutes the principal difference between hard and soft water (see Chapter I, § 29, page 71).

This is a striking instance of the various properties of gases and their several adaptations to our convenience and comfort. Thus carbonic acid, though perfectly irrespirable, and poisonous and destructive to life when taken into the lungs, may with impunity be taken into the stomach, and is one of the most efficient and agreeable means of refreshing ourselves when overcome by the heat of summer. But what is still more interesting in this gas, is the contrast between its properties, and those of the elements from which it is derived. Carbon, which in the form of charcoal may be taken into the stomach in a considerable quantity without being injurious, and whose presence in a dormitory is no more dangerous than atmospheric air itself; when combined with oxygen, an element without which life would instantly cease, and which may therefore be considered the very supporter of it, forms a poison which may destroy life in a very few minutes! And this very poison, when taken into the mouth and stomach, produces no other effect than an agreeable, gentle coolness — which is perfectly healthy and palatable!

Fig. CIII.



Before Seltzer and soda waters became as common as they are now, Nooth's apparatus was used for impregnating water or any other liquid with carbonic acid. Fig. CIII shows its construction and use. It consists of a vessel A, destined to hold some pulverized marble or chalk, upon which, through the opening *b*, may be poured some dilute sulphuric acid. The carbonic acid gas which is thus generated ascends through the valve *a*, into the second vessel B, filled with the liquid, which is to be impregnated with it. The valve *a*, is so constructed that it admits the carbonic acid into the vessel B, but prevents the liquid in that vessel from descending into A. The uppermost vessel C, is destined to receive the water which is displaced from the vessel B, by the rise of the gas. When the liquid in B, is sufficiently charged with the gas, it may be drawn off by means of the discharging cock D.

§ 80. It has been mentioned in § 36, page 85, as one of the criterions of pure water, that mixed with lime-water it must not become turbid, otherwise it contains carbonic acid. The reason of this is now easily understood. When lime-water is poured into water which contains carbonic acid, this substance combines immediately with the lime to an insoluble compound, called carbonate of lime, which is at first seen in form of white clouds and afterwards sinks to the bottom.

Combination of Carbon with Hydrogen.

§ 81. Carbon unites in two different proportions with hydrogen. The products of these combinations are two permanently elastic gases — *Sub-carburetted Hydrogen*, and *Carburetted Hydrogen.*

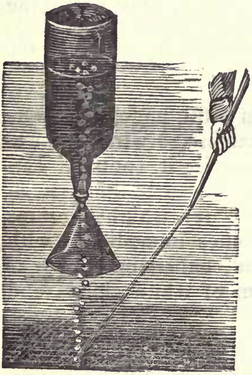
Sub-carburetted Hydrogen

is composed of 1 equivalent of Carbon = 6
and 2 equivalents of Hydrogen (each being 1) = 2

Consequently, chemical equivalent of sub-carburetted Hydrogen = 8.

§ 82. This gas, which is also called *light Carburetted hydrogen*, or heavy inflammable air, is formed wherever organic matter putrefies, in pools, swamps, and stagnant waters. It is also found in coal mines (the fire-damp of the miners), where by its dreadful explosion it proved frequently fatal to the workmen. (Disasters of this kind have since been obviated by Sir Humphrey Davy's safety lamp, for the description of which see the next section.)

Fig. CIV.



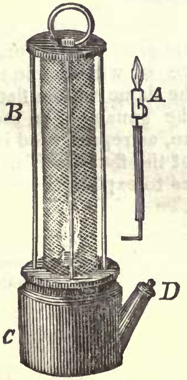
It may be readily procured by stirring the bottom of pools or stagnant water, and collecting the gas which rises in little bubbles with an inverted bottle, which for this purpose ought to be provided with a funnel, (see the adjoining figure, CIV).

§ 83. *Properties of sub-carburetted hydrogen.* It is a colorless gas which is highly inflammable, and burns with a yellowish blue flame, giving out considerably more light than pure hydrogen alone. But it does not support combustion, and is speedily fatal to animal life. Mixed with atmospheric air it forms a powerful explosive compound, which, on the application of the flame of a candle, detonates with great violence. When burnt in oxygen it is decomposed, its hydrogen combining partly with the oxygen to water, and its carbon forming with the remaining oxygen carbonic acid.

We have mentioned in § 82 that light carburetted hydrogen is spontaneously formed in coal mines, where by its explosions it proved frequently destructive to the workmen. This is so much more the case as the miners have no warning of its presence; it being lighter than atmospheric air, and on that account collects above the ground on which they work. To this must be added the necessity under which miners are to work by the light of lamps, in the immediate neighborhood of such an explosive compound, which frequently covers whole acres of surface, and extends several hundred perpendicular feet in height.

Now it has been observed that a high degree of temperature is necessary to ignite all inflammable mixtures of gases; and that metallic wire, even when red hot, is insufficient for this purpose; but that the flame of a candle will set fire to them; because the heat which is given out by it, is much greater than that of any red-hot metal. This observation, together with the discovery of Dr Wollaston, *that explosive mixtures cease to burn in very narrow tubes*, led Sir Humphrey Davy to suppose that if the flame of a candle or lamp were completely surrounded by wire-gauze, consisting of very fine meshes, it would perhaps protect the gas from being ignited, and yet afford, through the small apertures of the gauze, sufficient light for the miners to work by. This idea was most completely realized by the invention of his *safety lamp;* which is now generally used by miners, and by which thousands of lives are annually protected against the consequences which might attend explosions in coal mines.

Fig. C.V.



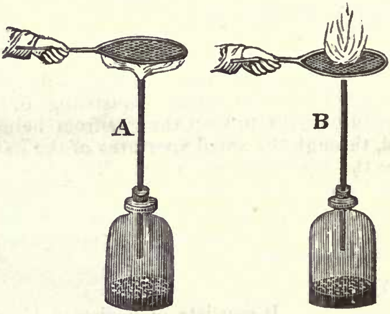
It consists of a cistern C, containing all that is necessary for a common lamp, and having a spout D, on its side for the purpose of feeding it with oil. The flame of the lamp is covered by a cylinder of wire-gauze, which is supported by three brass rods, to which is fixed the cover, and a ring or handle by which the whole is carried. A represents a piece of wire which moves up and down in a tube, and by which the lamp is trimmed without establishing a direct communication between it and the external air. This lamp, upon experiment, has been found to answer all the purposes for which it was intended, and may be carried with perfect safety into the most explosive mixtures of gases, even when the wire-gauze has become red-hot by heat — for the gas will not be ignited by it.

Query — What is the reason the flame does not pass through the wire-gauze of Sir Humphrey Davy's safety-lamp? *Ans.* — Because the meshes of which it consists act as so many narrow tubes through which (according to Dr Wollaston's experiments) the flame of the lamp does not pass; and the red-hot wire, of itself, is not sufficient to ignite it. *Ques.* — But what is the reason the flame does not pass through the wire-gauze? *Ans.* — Because the flame coming in contact with the wire, which is a good conductor, its heat becomes *latent* or hidden (Natural Philosophy, Chap. VI), which reduces its temperature below that which is necessary to ignite gas.*

That wire-gauze does completely intercept the flame of any burning substance, may yet be shown by the following easy

Experiment. — Provide a bottle filled with hydrogen gas; through its neck introduce a narrow pipe, and ignite the gas which will escape through the mouth of the pipe (see experiment, Fig. LXXXIII, page 69). If a piece of wire-gauze is held over the flame, as represented in A, the flame will be flattened down, but it will not pass through the gauze; if on the contrary the gas is ignited above the gauze, as represented in Fig. B, then it will indeed burn freely; but the flame will not be communicated to the pipe. This serves to explain the operation and usefulness of the safety-lamp.

Fig. CVI.



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* The learner ought to recollect that the flame of a lamp or candle consists of burning gas or vapors (see Fig. LXII and LXIII, Chap. I, page 53).

Carburetted Hydrogen — Olefiant gas.

Chemical Composition: 2 equivalents of carbon,
(each $= 6) = 12$
2 equivalents of Hydrogen (each $= 1) = 2$

Chemical equivalent of Carburetted Hydrogen $= 14$.

§ 84. This compound is altogether a product of art. It may be obtained by dry distillation of animal or vegetable substances, or from a mixture of one volume of alcohol and four volumes of strong sulphuric acid, gently heated in a retort. The mixture will soon turn black, and emit the gas, which may be collected over water as in the usual way.

Alcohol is a compound of carbon, hydrogen, and oxygen, as we shall see in the 7th Chapter, when treating on vegetable chemistry; but when sulphuric acid is added, which has a great affinity for water, (contained in the alcohol), it sets the carbon and part of the hydrogen free, which combine with each other, to olefiant gas.

§ 85. *Properties of Carburetted Hydrogen,* or *Olefiant Gas.* It is a perfectly colorless, elastic fluid, of a disagreeable smell, (but no taste) which is easily inflammable and burns with a yellowish white flame, much brighter than the common flame of a taper. When mixed with oxygen and ignited, it detonates with great violence. By passing it through a red-hot porcelain tube, it parts with a portion of its carbon, by which means it becomes converted into sub-carburetted hydrogen (see § 82).

§ 86. *Applications of the Olefiant Gas.* The flame of pure carburetted hydrogen gas gives, as we have said before, a most brilliant light, and is on that account extensively used for illuminating shops and streets instead of lamps and candles.

The brilliancy of the flames of other gases depends on the quantity of olefiant gas which enters into their composition, or, in general, upon the quantity of carbon which they contain; the light which they give out being always in proportion to that substance. Diamond, which is pure carbon, when burnt in oxygen gas or by the agency of a powerful galvanic battery, throws out so vivid a light, that if the experiment be made by candle-light, the very flame of the candles will yet appear casting a shadow on the wall.

Gas-light was employed for illumination, as long as a century ago, by Dr Clayton ; but for its general introduction we are indebted to Mr Murdock who first introduced it into England, from which it gradually spread all over the continent of Europe, and is now successfully employed in some of the large cities of America. That used in Europe for illuminating shops and streets, is generally prepared from bituminous coal distilled in close vessels at a red heat. Oil and resin have lately been employed with the same good effect. In America olefiant gas is prepared principally from the distillation of whale oil. This is done in large retorts, half filled with pieces of brick to increase the heated surface. The oil is by this means decomposed and yields a large quantity of gas, which is much purer, and contains a greater proportion of carburetted hydrogen than that which is prepared from coal. It is on that account better adapted to the purposes of illumination than coal-gas ; but its preparation is much more expensive. *Resin*, by a peculiar treatment has been discovered to yield the same gas at only one fourth of the expense of the gas prepared from oil, and is now much employed in the shops of London and Paris. The gas which is thus obtained is conducted in pipes to the place where it is to be burned.

The reason why carburetted hydrogen has also been called olefiant gas, is because it readily combines with chlorine to a yellowish liquid resembling *oil*.

Besides carburetted and sub-carburetted hydrogen, there exist yet a number of other combinations between hydrogen and carbon, the precise composition of which has not as yet been ascertained.

Combination of Carbon with Nitrogen — Cyanogen.

Chemical composition of Cyanogen.

2 equivalents of Carbon (each = 6) = 12
1 equivalent of nitrogen = 14

Consequently, chemical equivalent of Cyanogen = 26.

§ 87. Carbon combines with nitrogen and forms with it a gas, which is called *carburet of nitrogen* or *cyanogen* This gas does not occur in nature; but may be obtained by art, by boiling a substance called *Prussian blue* with *red oxide of quicksilver* in a sufficient quantity of water. By this means a compound is obtained, which upon cooling shoots into crystals, and is called *cyanuret of mercury*. This substance when dried at a temperature a little below the boiling point, and afterwards in a retort exposed to a gentle heat, becomes dark and liquid, and gives off a gas which may be collected over quicksilver. This gas is the carburet of nitrogen, or *cyanogen*.

§ 88. *Properties of Cyanogen.* It is a colorless, inflammable gas, which has a pungent smell and affects the eyes. Its most remarkable property consists in its capacity to combine with other substances in a manner similar to oxygen, although it is a compound, and oxygen is an element. On this account it has been called *cyanogen*, an appellation resembling that of other elements (hydrogen, oxygen, nitrogen, &c.) from two Greek words signifying 'formation of blue,' because it is a principal ingredient of Prussian blue. On this account we shall make an exception to the general principle laid down in the plan of this treatise, — to treat in the first three chapters only of the elements and their binary compounds — and proceed immediately with the

Combinations of Cyanogen with Oxygen.

§ 89. Cyanogen combines with oxygen in three different proportions, forming with it three different compounds, viz: *Cyanous acid*, *fulminic acid*, and *cyanic acid*. All these substances are products of art (the latter has only been discovered in 1828) and may be obtained indirectly from the action of alcohol on some of the salts called nitrates. (See Chap. IV). Their chemical composition is not yet satisfactorily determined.

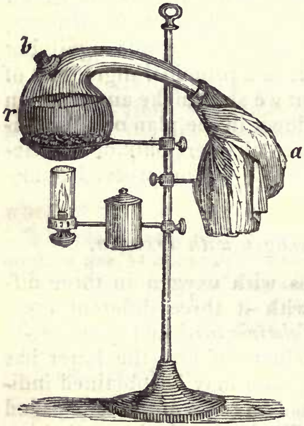
Combination of Cyanogen with Hydrogen — Prussic Acid.

Chemical composition: 1 equivalent of Cyanogen = 26
1 do. Hydrogen = 1

Chemical equivalent of Prussic acid = 27

§ 90. A combination of Cyanogen with hydrogen is called *hydro-cyanic* or ***Prussic acid.*** This acid is contained, and may be extracted from many vegetables, particularly from bitter almonds, from the stones of peaches, prunes, cherries, &c ; in short from all vegetable substances which smell like bitter almonds. But it may also be obtained from Prussian blue, by the following complicated process: Mix together 4 ounces of powdered Prussian blue, 2½ ounces of red oxide of mercury, and about 12 ounces of water; boil the mixture half an hour, and stir it frequently during that time. When the blue color of the mixture has disappeared and changed into a yellowish green, filter the solution, and add to the residue a sufficient quantity of boiling water to make up for the loss by the first boiling. When this solution is again filtered, put it into a tubulated retort *r*, (see the figure), containing 2 ounces of iron filings, and pour upon it, through the opening *b*, 3 or 4 ounces of dilute sulphuric acid. Connect the retort now with a receiver *a*, and apply to it the flame of a lamp. Vapors of Prussic acid will be formed in the retort *r*, which may be condensed in the receiver *a*, by covering it with a wet cloth, for the purpose of keeping it cool and secluding it from the light. The distillation may be continued until about three ounces of Prussic acid are obtained.

Fig. CVII.



The generation of Prussic acid by the process we have just described is accounted for in the following manner. Prussian blue is a combination of Prussic acid with iron; but when the red oxide of mercury is added, for which the Prussic acid has a stronger affinity than for iron, it quits its combination with this substance and unites with the oxide of mercury to a salt called *Prussiate of Mercury*, which is immediately dissolved by the boiling water. When the iron-filings and the sulphuric acid are added to this solution, the iron combines with the oxygen of the oxide of mercury, setting the mercury free, which is precipitated to the bottom, while the oxide of iron which is thus formed, combines with the sulphuric acid to another salt, which is called *Sulphate of Iron*. The Prussic acid, which by this means becomes completely disengaged from its new combination with mercury, is by the heat of the lamp volatilized, and passes in form of vapors into the receiver, where, in contact with the cold glass, it is again condensed into the liquid form.

§ 91. *Properties of Prussic*, or *hydro-cyanic acid.* It is a clear, colorless liquid ; has a strong (somewhat penetrating) smell, resembling that of peach blossoms, and when strongly diluted with water, has a cooling, pungent taste, like bitter almonds. In its pure state it is the most powerful poison in nature. A few drops placed on the tongue of a small animal causes its death in a very few seconds. An elephant was killed by a hundred drops of it, and Prof. Währing, of Vienna, died by diffusing a small quantity of it on his naked arm. The vapors of this gas are inflammable, and when mixed with oxygen, detonate on the application of an electric spark. It boils at a temperature of about 80 degrees Fahrenheit, and congeals a little below zero. Diluted with water it is employed in medicine ; — and it is also used in the dyeing of broadcloths.

It is liable to spontaneous decomposition into its elements, which seem to have but a feeble affinity for each other, and is on this account difficult to preserve, even in close vessels and secluded from the light of day.

The first stage of its decomposition is marked by the liquid assuming a brown color, which soon turns into black and deposites a dark sediment. When arrived at this stage it loses its peculiar smell and emits that of ammonia (see § 62, page 102). It is then no longer a poison and has lost all its characterising properties.

§ 92. Prussic acid differs from the acids we have thus far become acquainted with, in the following properties :

1st. In its chemical composition; it being a combination of *three* elements, (nitrogen, carbon, and hydrogen) without oxygen, and

2d. By its possessing the acid qualities in a very feeble degree; for it has neither a sour taste, nor does it redden litmus paper;

But in combination with those substances called bases it forms, as we shall see, salts like the rest of the acids (see Introduction, page 38); and when separated from these again by the agency of galvanic electricity, it adheres to the positive pole — showing thereby that it is a *negative* electric. (Compare what we have said in the Introduction, page 38, with regard to the nature of acids).

When a quantity of potassium sufficient to absorb 50 measures of cyanogen is heated with 100 measures of vapors of Prussic acid, the 50 measures of cyanogen are wholly absorbed, and nothing but 50 measures of pure hydrogen remain; which proves that Prussic acid is composed of *equal volumes* of cyanogen and hydrogen. But as the cyanogen is about 26 times heavier than hydrogen (its specific gravity being nearly 26 times that of hydrogen), it follows that its composition, by *weight* is 1 equivalent of hydrogen to 26 of cyanogen, as staed at the head of the 87th section.

Other Combinations of Cyanogen.

§ 93. Cyanogen combines yet with Chlorine in two proportions, forming with it *Proto-chloride* and *per-chloride of Cyanogen.* In a similar manner does it combine with the two elements *Iodine* and *Bromine.* All these substances have similar properties; they are possessed of a peculiar, irritating odor, and are active poisons.

A compound of cyanogen and sulphur is called *sulphuretted* cyanogen. It is colorless, has a pungent smell, and reddens litmus paper.

Combinations of Carbon with Chlorine.

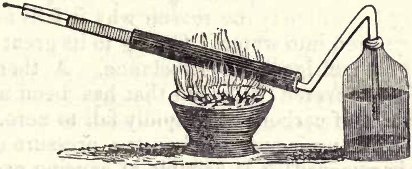
§ 94. Carbon and chlorine combine with each other in three different proportions, forming *sub-chloride*, *chloride*, and *per-chloride of carbon.* All these combinations are mere products of art, and are as yet little employed in the arts.

Combination of Carbon with Sulphur — Sulphuret of Carbon.

Chemical composition: 1 equivalent of Carbon = 6
2 equivalents of sulphur (each being 16) = 32
Consequently, chem. equiv. of Sulphuret of Carbon = 38.

§ 95. Carbon and sulphur may be made to combine by the following process, described in the Library of Useful Knowledge. Place an earthen tube of about an inch and a half in diameter, a little inclined across a chafing dish, and fill it nearly with small pieces of charcoal, well burnt and quite free from moisture. To the higher end of this tube adapt a glass tube filled with small pieces of sulphur, which may be pushed forward by means of a wire passing air-tight through a cork. To the other end of the earthen tube, a bent glass tube must be adjusted, which must pass below the surface of some water contained in a bottle. When the fire in the chafing dish has been lighted, and the centre of the tube become red-hot, the sulphur in the glass tube must be pushed forward to come in contact with the ignited charcoal, and immediately bubbles of gas will escape from under the water into the bottle, and a vapor will appear, which will condense under the water into a liquid. This is *sulphuret of carbon* — mixed however with a portion of water, from which, and other impurities, it may be freed by distilling it over at a gentle heat (not exceeding 110 degrees Fahrenheit), in a retort containing a little *chloride of calcium*, a substance which absorbs water very rapidly.

Fig. CVIII.



§ 96. *Properties of Sulphuret of Carbon.* It is a colorless, transparent liquid, has a strong *acid* (not acrid) taste, a nauseous, fetid smell, and is so exceedingly volatile as to boil already at a temperature of 110 degrees Fahrenheit. Its boiling point, therefore, is 102 degrees below that of water. This is the reason why in distilling it over, the heat applied to it must not exceed 110 degrees Fahrenheit. No degree of artificial cold has ever made it congeal; but it is highly inflammable, and emits during its combustion copious fumes of sulphuric acid (owing to its decomposition, in consequence of which the sulphur combines with the oxygen of the atmosphere to sulphuric acid). It is heavier than water, its specific gravity being 1.27, that of water being 1; which is the reason why it falls to the bottom when poured into water. Owing to its great volatility it is a highly refrigerating substance. A thermometer whose bulb is covered with lint that has been moistened with sulphuret of carbon, will rapidly fall to zero. Under the receiver of an air-pump (when the pressure of atmospheric air is removed) it is capable of causing even quicksilver to freeze.

Recapitulation of the principal binary and ternary Combinations of Carbon.

Carbon combines with
- *Oxygen* to
  - *Carbonic oxide.*
  - *Carbonic acid.*
- *Hydrogen* to
  - *Sub-carburetted*
  - *Carburetted*

  hydrogen.
- *Nitrogen* to *Cyanogen*, which combines again with
  - *oxygen* to
    - *cyanous*
    - *fulminic*
    - *cyanic*

    acid.
  - *hydrogen* to *Prussic acid.*
  - *chlorine* to
    - *protochloride*
    - *per-chloride*

    of *Cyanogen.*
  - *sulphur* to *sulphuretted cyanogen.*
- *Chlorine* to
  - *sub-chloride*
  - *chloride*
  - *per-chloride*

  of *Carbon.*
- *Sulphur* to *sulphuret of carbon.*

B. Sulphur.

Chemical Equivalent = 16.

§ 97. Sulphur is one of the few elements which occur in their simple form, and abound in all the three kingdoms of nature, but it is particularly found in the vicinity of volcanos, and in mountains of quartz and gypsum.

It has been discovered in the sulphur mountains of Ticsan near Quito; in the valley of Noto and Mazzara; on the banks of the Salso in Sicily; in Spain; in Poland (near Krakau); in Auvergne, near Mount Vesuvius, and in a crystallized state *(sofatora)* near Puzuoli in the kingdom of Naples and in the neighborhood of Mount Ætna, in Iceland, in Teneriffe, Guadaloupe, Java, and the Island of Bourbon. The volcano Puraçé, in South America, covers its immediate vicinity with crusts of sulphur.

Sulphur is also contained in many plants, especially in mustard, onions, and garlic, and in many animal substances, especially in the eggs of fowls.

Fig. CIX.

To purify it from stones and other earthy substances, it is melted and distilled (sublimed). For this purpose a heat of about 500 degrees Fahrenheit may be applied to some sulphur in a retort. It will first melt and then be changed into vapors, which when coming in contact with the colder receiver are condensed again and adhere to the sides of the glass in form of a fine powder called *flour* of sulphur. The properties of this powder are yet the same as that of sulphur.

§ 98. *Properties of Sulphur.* Sulphur is a greenish-yellow, tasteless mineral; which is highly inflammable, burns with a faint blue light, and emits when rubbed, or during combustion, a peculiar suffocating odor. The heat which it throws out is so small that it may be burnt out of gunpowder, of which it is a principal ingredient, without igniting it. Its specific gravity is 1.92 (water being 1), and it is therefore nearly twice as heavy as water. At the temperature a little above the boiling point of water it becomes liquid, and is then cast into moulds and sold in commerce under the name of *roll-brimstone.* When in a state of fusion it is poured into water it becomes of a consistency like wax, and is then used for taking impressions of coins, medals, cameos, &c, for which purpose it is particularly adapted; because its color, when fused, changes into brown, and resembles that of bronze. The applications of sulphur are numerous. It is used for matches; in the manufactory of gun-powder (of which it forms a principal ingredient), in the preparation of sulphuric acid, of cinnabar, of blue vitriol, &c. and it is also extensively employed in medicine.

Combination of Sulphur with Oxygen.

§ 99. Sulphur combines with oxygen in four different proportions; in the proportion of 1 to 1, 1 to 2, 2 to 5, and 1 to 3 equivalents, forming with it *hypo-sulphurous acid*, *sulphurous acid*, *hypo-sulphuric acid*, and *sulphuric acid.* The first and third of these combinations are products of art, and of little use in common life; but the second and fourth are highly important to the manufacturer and the physician. We shall therefore treat only of *sulphurous* and *sulphuric* acid.

Sulphurous Acid

is composed of 1 equivalent of sulphur = 16
and 2 equivalents of oxygen (each 8) = 16

Consequently, chem. equiv. of sulphurous acid = 32.

§ 100. This compound is, in a gaseous form, contained in the atmosphere in the vicinity of volcanos. It is also found (absorbed) in water; but may be obtained also by burning sulphur in atmospheric air. It may also be produced in a state of great purity by the action of sulphuric acid (for the preparation of which see the following section) on mercury. A mixture of these two substances may be gently heated in a retort, and the gas which will be given off collected over mercury — water having too great an affinity for it.

This process is easily explained in the following manner: sulphuric acid is a compound of 1 equivalent of sulphur with three of oxygen. When this is heated with mercury for which its oxygen has a great affinity, one equivalent of oxygen combines with the metal, and the two equivalents of oxygen which remain united with the sulphur, form sulphurous acid gas.

§ 101. *Properties of Sulphurous Acid.* It is a colorless, transparent gas, which possesses a peculiar smell and extinguishes all burning bodies. It is itself incombustible, and when taken into the lungs causes coughing and suffocation. By a pressure of 30 pounds to the square inch, it becomes liquefied. It is speedily absorbed by water, which is capable of absorbing more than 33 times its own bulk of it, and forms with it what is properly called *liquid sulphurous acid;* but it cannot in this state be preserved for any length of time.

All vegetable colors, with the exception of cochineal, are destroyed by it. (Blue vegetable colors are first turned into red and then wholly discharged; cochineal is only turned lighter, and changes into a yellowish red.) It is extensively used in bleaching, especially for silk and straw ware.

Sulphuric Acid — (Oil of Vitriol).

Chemical composition: 1 equivalent of Sulphur = 16
3 equivalents of Oxygen (each = 8) = 24

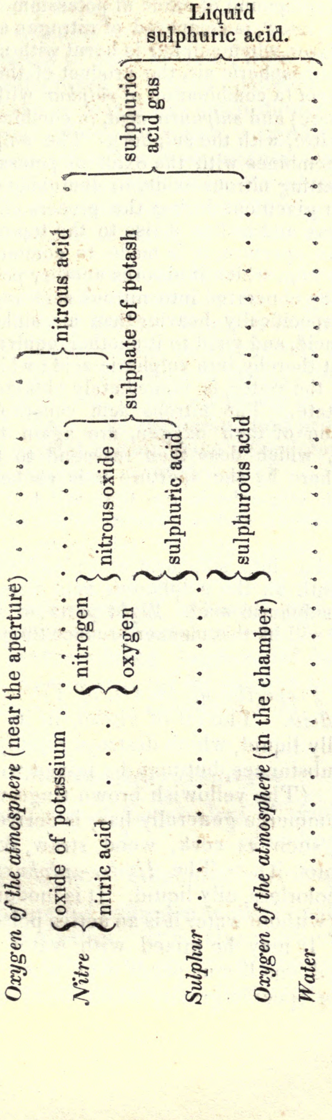
Chemical equivalent of sulphuric acid = 40.

§ 102. Sulphuric acid is the highest degree of oxygenation of which sulphur is capable. It occurs in nature diluted with water in the Rio Vinagre, in South America; in the Indian Lake at Java, and in Italy, and is of all the acids the most important to the arts. It is therefore manufactured in great quantities, and forms an important article of commerce.

In commerce there are two sorts of sulphuric acid, *Hydro-sulphuric acid*, or *oil of vitriol*, and *sulphuric acid properly speaking*. The first is obtained from a substance called *green vitriol of iron*, and the second from burning *saltpetre with sulphur*.

The process by which the oil of vitriol is procured is the following: *Green vitriol*, *copperas*, or as it is properly called, *sulphate of iron* (because it is composed of sulphuric acid and protoxide of iron) is distilled at a high heat, by which means it becomes decomposed, and a dense, oily, colorless liquid is obtained, which in contact with the atmosphere emits copious white vapors. This liquid is afterwards again distilled at a lower temperature, and made to pass into a receiver surrounded with ice, where it forms transparent, colorless vapors, which condense into a white, crystalline solid. This is supposed to be the sulphuric acid in an *an-hydrous* state (without water), and the residue in the retort, which is now no longer fuming, is the common oil of vitriol as it occurs in commerce. The solid substance liquefies again at a temperature a little above 60 degrees Fahrenheit, and has so strong an affinity for water, that it absorbs it from the atmosphere as soon as it is brought in contact with it.

Hydro-sulphuric acid (sulphuric acid dissolved in water) which is the *sulphuric acid of commerce*, is manufactured in large quantities by burning a mixture of 8 parts of sulphur and 1 of nitre in close leaden chambers, containing at the bottom a small sheet of water. During combustion fumes of sulphuric acid rise and are absorbed by the water; from which the acid is afterwards obtained in a concentrated state by evaporating the solution. The theory of this process is somewhat complicated, and will be best understood from the following table.


Oxygen of the atmosphere (near the aperture)
Nitre
oxide of potassium
nitric acid
nitrogen
oxygen
nitrous oxide
nitrous acid
sulphate of potash
Sulphur
sulphuric acid
Oxygen of the atmosphere (in the chamber)
sulphurous acid
Water
sulphuric acid gas
Liquid sulphuric acid.

Nitre is a compound of oxide of potassium with nitric acid, which, as we know, is composed of nitrogen and oxygen (§ 56, page 99). Now when sulphur is burnt with nitre in chambers containing atmospheric air, the product of the combustion are *sulphurous acid* (a combination of *sulphur* with the oxygen of the atmosphere) and *sulphuric acid*, (a combination of the oxygen of the nitre, with the sulphur). The sulphuric acid thus generated, combines with the oxide of potassium to sulphate of potash, setting nitrous oxide, or deutoxide of nitrogen free. But the heat given out during the process of combustion expands this gas and makes it rise to the top of the chambers, where, by an aperture, it is made to communicate with the atmosphere, from which it absorbs another portion of oxygen, and is thereby converted into nitrous acid vapor. These vapors being specifically heavier than air, sink down upon the sulphurous acid, and yield to it another equivalent of oxygen, converting it thereby into sulphuric acid; which being rapidly absorbed by the water, is immediately obtained in the liquid (hydrous) state. The nitrous acid vapors which have now lost a portion of their oxygen, are again transformed into nitrous gas, which does then reascend to the roof of the chamber, where by the aperture it is as before brought in contact with atmospheric air, from which it absorbs a fresh portion of oxygen and is converted into nitrous acid vapor. These sink again upon the sulphurous acid, and convert another portion into sulphuric acid; and so is this process continued until all the sulphurous acid formed, is converted into liquid sulphuric acid. Eight parts of sulphur and one part of nitre will in this manner produce 20 parts of sulphuric acid.

§ **103.** *Properties of the Oil of Vitriol, and of Liquid Sulphuric Acid.* The oil of vitriol, in its pure state, is a colorless, oily liquid, which destroys rapidly all animal and vegetable substances, but may be mixed with water in any proportion. (The yellowish brown tinge which the oil of vitriol of commerce generally has, is derived from organic substances, such as cork, wood, straw, &c, accidentally dropped into it). The *Hydro-sulphuric Acid*, when pure, is a colorless, oily liquid. It is inodorous, and dilute with water (without water it is an active poison) has a strong acid taste. It may be mixed with water in any proportion, and reddens litmus paper even when largely diluted with it. Its specific gravity when most concentrated, is

1.85, that of water being 1. If it is much heavier, it is a sign that it contains some foreign heavy substances (commonly sulphate of soda or lead, from the manner in which it is manufactured in leaden chambers), and if it is much lighter it shows that it has been diluted with water. Owing to its great affinity for water, it rapidly destroys all organic substances of whose composition water forms a large ingredient, and converts them (by absorption) into charcoal. Its boiling point is about 620 degrees Fahrenheit, and it crystallizes at about 15° below zero.

§ 104. Of the numerous *applications of sulphuric acid to the arts* we will only mention a few highly important ones. To those belong the use which is made of it in the manufacture of Glauber's salts, so extensively used in medicine (see Chap. IV — Sulphate of Soda); in the bleaching of linen and cotton, in the cleansing of rags for the manufactory of paper; in the dyeing and printing of calicos, &c. The annual consumption of sulphuric acid, in England alone, amounts to 3000 tons!!

Combination of Sulphur with Hydrogen.

§ 105. Sulphur combines in two different proportions with hydrogen, viz: In the proportion of 1 equivalent of sulphur with 1 equivalent of hydrogen, and in the proportion of 2 equivalents of sulphur with 1 equivalent of hydrogen, the products being *sulphuretted hydrogen*, and *bi-sulphuretted hydrogen.* (The syllable '*bi*' signifying double; because sulphur is combined with a double proportion of hydrogen).

Sulphuretted Hydrogen

is composed of 1 equivalent of sulphur = 16
1 do. of hydrogen = 1

Chemical eqvivalent of Sulphuretted hydrogen = 17.

§ 106. Sulphuretted hydrogen occurs in nature, combined with water or alkalies. It is also given off during the putrefaction of a variety of animal substances; and may be easily obtained for the sake of experiment, by subliming sulphur in hydrogen gas (see the experiment represented in Fig. CIX, page 141). The two elements, hydrogen and sulphur, combine during this process without a change of volume. It may also be produced in abundance by the action of sulphuric acid on *sulphuret of iron*, a substance obtained by melting together sulphur and iron filings. Sulphuretted hydrogen is by this means obtained by elective affinity; the oxygen contained in the water of the hydro-sulphuric acid unites with the metal which remains dissolved in the acid, setting hydrogen and sulphur free, which unite with each other to sulphuretted hydrogen.

§ 107. *Properties of Sulphuretted Hydrogen.* Sulphuretted hydrogen is a colorless, inflammable gas, which smells and tastes after foul eggs, and burns with a light blue flame. It is incapable of supporting combustion and totally irrespirable; when taken into the lungs it causes cramp and suffocation. It is so exceedingly fatal to animal life that a dog dies in an atmosphere containing only $\frac{1}{800}$; and a horse in one, which contains only $\frac{1}{200}$ part of this gas. When dissolved in water, it acts like an acid, and reddens litmus paper (see Introduction, page 38). By cold and pressure it may be reduced to the liquid state; but it is immediately transformed again into gas, when brought in contact with the atmosphere.

It is also remarkable for its action upon almost all metallic oxides; when gently heated, and brought in contact with sulphuretted hydrogen, they form sulphurous metals and water (the hydrogen combining with the oxygen of the oxide, and the sulphur with the metal). It is easily decomposed by sulphuric acid; but more especially by chlorine. Hence the use of chloride of lime in purifying the air from the exhalations of putrefying organic matter.

§ 108. Sulphur combines also with chlorine (wherefore sulphuretted hydrogen is decomposed by chlorine), Bromine, and Iodine. Neither of these combinations is of much use in the arts. But sulphur is not known to combine with nitrogen.

Recapitulation of the principal Binary Combinations of Sulphur.

Sulphur combines with	*oxygen* to	*hypo-sulphurous* *sulphurous* *hypo-sulphuric*	acid.
	hydrogen to	*sulphuretted* *bi-sulphuretted*	hydrogen.

C. Selenium.

Chemical Equivalent = 40.

§ 109. This substance has but lately (in 1817) been discovered by Berzelius, a celebrated Swedish chemist. It occurs in very minute quantities, combined with some of the metals, such as lead, copper, cobalt, quicksilver, silver, gold, &c, and is only separated from them by an extremely tedious process. After fusion it has a greyish color, and a metallic lustre. When rapidly cooling its color is reddish brown — as a powder it has a deep red color. It is brittle, boils at about 12 degrees above the boiling point of water, and when warm is very ductile.

Selenium combines in three different proportions with oxygen. The compounds are *oxide of selenium, selenious acid,* and *silenic acid.* With hydrogen it is only known to combine in one ratio, forming with it *selenietted hydrogen.* With sulphur it unites in all proportions, the various products being known by the name of *sulphuretted selenium.*

D. Phosphorus.

Chemical Equivalent = 12, *(doubtful).*

§ 110. Phosphorus is a light yellow, soft solid, which at the mean temperature of the atmosphere is of the consistency of wax, and exposed to the atmosphere emits white luminous vapors. It is chiefly contained in the bones of animals, and has not as yet been found in its simple form. It may, however, be easily procured by the following process.

Reduce a quantity of bones, which have been burnt in an open fire to a fine powder; and digest them for several days with half their weight of concentrated sulphuric acid, adding enough water to give the mixture the consistency of a thin paste. The solution is then mixed with twice its bulk of hot water, and after being well stirred, filtered through a straining cloth. (See Fig. IX, page 18).

This solution is again evaporated to the consistency of syrup; then mixed with one fourth its weight of powdered charcoal, and strongly heated in an earthen retort. A large quantity of gas will be formed during this process, which, when the mouth of the retort is conducted into a receiver filled with water, will distil over in drops, which will congeal in contact with the water. The solid thus obtained is pure phosphorus.

To understand this process it is necessary to state that all bones are composed of a particular salt called *phosphate of lime*, mixed, however, with a variety of animal substances. By burning bones in an open fire (which process is also called calcination) the phosphate of lime is separated from these substances, and when subsequently digested with concentrated sulphuric acid, decomposed into its constituent principles, phosphoric acid and lime. The lime unites by elective affinity with the sulphuric acid to an insoluble compound (sulphate of lime) and the phosphoric acid remains dissolved in the solution; consequently, when the solution is filtered, nothing but pure sulphuric acid will pass through the straining cloth. When the solution is afterwards evaporated and distilled with charcoal at a strong heat, the charcoal unites with the oxygen of the acid and sets the phosphorus free. This passes in form of gas from the retort into the receiver, and congeals in contact with the water.

§ 111. *Properties of Phosphorus.* Pure phosphorus, obtained in the manner we have just described, is a soft, yelolw solid, which by exposition to solar light, especially to the violet rays of the spectrum, changes into red, but may be rendered perfectly colorless by a second distillation. It is so exceedingly inflammable that it may be ignited by mere friction, or by the natural heat of the palm of the hand. Owing to its great affinity for oxygen it combines with it at the common temperature of the atmosphere, so that in order to preserve it, it is necessary to keep it under water. In contact with air it emits a light smoke (owing to its slow combustion with oxygen) and a smell somewhat like garlic; but in the dark it throws out a beautiful greenish light. Its specific gravity is 1.7, that of water being 1. It is perfectly tasteless, but when taken into the stomach proves a very active poison.

It is insoluble in water, but readily combines with oil or ether, to which substances it communicates the property of throwing out light in the dark.

Its affinity for oxygen is so great that it will take up of this gas more than $1\frac{1}{2}$ times its own weight, and so easily does it ignite by friction that it is used in the construction of phosphoric match boxes.

Combinations of Phosphorus with Oxygen.

§ 112. Phosphorus combines with oxygen in five different proportions, forming with it two oxides and three acids, viz: *White oxide of Phosphorus*, *Red oxide of Phosphorus*, *hypo-phosphorus acid*, *Phosphorous acid*, and *Phosphoric acid.* The exact proportions in which phosphorus combines with oxygen being not known, and these compounds being of little application to the arts, we will only describe the most remarkable of them,

Phosphoric Acid,

which is composed of 1 equivalent of Phosphorus = 12
and 2 equivalents of Oxygen (each = 8) = 16

Consequently, chemical equiv. of Phosphoric acid = 28.

§ 113. This compound of phosphorus occurs in nature, combined with lime, clay, oxide of iron, lead, copper and manganese, &c; but it may be obtained by art, by

Fig. CX.

burning phosphorus in atmospheric air, or better in pure oxygen gas, (see the adjoining figure). (The phosphorus may be ignited by a red-hot wire, and must be introduced into the jar from under the water, to prevent spontaneous combustion by friction or the heat of the hand). During combustion dense white vapors will be formed, which, like snow, fall to the bottom of the jar, and constitute what is called the pure, *anhydrous, phosphoric acid.* This unites afterwards with the water to *hydro-phosphoric acid,* and may be evaporated to dryness. It may also be obtained from the action of phosphorus or nitric acid, or by digesting calcined bones with sulphuric acid, as we have seen in the process of procuring phosphorus. (§107.)

§ 114. *Properties.* Phosphoric acid is a colorless, inodorous, transparent liquid, which easily absorbs water from the atmosphere, and has all the essential qualities of a powerful acid (Introduction, page 38). It has, however, thus far, no technical application.

Combinations of Phosphorus with Hydrogen.

§ 115. Phosphorus combines with hydrogen in two different proportions; the products are *Proto-phosphuretted hydrogen,* and *Per-phosphuretted hydrogen.*

Proto-phosphuretted Hydrogen

is composed of 1 equivalent of Phosphorus = 12
and 2 equivalents of Hydrogen (each 1) = 2

Consequently, chemical equiv. of Proto-phosphuretted hydrogen = 14.

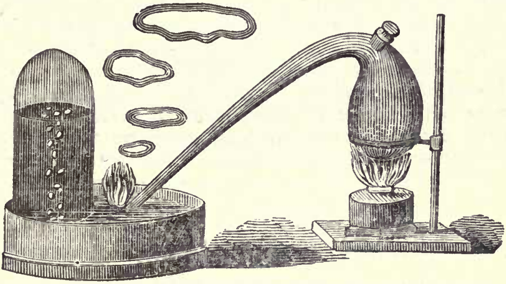
Per-phosphuretted Hydrogen,

on the contrary, is composed of 1 equivalent of phosphorus = 12
1 equivalent of Hydrogen = 1
Chemical equiv. of per-phosphuretted hydrogen = 13.

Both compounds consist of phosphorus dissolved in hydrogen.

§ 116. Per-phosphuretted hydrogen is obtained, by boiling Phosphorus in a small retort with a hot solution of potash, which must entirely fill the vessel. The gas thus generated must be collected by the pneumatic tub, employing a hot solution of potash instead of water. During the boiling of the liquid, the oxygen of the water unites with part of the phosphorus to phosphorus acid, which combining with the potash, sets the hydrogen of the water free. This, under the influence of heat, combines with the remaining portion of phosphorus to phosphuretted hydrogen.

Fig. CXI.



When the gas, as it is extricated, is allowed to escape from under the surface of the alkaline solution into the air, each bubble as it rises will spontaneously take fire and explode, leaving after the explosion an horizontal ring (see the figure) of white smoke, which preserves its form for a considerable time, and becomes larger as it ascends.

§ 117. *Properties of per-phosphuretted hydrogen.* Per-phosphuretted hydrogen is a colorless gas of a highly offensive smell (resembling garlic, or foul fish), which in contact with atmospheric air, or pure oxygen, becomes spontaneously inflamed, and explodes, as we have seen from the last experiment (Fig. CXI). It is more than 13 times heavier than hydrogen gas, and but slightly soluble in water. When suffered to stand for some time in a glass receiver, it becomes spontaneously decomposed, and deposits phosphorus. A series of electric sparks pass through it, produces a similar effect, and precipitates phosphorus.

Proto-phosphuretted hydrogen is produced by heating phosphorus acid in close vessels, secluded from contact with air. It is a colorless gas, resembling per-sulphuretted hydrogen in nearly all essential properties. It does not, however, inflame spontaneously when brought in *contact* with atmospheric air; but when mixed with it, or pure oxygen, it detonates violently on the application of an electric spark.

A beautiful Experiment may be made by mixing 10 parts of water with 1 part of phosphorus, 2 parts of granulated zinc, and 6 parts of concentrated sulphuric acid. Owing to the decomposition of the water, and a subsequent combination of its hydrogen with the phosphorus, per-phosphuretted hydrogen, will be generated and rise in little bubbles. These, in contact with atmospheric air, become spontaneously inflamed, and burn with a bright flame like phosphorus.

Other Combinations of Phosphorus.

§ 118. Phosphorus combines also with carbon, sulphur, selenium, chlorine, iodine, boron, and the metals. These combinations have thus far been little examined, and are of little or no application in the arts.

Recapitulation of the most important Binary Combinations of Phosphorus.

Phosphorus combines with
- *oxygen* to
  - *white oxide*, *red oxide* } of *phosphorus.*
  - *hypo-phosphorous*, *phosphorus*, *phosphoric* } *acid.*
- *hydrogen* to
  - *proto-phosphuretted*, *per-phosphuretted* } *hydrogen.*

E. Boron.

Chemical Equivalent = 6, *(doubtful).*

§ 119. This element is not found in its simple state; but is extracted from *boracic* acid, a substance we are about to describe in the next section.

For this purpose potassium (a metal) may be heated with boracic acid, in a copper tube to about 302° Fahrenheit. When hey become red-hot, the oxygen of the acid combines with the metal, and sets the boron, which is the basis of boracic acid, free.

Properties. It appears as a dark green powder, which is inodorous, tasteless, and but sparingly soluble in water. Heated in close vessels it undergoes no change, but when heated in the open air to about 600° Fahrenheit, it burns with a pale green flame, the product being *boracic acid.*

Boracic Acid

is probably composed of 1 equivalent of boron = 6
and 2 equivalents of oxygen (each = 8) = 16

Whence, chemical equivalent of boracic acid = 22.

§ 120. This is the only combination of boron with oxygen. It is a substance which is generally obtained in form of crystals, and is found mixed with a little sulphur on the walls of cellars and caves, and at the craters of volcanos. It is also contained in some of the springs. It may be obtained by art, by dissolving borax (a substance resembling alum, and which is imported from India under the name of *Tincal*), in boiling water, adding to it half its weight of dilute sulphuric acid. When the solution is evaporated and cooled, boracic acid is precipitated in form of scaly, shining crystals.

Borax is a combination of boracic acid with soda. When it is dissolved in hot water, and sulphuric acid is added, the soda combines by elective affinity with the sulphuric acid, and the boracic acid sinks to the bottom.

§ 121. *Properties.* It is inodorous, possesses but very little taste, and is sparingly soluble in water, with which it forms a solution which reddens litmus paper. It is also dissolved by alcohol, to whose flame it gives a beautiful green color. Boracic acid is used in the manufactory of artificial borax, which is much employed in medicine. It is also used in calico printing, especially in France, and in coloring gold.

Boron combines yet with sulphur, chlorine, fluorine, and the *Metals.*

*F. Iodine.**

Chemical Equivalent = 124.

§ 122. This element does not occur in its simple form in nature; but is often found combined with some of the metals, particularly with *sodium*, a substance of which we shall speak in the next chapter. It has lately been discovered also in the Mexican silver mines, and in many of the lead ores of South America. It is commonly extracted from the ashes of sea-weeds, or from a substance called *kelp*, generated during the manufacture of soda.

The process is simply this: The ashes of sea-weeds, or kelp, are dissolved in water, which upon evaporation, leaves a salt called carbonate of soda, in form of crystals. These being removed, the remaining liquid is put into a tubulated retort, (see Fig. CVII, page 136), and sulphuric acid is poured upon it. As soon as this is done beautiful violet vapors appear, which become condensed in the receiver in crystalline plates, resembling plumbago (see page 123), and may afterwards be dried between folds of blotting paper. A small quantity of oxide of manganese, added to the liquid in the retort, facilitates the process.

§ 123. *Properties of Iodine.* Iodine is a substance which at the common temperature of the atmosphere is of a greyish-black color, and possesses a metallic lustre. Its other properties resemble chlorine (see § 65, page 103), and it is a strong poison when used in large quan-

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* From a Greek word signifying violet colored, because its vapors have a beautiful violet color.

tities. In small quantities it is used for medicinal purposes. Its taste is sharp and acrid, and continues for a long time upon the tongue. It destroys vegetable colors and gives the skin a yellow stain, which however, soon disappears. It fuses at about 225 degrees, and becomes converted into beautiful purple vapors when heated to 350 degrees Fahrenheit. It is (like chlorine) a non-conductor of electricity, and but sparingly soluble in water; but is easily dissolved by ether, alcohol, or oil of turpentine. With starch it forms a compound of a beautiful indigo color, which affords a means of detecting its presence even in very minute quantities.

It is principally used in medicine, and in the manufactory of *Iodide of quicksilver*, which is a red pigment, employed in cotton-printing and painting.

Combination of Iodine with Oxygen — Iodic Acid.

Chemical composition: 1 equivalent of Iodine = 124
5 equivalents of Oxygen (each = 8) = 40

Consequently, chemical equivalent of Iodic acid = 164.

§ 124. Iodine combines in only one proportion with oxygen. The product is *iodic acid*, a white, half-transparent solid, which is perfectly inodorous, and has a sharp, sour, astringent taste. It is obtained by bringing protoxide of chlorine (see § 66, page 144) in contact with iodine, and applying a gentle heat to the orange-colored vapors which are thus formed. By this means vapors of iodine and chlorine are given off, and a compound of iodine and oxygen remains. No particular application is made of this compound in the arts.

Combination of Iodine with Hydrogen — Hydriodic Acid.

Chemical composition: 1 equivalent of Iodine = 124
1 do. of Hydrogen = 1

Consequently, chemical equiv. of Hydriodic acid = 125.

§ 125. Iodine combines with hydrogen to *hydriodic acid.* This combination is effected by the action of moistened iodine on phosphorus. It is effected by double elective affinity (see Intro. page 9). The oxygen of the water combines with the phosphorus, and the hydrogen with the iodine.

Properties. It is a colorless gas, of a very pungent and an intensely sour taste; which reddens blue vegetable colors without bleaching them. Combined with those substances called bases (see Intro. page 38) it forms salts, of which some are now used in medicine.

§ 126. Iodine combines yet with carbon, and in several proportions with sulphur and phosphorus. It has likewise a strong affinity for boron, nitrogen, silicon, and the metals.

Recapitulation of the Principal Binary Combinations of Iodine.

$$\textit{Iodine}\text{ combines with }\begin{cases}\textit{oxygen}\text{ to }\textit{iodic acid.}\\ \textit{hydrogen}\text{ to }\textit{hydriodic acid.}\end{cases}$$

G. Bromine.[*]

Chemical Equivalent = 75.

§ 127. This is an element but recently discovered (in 1826) by *Balard*, a French chemist. It may, like iodine, (to which it bears a strong analogy), be obtained from the ashes of sea-weeds, or also from sea-water.

The washings of sea-weeds, or the liquor which remains in salt-pans after sea water has been evaporated for the purpose of obtaining common table salt, is mixed with a solution of chlorine. This mixture being distilled by the application of a gentle heat, the vapors must be made to pass over chloride of lime. This salt, after absorbing the watery parts, will leave a few drops of a blackish-red, volatile liquid, which is then the pure bromine.

§ 128. *Properties of Bromine.* At the common temperature of the atmosphere it is a dark red fluid; thin

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[*] From a Greek word, signifying 'a strong, disagreeable smell.'

strata of it viewed through the light appear of a beautiful hyacinth color. Its smell is exceedingly disagreeable, and its taste sharp and nauseous. At a few degrees below zero of Fahrenheit's thermometer, it congeals, and becomes a grey, crystalline mass. It does not corrode the skin permanently, is exceedingly volatile, boils at a temperature of 116° Fahrenheit, and gives off red vapors. It is sparingly soluble in water ; but is readily dissolved in ether, alcohol, and many of the fat oils.

Combinations of Bromine.

§ 129. Bromine combines with oxygen to *bromic acid*, a colorless, inodorous, sour liquid, which reddens litmus paper ; and is composed of

1 equivalent of bromine = 75
and 5 equivalents of oxygen (each = 8) = 40

Consequently, chemical equiv. of bromic acid = 115.

With hydrogen it combines in 2 proportions, forming *hydrobromous* and *hydrobromic acid.* The latter (the most remarkable of the two), is a colorless gas, which tastes and smells sour, is rapidly absorbed by water, and emits white vapors. A solution of it in water has nearly the same properties.

Bromine unites yet with chlorine, carbon, sulphur and phosphorus. Through the intermission of hydrobromic acid it unites with the metals potassium, tin, zinc, and iron.

Recapitulation of the Principal Binary Combinations of Bromine.

$$\textit{Bromine}\text{ combines with}\begin{cases}\textit{oxygen}\text{ to }\textit{bromic acid.}\\ \textit{hydrogen}\text{ to }\left\{\begin{array}{l}\textit{hydrobromous}\\ \textit{hydrobromic}\end{array}\right\}\text{ acid.}\end{cases}$$

H. Silicon (Silicium).

Chemical Equivalent = 8.

§ 130. This substance, (discovered by Berzelius in 1823) was formerly known only in combination with the fixed alkalies, *potash, soda, lithia, lime,* &c. (see Chap. III). From these combinations, silicon, or silicium itself is obtained by the action of heated potash. It is a dark brown powder, without metallic lustre, which adheres easily to other substances, and is a non-conductor of electricity. It may be exposed to the most powerful heat without fusing, and with the exception of *fluor* (of which we shall soon speak), is not acted upon by any of the mineral acids.

Combination of Silicon with Oxygen — Silex.

Chemical composition: 1 equivalent of Silicon = 8
1 do. of Oxygen = 8

Consequently, chemical equivalent of Silicon = 16.

§ 131. Silicon combines with oxygen only in one proportion. The product of this combination, which is an *oxide of silicon*, is called *silex, silica,* or *silicious earth*, is the principal ingredient of all fossils in the mineral kingdom. It is found almost in its simple form in *rock-crystal, flint* and *agate.* In many other fossils it is found combined with clay, lime, magnesia, &c. It has also been discovered in plants, and animal matter, viz.: in the enamel of the teeth, in bones, &c.

Silex is obtained by art in the following manner: One part powdered quartz is melted in a crucible with three or four parts of pure carbonate of potash (a salt hereafter to be described) and when cooled, dissolved in dilute muriatic acid. The precipitate which will be thus formed must be thoroughly washed and dried until it is perfectly tasteless.

§ 132. *Properties of Silex.* Silex obtained in the manner just described, is a white, inodorous, tasteless powder, which feels harsh when rubbed between the fingers, and melts only in the highest degree of heat produced by the most powerful galvanic batteries. It is perfectly insoluble in water, and, with the exception of fluoric acid, in all the mineral acids. Combined with hydrogen it forms a *hydrate,* which in nature occurs as a precious stone, known by the name of *opal.* Silex is of inestimable application in the manufactory of *glass, earthen ware* and *porcelain.*

Silicious earth (silica) occurs as principal ingredient in the following fossils :

1. In *Rock, or Mountain Crystal. — Properties.* It is colorless, sometimes yellow, brown or black (as topaz) ; has a strong glassy lustre, is perfectly transparent, and gives sparks on steel. It abounds particularly in Madagascar, and the island of Ceylon.

2. In *Amathyst. — Properties.* It has a violet color, glassy lustre, and is transparent. The finest amathysts are found in Siberia, at the foot of the Ural mountains, and in Brazil.

3. In *Common Quartz.* — Its color is a mixed *white (milk-quartz)*, gray, red *(rose-quartz)*, brown *(iron* or *flint quartz)*, or blue *(sapphire quartz).* It forms a principal part of most all mountainous masses, particularly of *granite.* It is used most extensively in the manufactory of *glass, porcelain* and *china-ware.* It is also a common building material, and is used in the paving of streets and roads. (In France it is also employed for mill-stones).

4. In *Flint.* — This is generally found in round masses, of a grey, yellow, brown, or dark color, in layers of chalk or limestone. It is used in the manufactory of English china *(flint*-ware), and glass *(flint*-glass). To the same species of stone belong also *Agate, Chalcedon, Jaspis, Carnelion,* and *Chrysoprase.*

5. In *Pumice,* a spungy, glassy stone, with a lustre like mother of pearl, and a yellowish, sometimes *green,* color. It is a *volcanic* product, forming great masses in the neighborhood of volcanos, particularly in *Italy, Iceland, Quito,* and *Mexico.* It is used for polishing *ivory, marble, alabaster, parchment,* and *leather.*

6. In *Sand.* — This is a product of the decomposition of various kinds of stones and rocks, especially of stones which abound in *quartz, glimmer,* and *granite.* It is found in all low countries, in the beds of rivers, and on the sea-shore. It is of almost universal application in the arts ; and is used in the manufactory of glass, in the preparation of mortar, in the grinding, polishing, and cleansing of articles ; in the manufactory of bricks, in the casting of metals, &c.

Silicious earth is also contained in *tripoli* or *rotten stone,* a yellowish white earthy substance, which is found in many countries, especially in the neighborhood of coal mines. It is used for polishing metals, particularly brass.

Recapitulation.

Silicon combines with oxygen to *Silex*, or *Siliceous earth.*

I. Fluorine (?)

Chemical Equivalent (not ascertained).

§ 133. Fluorine is a substance whose existence is not yet satisfactorily proved. It was first (by Thenard, a French chemist) supposed to exist in all three kingdoms of nature, combined with the metals *calcium*, *alumium*, *sodium*, and *yttrium* (see Chap. III). It is believed to be analogous to *bromine*, *iodine*, and *chlorine*, and to form with hydrogen *fluoric acid*, like chloric acid, iodic acid, bromic acid, which are products of chlorine, iodine, and bromine combined with hydrogen.

Fluoric Acid.

Chemical Equivalent = 10.

§ 134. *Fluoric Acid (hydro-fluoric acid)*, is obtained by the action of strong sulphuric acid on the well-known substance *fluor-spar*. For this purpose the retort and receiver must be made of platinum or lead, glass vessels being instantly corroded and destroyed by this acid, which easily combines with silicon, the principal ingredient of glass.

Fluor-spar is found crystallized in various colors, green, red, yellow, &c. It assists the fusion of earthy minerals in metallurgical operation. If fluorine is a substance analogous to chlorine, iodine, and bromine, then fluor-spar may be supposed to be a *fluoride* of *calcium.*

§ 135. *Properties of Fluoric acid.* It is a colorless liquid of an exceedingly sharp, sour taste, a pungent, penetrating smell, and a strong caustive power, which when exposed to the atmosphere, emits white fumes. It absorbs water largely, is exceedingly volatile, boils at about 60° Fahrenheit, and does not congeal at 40 degrees below zero of the same thermometer. Its vapors are very obnoxious to animals and all organic formations, which are speedily destroyed by them. (This is the reason why the investigation of its properties, and probably also its decomposition into fluorine and hydrogen is so difficult, and indeed, almost impracticable.) It may be mixed with water in any proportion, the mixture giving off great heat. If lime is thrown into it, heat and water are given off, and a substance similar to fluor-spar (probably fluoride of calcium) is produced.

Owing to its affinity for silicon (the principal ingredient of glass) it has the peculiar power of operating on glass. Plates of glass, *covered* with a composition of bees-wax and oil of turpentine may be etched with it (or its vapors) like a copper-plate.

Other Combinations of Fluorine.

§ 136. There are but two more combinations of fluorine with other substances known — viz. : with *boron*, the product of which is *fluoboric acid;* and with *silicon*, the product of which is *fluoride of silicon.* The former is a colorless gas, of a pungent, suffocating smell, and a strong, sour taste. It absorbs water, and produces white fumes in contact with the atmosphere. The properties of the latter are similar to those we have just mentioned.

Recapitulatiom of the most important Binary Combinations of Fluorine.

Fluorine combines with
- *Hydrogen* to *fluoric acid.*
- *Boron* to *fluoboric acid,*
- *Silicon* to *fluoride of silicon.*

RECAPITULATION.

Questions for reviewing the most important Principles contained in Chapter II.

A. Questions on Carbon.

[§ 72.] What other non-metallic elements are there, besides the four gases, oxygen, hydrogen, nitrogen, and chlorine? What characterizing properties have these in common with the gases.

[§ 73.] What is the chemical equivalent of carbon. Of what substance does carbon form the principal ingredient?

Where are diamonds principally found? What is the specific gravity of diamond. What becomes of diamonds when submitted to the heat produced in the focus of a burning-glass, or when burnt in pure oxygen? What are the products of the combustion of diamond?

Describe the principal properties of plumbago. For what is it used?

What are the principal properties of Anthracite coal? Where is it chiefly found?

What are the properties of Lehigh coal?

What are the properties of black and brown coal?

What does turf consist of?

How is vegetable charcoal obtained? For what purpose is charcoal used? What is its most remarkable property? Is charcoal affected by heat, when submitted to its action in close vessels? What influence does charcoal exercise on other bodies? What does its mechanical structure enable it to do? How is *animal charcoal* obtained?

Why has charcoal so different an appearance from diamond, both substances being composed of the same element? What is the probable reason that diamond has not as yet been generated, or, in other words, why has not carbon been obtained in its pure, crystallized state?

[§ 74.] In how many different proportions does carbon combine with oxygen? What two products of these combinations deserve our special notice?

What is the chemical composition of carbonic oxide?

[§ 75.] Does carbonic acid occur in nature? How then is it procured by art?

How do you explain both processes?

[§ 76.] What are the principal properties of *carbonic oxide*?

[§ 77.] What is the chemical composition of *carbonic acid?* Where is carbonic acid found? By what other processes is it continually produced?

By what process may it be obtained by art? (Explain the experiment represented in Fig. CII).

Explain this process.

[§ 78.] What are the principal properties of carbonic acid?

Why is there danger from burning charcoal in a confined room?

[§ 79.] What is the cause of the agreeable pungent taste, common to all sparkling, fermenting liquors? What is the pleasant, fresh taste of pump-water owing to? What then constitutes the principal difference between river and pump water?

What apparatus was formerly used for impregnating water or any other liquid, with carbonic acid? (Describe Fig. CIII).

[§ 80.] Why must pure water not become turbid when mixed with lime water?

[§ 81.] In how many different proportions does carbon combine with hydrogen? What are the products?

[§ 82.] What is the chemical composition of *sub-carburetted hydrogen*?

Where is this gas found? Where else is it to be found? By what means may it be procured for examination?

[§ 83.] What are the characterizing properties of subcarburetted *hydrogen*?

What has been observed respecting the temperature which is necessary to ignite an inflammable mixture of gases? What discovery did Dr Wollaston make? To what idea was

Sir Humphrey Davy led by this discovery? How was this idea realized?

Describe Davy's safety lamp (Fig. CV).

Explain its operation.

By what experiment can you show that wire-gauze completely intercepts the flame of any burning substance? What does this serve to explain?

[§ 84.] What is the chemical composition of carburetted hydrogen? Is this compound found in nature, or is it merely a product of art? How is it obtained?

Explain this process?

[§ 85.] What are the properties of carburetted hydrogen?

[§ 86.] What application is made of carburetted hydrogen, or olefiant gas?

On what does the brilliancy of other gases depend? How does diamond burn in pure oxygen gas?

By whom was gas light first employed for illumination? Who introduced it first into England? From what was the gas used in Europe first prepared? How is the olefiant gas used in America prepared? By what process is the oil decomposed and yields the gas? Is the gas procured from resin cheaper or dearer than that prepared from oil?

Why has carburetted hydrogen been called olefiant gas?

Are there any other combinations between hydrogen and carbon, besides those you have mentioned?

[§ 87.] What is the chemical composition of cyanogen? Does this gas occur in nature? By what means then may it be obtained?

[§ 88.] What are the principal properties of cyanogen? What is its most remarkable property?

[§ 89.] In how many different proportions does cyanogen combine with oxygen? What are the products?

[§ 90.] What is the chemical composition of Prussic acid? In what substances is this acid principally contained? By what process may it be obtained?

How is this process explained?

[§ 91.] What are the properties of Prussic, or hydrocyanic acid?

Can this acid be very well preserved for any length of time? Why not? By what is its first stage of decomposition marked? What properties does it then lose?

[§ 92.] In what respect does Prussic acid differ from other acids you have thus far become acquainted with?

What does it form in combination with those substances called *bases*? To what pole does it adhere, when it is separated again from these substances by the agency of galvanic electricity?

By what experiment is it proved that Prussic acid is composed of equal *volumes* of hydrogen and cyanogen? What follows from it, with regard to its composition by *weight*?

[§ 93.] With what other substances does cyanogen yet combine? What properties have all these compounds? What is a compound of cyanogen and sulphur called? What properties has it?

[§ 94.] In how many different proportions does *carbon* combine with chlorine? What are the compounds called?

[§ 95.] What is the chemical composition of *sulphuret of carbon?* By what process can carbon and sulphur be made to combine? (Explain the process represented in Fig. CVIII).

[§ 96.] What are the leading properties of sulphuret of carbon? Why must sulphuret of carbon be distilled at so low a heat as 110 degrees Fahrenheit? What is the specific gravity of sulphuret of carbon? What is its great volatility the cause of?

What are the principal binary and ternary combinations of Carbon?

B. QUESTIONS ON SULPHUR.

[§ 97. What is the chemical equivalent of sulphur? Where does sulphur occur? Where does it abound?

In what countries particularly has it been discovered?

Where is sulphur yet contained?

By what process can sulphur be purified from stones and other earthy substances with which it is mixed?

[§ 98.] What are the principal properties of sulphur? What is its specific gravity? How is *roll-brimstone*, obtained, which occurs in commerce? What becomes of sulphur, when in a state of fusion it is poured into water? For what is it then used? What are the principal applications of sulphur?

[§ 99.] In how many different proportions does sulphur combine with oxygen? What are the products? Which of these combinations are the most remarkable ones?

[§ 100.] What is the chemical composition of sulphurous acid? Where does this compound occur? By what means may it also be produced in a state of great purity?

How is this process explained?

[§ 101.] What are the principal properties of sulphurous acid? What do you understand by liquid sulphurous acid? How does this acid act upon vegetable colors? For what purpose is it chiefly used?

[§ 102.] What is the chemical composition of *sulphuric acid?* What degree of oxygenation of sulphur is sulphuric acid? Where does it occur?

How many different sorts of sulphuric acid occur in commerce? What are their names? From what is the first, and from what is the second obtained?

Explain the process by which the oil of vitriol is procured?

How is hydro-sulphuric acid (or the common sulphuric acid of commerce) manufactured?

How is this complicated process explained? (Let the pupil explain the table on page 145).

[§ 103.] What are the characterizing properties of oil of vitriol? What are the properties of sulphuric acid?

[§ 104.] What are the principal applications of sulphuric acid?

[§ 105.] In how many different proportions does sulphur combine with hydrogen? What are the compounds?

[§ 106.] What is the chemical composition of sulphuretted hydrogen?

Where does it occur? Where is it spontaneously produced (or given off)? How may it be obtained for the sake of experiment? By what other means may it be obtained in abundance? How is this process explained?

[§ 107.] What are the properties of sulphuretted hydrogen? For what is sulphuretted hydrogen particularly remarkable? By what substance is it decomposed? What does this explain?

[§ 108.] With what other substances does sulphur combine? Is sulphur known to combine with nitrogen?

What are the principal binary combinations of sulphur?

C. QUESTIONS ON SELENIUM.

[§ 109.] What is the chemical equivalent of selenium? Where does it occur? What are its properties?

In how many different proportions does it combine with oxygen? Name the compounds. What compounds does it form with hydrogen? In how many different proportions does it unite with sulphur? What are the compounds called?

D. QUESTIONS ON PHOSPHORUS.

[§ 110.] Has phosphorus as yet been found in nature in its simple form? From what is it chiefly obtained?

Describe the process by which phosphorus is obtained. Explain this process.

[§ 111.] What properties distinguish phosphorus obtained in the manner you have just described?

Why is it necessary to keep phosphorus under water? What does phosphorus emit in contact with air?

With what liquids does phosphorus readily combine?

How much oxygen is phosphorus capable of taking up? For what is it used?

[§ 112.] In how many different proportions does phosphorus combine with oxygen? What are the products called?

[§ 113.] What is the chemical composition of *phosphoric acid*? Where does this composition occur? How may it be obtained by art? (Explain the experiment and process represented in Fig. CX).

[§ 114.] What are the characterizing properties of phosphoric acid?

[§ 115.] In how many different proportions does phosphorus unite with hydrogen? What are the products thence obtained called?

What is the composition of *proto-phosphuretted hydrogen?* What is the composition of *per-phosphuretted hydrogen* ?

[§ 116.] By what process is per-phosphuretted hydrogen obtained? (Explain the experiment represented in Fig. CXI). How is this process explained?

What takes place when the gas, as it is extricated, is allowed to escape from under the surface of the alkaline solution into the air?

[§ 117.] What properties does phosphuretted hydrogen possess?

How is proto-phosphuretted hydrogen produced? To what are its properties similar? What takes place when the gas is mixed with oxygen, and an electric spark is applied to the mixture?

What beautiful *experiment* may be made with water, phosphorus, zinc, and sulphuric acid? How is this experiment explained?

[§ 118.] With what other substances does phosphorus yet unite?

What are the most important binary combinations of Phosphorus ?

E. QUESTIONS ON BORON.

What is the chemical equivalent of boron?

[§ 119.] Is this element found in its simple state? How then is it obtained?

Explain the process.

What are the properties of boron?

What is the product of the combustion of boron?

[§ 120.] What is the chemical composition of *boracic acid*? Are there any other combinations of boron with oxygen? In what form is boracic acid generally obtained? Where is it found? How may it be produced by art?

Explain this process.

[§ 121.] What are the properties of boracic acid? With what other substances does boron yet combine?

F. QUESTIONS ON IODINE.

[§ 122.] What is the chemical equivalent of iodine? Does this element occur in its simple form? With what substances is it found combined? Where has it lately been discovered? From what substances is it commonly extracted?

Describe the process.

[§ 123.] What are the principal properties of iodine? What sort of compound does it form in combination with starch? For what purposes is it principally used?

[§ 124.] In how many proportions does iodine combine with oxygen? What is the product of this combination called? By what means is it obtained?

[§ 125.] What is a combination of iodine with hydrogen called? What is its chemical composition? How is this combination effected?

What are the properties of hydriodic acid?

[§ 126.] With what other substances does iodine combine?

What are the principal binary combinations of Iodine?

G. QUESTIONS ON BROMINE.

[§ 127.] What is the chemical equivalent of bromine? By whom was it discovered? How may it be obtained?

Explain the process.

[§ 128.] What are the principal properties of bromine?

[§ 129.] To what compound does bromine combine with oxygen? What is the chemical composition of this compound? In how many different proportions does it combine with hydrogen? What are the two compounds called? Which of the two is the most remarkable? What are its properties?

With what other substances does bromine yet combine?

What are the principal binary combinations of Bromine?

H. QUESTIONS ON SILICON (SILICIUM).

[§ 130.] What is the chemical equivalent of silicon? By whom was this substance discovered? With what other substances was it formerly known only to be combined? By what means may it be separated from these combinations? What are its properties?

[§ 131.] In how many proportions does it combine with oxygen? What is the compound called? What is its chemical composition? Where is it found?

How may silex be obtained by art?

[§ 132.] What are the principal properties of silex? What does it form when combined with hydrogen? In what consists the principal application of silex?

In what fossils does silicious earth, or silex, principally occur? [Let the pupil at first merely *enumerate* the fossils, without describing them].

What are the properties of *Rock* or *Mountain Crystal* ?
What are the principal properties of the *Amathyst* ?
What, those of common quartz? For what purposes is common quartz used?

What are the principal properties of *Flint* ? For what purposes is it used? To what species of stone belong *Agate*, *Chalcedon*, *Jaspis*, *Carnelion*, *Chrysoprase* ?

What are the properties of *Pumice* ? What sort of product is it? Where is it found? For what is it used?

What sort of natural product is sand? Where is it found? For what purposes is it used?

In what other substances is silicious earth contained? What sort of substance is *tripoli*, or *rotten stone* ? Where is it found? For what is it used?

I. Questions on Fluorine.

[§ 133.] Is the existence of *Fluorine* as yet satisfactorily proved? By whom was this substance first supposed to exist? To what elements is it supposed to be analogous? What substance is it supposed to form with hydrogen?

[§ 134.] What is the chemical equivalent of fluoric acid? By what means is *fluoric acid* obtained?

In what state is fluor-spar obtained? What does it assist? What is fluor-spar supposed to be?

[§ 135.] What are the properties of *fluoric acid?* What properties do its vapors possess? What is this the reason of? What takes place when lime is thrown into a solution of it in water?

What peculiar power does it possess in consequence of its affinity for the principal ingredient of glass? How may plates of glass be etched by fluoric acid?

[§ 136.] With what other substances does fluorine yet combine? What are the products? What are the properties of fluoric acid? What are the properties of fluoride of silicon similar to?

What are the most important binary combinations of Fluorine ?

CHAPTER III.

OF THE METALS.

Preliminary Remarks.

§ 137. Several attempts have been made to fix upon the general characteristics of metals; their properties, however, are so various and relative, that we can only approximate more or less to a satisfactory result. With this view on the subject it may be said that all metals are more or less distinguishable by the following properties:

1. By a peculiar lustre, called the *metallic* lustre, which is owing to their capacity of reflecting light.

2. By being generally good conductors of heat and electricity. They are, moreover, commonly electro-positive bodies; for when in a combined state with other substances, they are submitted to the action of a galvanic battery (see Figs. LIX and LX, pages 40 and 41), these combinations are again dissolved into their elements, and the pure metal is always found to adhere to the negative pole. (Compare the remarks in the Introduction, page 41.)

3. By their opacity, to which hitherto but few apparent exceptions have been found.

§ 138. All metals, as far as our experience goes, are *simple bodies*, or *elements*, all efforts to decompose them having thus far proved ineffectual. They are in number *fortyone*.

1. Potassium,
2. Sodium,
3. Lithium,
4. Calcium,
5. Barium,
6. Strontium,
7. Magnesium,
8. Yttrium,
9. Alumium,
10. Glucinum (Berillium),
11. Zirconium,
12. Thorium,
13. Mercury,
14. Silver,
15. Gold,
16. Platinum,
17. Palladium,
18. Rhodium,
19. Iridium,
20. Osmium,
21. Nickel,
22. Iron,
23. Tin,
24. Lead,
25. Copper,
26. Zinc,
27. Bismuth,
28. Cobalt,
29. Antimony,
30. Arsenic,
31. Manganese,
32. Tellurium,
33. Titanium,
34. Cerium,
35. Uranium,
36. Columbium,
37. Tungsten,
38. Cadnium,
39. Chromium,
40. Molybdenum,
41. Vanadium.

§ 139. These metals vary from each other in color, hardness, brittleness, ductibility, and fusibility. All of them, however, have a greater or less affinity for oxygen, and combine with it under the following circumstances :

1. When exposed to the atmosphere.

2. When brought in contact with water (which contains oxygen), or any of the acids formed by the combination of oxygen. For this purpose concentrated sulphuric and nitric acid are commonly used.

Most metals when exposed to the air or to moisture lose their metallic lustre, tenacity, and other apparent properties of metals. They then crumble to powder, or soil the fingers, having at the same time increased in weight. This change is occasioned by the metals having combined with the oxygen of the atmosphere or the water, or, in other words, by its having been changed into an *oxide* (see classification of bodies, page 38). The increase of weight is of course proportional to the quantity of oxygen taken up in the combination. (See the remark § 9, to the experiment represented in Fig. LXVI, page 54).

Among the various metals iron especially absorbs oxygen from the air and from moisture; and is by this means converted into a friable substance which collects on its surface. This substance, which is an oxide of iron, is called *rust*. In order, therefore, to prevent metals, and especially iron, from rusting, it is necessary to keep them from the atmosphere. Sir Humphrey Davy proposed also galvanic electricity as a preventive against the oxydation of metals. Thus, copper is preserved from combining with the oxygen of the atmosphere by bringing it in contact with iron, only $\frac{1}{100}$ part its size. The reason is this. When copper and iron are placed upon one another, the copper becomes negatively electric (see Nat. Phil. Chap. IX), in which state it cannot attract the oxygen of the atmosphere, which is itself a negatively electric substance; but must repel it, according to the laws of electricity. Steel instruments are kept in silver paper, made of a mixture of tin and zinc, for a similar reason. In a great many cases, however, galvanic electricity *favors* the oxydation of metals.

§ 140. Oxygen is not the only substance with which metals are known to combine. They unite also,

1st. With *Carbon*. The products of these combinations are called *carburets*. They do not occur in nature, and are produced only by the fusion of the oxides of metals in contact with charcoal and other substances containing carbon.

2d. With *sulphur*. The result of these combinations are termed *sulphides*. They occur abundantly in nature, and form by far the most important ores of copper, lead, tin, antimony, silver and quicksilver.

3d. With *Chlorine*. These combinations are called *chlorides*, and are large products of nature. To this class belong the chloride of Potassium, sodium, calcium, magnesium, lead, &c.

4th. With *Cyanogen*, forming what are called cyanides. These combinations are mere products of art.

5th. With *Silicon*, forming silicides.

6th. With *Fluoride*, forming fluorides, which are frequently found in nature, particularly fluoride of calcium (fluor spar), fluoride of yttrium, &c.

Besides these combinations, many metals unite yet with hydrogen, selenium, phosphorus, boron, and iodine; forming respectively *hydrates*, *selenides*, *phosphorides*, *borides*, and *iodides*. But we shall not stop to describe these, intending to treat only of the most remarkable and useful metallic combinations.

§ 141. *Alloys of metals.* Metals frequently combine with one another; these combinations are called *alloys;* but the combinations of quicksilver with other metals have received the special appellation of *amalgams*. The alloys of metals have each a peculiar color, according to the proportion of the metals in which they are compounded. They are generally harder, though easier fusible than either one of the metals of which they are compounded.

§ 142. Of two metals which have different degrees of fusibility and no particular chemical attraction for each other, one may be made to melt (reduced to the liquid state), while the other remains yet in the solid state. This is, for instance, the case with the ores of copper and lead, tin and copper, bismuth and cobalt, &c. On account of this property, fusion is a means of *refining ores*, the more fusible metal being by this means liquefied and separated from the other, which remains in a state of solidity.

§ 143. Metals which easily melt are capable of advancing the fusion of other metals for which they have a strong chemical affinity. Upon this property is founded the process of *soldering*. This consists in uniting two pieces of the same, or different metals, by means of a third metal which is more fusible than either of them. To give an

EXAMPLE — To solder tin ware, tinkers make use of a composition (that is, of a solder) made of equal parts of tin and lead.

Cast iron is soldered either by copper, silver, or tin, or also by a mixture of copper and tin.

Copper and *brass* are soldered by a mixture of 5 parts of silver, 6 parts of brass, and 2 parts of zinc.

Zinc is soldered by a mixture of lead and tin.

Platinum by fine gold.

Gold by a mixture of gold and silver; and

Silver by a mixture of silver and copper.

§ 144. Another process of art, founded on the natural attraction which exists between some of the metals, is the covering of one metal by another. As an example we will mention the tinning of vessels made of sheet iron; the gilding and silvering by means of amalgams with which the substance to be gilded or silvered is merely covered as with a pigment; finally the plating of brass, steel, or copper ware, with gold, silver, or platinum, where one hard metal is rolled upon another, and remains upon it merely by the natural force of attraction, without any solder between them.

§ 145. We have already said that few of the metals are found in nature in their simple form; but generally combined with sulphur, oxygen, the acids, or earths, in which state they are called metallic *ores*. They occur more or less in all quarters of the globe, but particularly in mountainous districts and in the neighborhood of volcanos. They are generally bedded in strata, extending sometimes several miles in length, which by the miners are called *veins*. Hence the common phrase of the miners, 'to strike a new vein.' In these veins the metals are most commonly found combined with those substances we have just named, which on this account are called *mineralizers*. Sulphur being most abundantly found combined with the metals, is therefore called a *mineralizer* of them. But there are metals which are sometimes found in their simple form, and are then said to be *native* metals. In this state gold and silver are frequently found in North and South America. The gold of South Carolina and Georgia, for instance, is so pure that without alloy it cannot very well be worked. The silver mines of Potosi, in South America, have been known to yield native silver, in lumps of forty or fifty pounds in weight.

§ 146. The substances with which the metals are combined (the mineralizers) being so different from each other in their chemical composition, it is evident that different methods must be employed for different ores, in order to extricate the pure metal from them. This process of extracting the pure metal from the ore is called the *reduc-*

tion of the metals. Three means are principally resorted to for this purpose.

1st. *The roasting* of metals, which consists in placing metallic ores upon a wood or coal fire, and heating them to redness. By this means sulphur and other substances which are mixed with the metals are separated. But there are *ores* which do not require to be roasted.

2d. The *smelting of ores,* or the melting out of the metals from the ore. For this purpose the ore and charcoal are mixed together in a furnace, and in this state intensely heated, by which means the oxygen which is combined with the metal, unites by *elective* affinity with the burning charcoal, for which it has a most powerful affinity, setting thereby the metal free. When the metal is thus extricated from the ore, care is taken to cover its surface with a melted mass of some earthy or alkaline substance, called the *flux*, to prevent its subsequent oxydation in contact with the atmospheric air.

3d. The refining of metals, which process has already been described in § 142, page 177.

§ 147. Before we go on to treat of the different metals and their properties, it will be well to say a few words on the similar properties of some of them, which enable us to form them, as it were, into classes. Thus:

Potassium, sodium, lythium, calcium, barium, and *strontium,* are generally called the *alkaline* metals; because in combination with oxygen they form respectively the fixed alkalies, *potash, soda, lithia, lime, baryta,* and *strontia.* These metals have all the strongest affinity for oxygen, absorb it at all times from the atmosphere, and retain it at the highest degree of heat. Their oxides, (the alkalies which we have just enumerated) have all a hot, bitter, caustic taste, are soluble in water, change blue vegetable colors into green, and yellow colors into brown.

Magnesium, yttrium, allumium, glacinum, zirconium, thorium are called *earthy* metals, because in combination with oxygen they form the earths *magnesia, glucina, yttria, alumia, zirconia,* and *thoria.*

The nine metals, *mercury, silver, gold, platinum, palla-*

dium, *iridium*, *osmium*, and *nickel*, are commonly called the *noble* metals ; because they do not easily undergo any change or combine with oxygen.

Of the remaining twenty metals, *iron*, *lead*, *tin*, *copper*, *zinc*, *bismuth*, *cobalt*, *antimony*, *arsenic*, *manganese*, *tellurium*, *titanium*, *cerium*, *uranium*, *columbium*, *tungsten*, *cadmium*, *chromium*, *molybdenum*, and *vanadium*, the first five (iron, lead, tin, copper and zinc) are the most useful to man, and are most generally employed in the arts.

We will now proceed to describe each metal and its principal binary combinations in the same order as we have just enumerated them.

A. OF THE SIX ALKALINE METALS, POTASSIUM, SODIUM, LITHIUM, CALCIUM, BARIUM, AND STRONTIUM.

1. *Potassium.*

Chemical Equivalent = 40.

§ 148. Potassium is a metal which was first obtained by Humphrey Davy from the decomposition of a substance called *hydrate of potash* (see the next section) through the agency of a strong galvanic battery. It may also be obtained in larger quantities, by heating hydrate of potash with iron filings in a gun barrel.

The first process requires a galvanic battery composed of at least 200 double plates, of 4 inches square. The hydrate of potash must be slightly moistened (to increase the conducting power of electricity) and placed between two plates of platinum connected with the two poles of the apparatus. The substance will soon undergo fusion, when the oxygen of which it is compounded, will separate at the positive pole, and the pure metal (Potassium) will, in little globules, collect near the negative pole of the battery.

For the decomposition of hydrate of potash by the action of heated iron-filings, by which means potassium is obtained in larger quantities, we are indebted to the combined researches of Gay-Lussac and Thénard.

The apparatus employed for this purpose is represented in Fig. CXII.

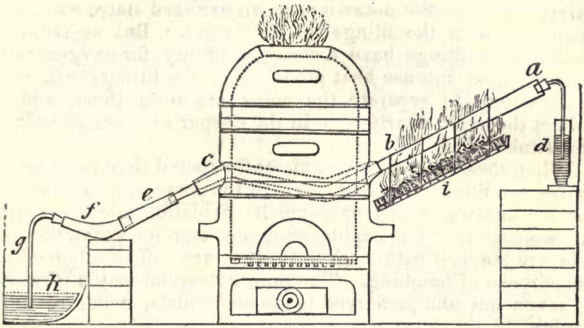

Fig. XCII. It consists of a very strong gun-barrel, *a b c*, which must be curved as represented in the figure. Towards one end *c*, of this barrel, it must be tapering to a smaller opening, and the whole space between *a* and *b*, must be covered with a lute of infusible clay, which may be made of 5 parts of sand and 1 of potters' clay. Into this barrel, between *b* and *c*, introduce some clean iron-filings, and between *a* and *b*, pieces of solid hydrate of potash. The barrel must afterwards be corked and in *a* provided with a safety tube, whose lower end (as is represented in the figure) must be immersed into a vessel *d*, filled with mercury. To the smaller end of the barrel, a short piece *(e)* of copper is accurately ground, which fits again into a receiver *f*, made of the same metal. This receiver is also provided with a safety tube *g*, which dips below the surface of mercury contained in the vessel *h*. A strong heat should now be raised in the furnace, until the barrel between *b* and *c*, becomes white hot; the other parts of the barrel being all this time kept cool by wet rags tied around them. The hydrate of potash in the part *a b*, of the barrel, may now be made to melt by burning charcoal contained in a movable cage *i*, when in consequence of the inclination of the barrel it will flow upon the ignited iron filings, in the part *b c*, by which means a large quantity of hydrogen (the product of the decomposition of hydrate of potash), will be given off and escape through the safety tube *g*. The movable cage must now be removed for a little while, until the evolution of the gas ceases; after which it must be again put in its place; and this operation must be continued until no more gas is evolved. The hydrogen of the hydrate of potash will then have escaped through the safety tube, and the potassium in an oxidized state, will have combined with the filings in the barrel. But as strongly heated iron filings have a stronger affinity for oxygen than potassium, an intense heat produced in the furnace will now be sufficient to separate the potassium from them, and to collect the metal nearly pure in the copper receiver *f*, and the short tube *e*.

When these vessels are sufficiently cooled they must be removed and filled with naphta, to give the potassium contained in them a coating, which prevents its oxidation in contact with atmospheric air. The naphta being now emptied again, the vessels are stopped with cork until they are sufficiently cool for the purpose of handling. The pure potassium may afterwards be taken out and preserved in stopped phials, under rectified naphta.

As a small portion of potassium will always collect at the lower end *f*, of the barrel, it will be well to stop the barrel itself with corks as soon as the copper barrel and receiver are removed from it. When sufficiently cooled some naphta must be suffered to pass through it, to prevent the oxidation of whatever portion of the metal may have collected in it, which may afterwards be collected and preserved as above stated.

If at any time during the process gas should escape through the safety tube *d*, instead of *g*, it is a sign that a piece of potassium has lodged between *c* and *e*, to remove which it is only necessary to apply some burning charcoal to the spot, which will liquefy the potassium, and enable the process to go on regularly.

The potassium thus obtained is less pure than that which is procured by galvanic electricity; but it is obtained in much larger quantities and at a comparatively less expense. The only difficulty consists in producing a sufficiently high heat for the iron filings to decompose the oxide of potassium without melting the barrel, and it is on that account that the part *d c*, which is to be heated in the furnace, must be covered with a lute of infusible clay.

§ 149. *Properties of Potassium.* Potassium, obtained by either of the processes just described, is at the ordinary temperature of the atmosphere, of a soft, solid consistency, and easily moulded between the fingers. Its color is that of tin; it has a strong metallic lustre, is perfectly opaque, and a good conductor of heat and electricity. It is specifically lighter than water, (its specific gravity being only 0.865, that of water being 1). fuses at 150° Fahrenheit, and burns with a white flame when heated in contact with air. It decomposes water at the common temperature of the air, by combining with its oxygen, for which it has the strongest affinity of any substance known. On this account (because it would absorb the oxygen from the atmosphere) it is necessary to keep it under naphta.

Combination of Potassium with Oxygen.

§ 150. Potassium forms three different combinations with oxygen, viz.: *Sub-oxide, Protoxide*, and *Peroxide of Potassium.* The most remarkable among these is the protoxide of potassium, *commonly known by the name of*

Potash, or Potassa.

It is composed of 1 equivalent of Potassium = 40
1 equivalent of oxygen = 8

Consequently, chemical equivalent of Potash = 48.

This substance occurs in all three kingdoms of nature, combined with the acids and in some of the fossils, such as fluor-spar, basalt, granite, &c. The purest potash is obtained by burning potassium in dry air. It is of a greyish-white color, hard, brittle, and easily soluble in water. It is very caustic, and destroys animal and vegetable substances.

The potash of commerce is obtained by the incineration (burning to ashes) of vegetable substances, wherefore it is called the *vegetable alkali.* These ashes are afterwards boiled down in pots, whence the name of *Potash.* The purest is called *Pearl-ash.* Potash unites with water to *hydrate of potash* (caustic potash), which is easily dissolved in water, and combined with fat or oil forms *soap*, a product of universal usefulness.

§ 151. *The hydrate of potash* is a white solid mass, which melts at a red heat and emits white caustic vapors. It is obtained from a solution of a salt called *carbonate* of potash, in 10 or 12 parts of distilled water. A silver plated kettle must be used for this purpose, as other metals are affected by the solution. When the liquid is boiling ½ part of fresh burnt marble or lime must be added in a state of powder, and after being repeatedly stirred up with it, the solution must be evaporated to dryness.

§ 152. A solution of hydrate of potash is termed *caustic lye.* It is either colorless, or of a pale yellow color; otherwise it is similar to the hydrate of potash.

Potash, hydrate of potash, and caustic lye, are used in various processes in the arts, especially in the manufactory of glass (see Chap. IV), in bleaching, dyeing and calico-printing.

§ 153. Potassium unites with chlorine to

Chloride of Potassium,

which is composed of 1 equivalent of potassium = 40
1 do. of chlorine = 36

Consequently, chem. equiv. of chloride of potassium = 76.

In this state it is found in salt springs, and in sea water. It may also be produced by introducing small pieces of potassium into chlorine. The combination is so rapid and intense as to cause a vivid inflammation, during which each grain of the metal absorbs about 1 cubic inch of the chlorine, by which means it is converted into a white saline body, which has a bitter taste, and when mixed with 4 parts of water, forms a highly refrigerating mixture.

Potassium unites also with sulphur, selenium, and sodium. The combination with sulphur, which is termed *sulphuret* of potassium, is used in medicine.

Recapitulation of the Principal Binary Combinations of Potassium.

Potassium combines with
- *oxygen* to
  - *sub-oxide*
  - *protoxide*
  - *peroxide*

  of *potassium.*
- *chlorine* to *chloride of potassium.*
- *sulphur* to *sulphuret of potassium.*

2. *Sodium.*

Chemical Equivalent = 24.

§ 154. Sodium is produced from *hydrate of soda*, in the same manner in which potassium is obtained from hydrate of potash (see § 149). It is a white metal, of the color of silver, which has a strong metallic lustre, and is, like potassium, a good conductor of heat and electricity. It is opaque and *solid* at the common temperatures of the atmosphere, *soft* at 160°, and becomes *liquid* at from 180 to 190 degrees of Fahrenheit's thermometer. It decomposes *water* without combustion ; but burns when only *damped* with this liquid. Next to potassium, it has the strongest affinity for oxygen of any substance known.

Combination of Sodium with Oxygen — Oxide of Sodium, or Soda.

Chemical composition: 1 equivalent of sodium = 24
1 do. of oxygen = 8

Consequently, chemical equivalent of soda = 32.

§ 155. *Sodium* combines with oxygen in three different proportions, the products of which are *sub-oxide*, *protoxide*, and *peroxide of Sodium*. The protoxide of sodium, commonly called *soda*, occurs native in mineral seams or crust, (mineral alkali) combined with some of the acids from the mineral and vegetable kingdoms. The purest soda is obtained by the combustion of sodium. It is a greyish, white mass, hard, brittle, less fusible and volatile than potassium, and extremely caustic. It is soluble in water and alcohol, and in short, possesses all the alkaline properties (see § 147, page 179) in an eminent degree. It is largely used in medicine and the arts.

§ 156. A combination of *chlorine* with *sodium*, called *chloride of sodium*, constitutes our

Common Table Salt.

Chemical composition: 1 equivalent of sodium = 24
1 do. of chlorine = 36

Consequently, chemical equiv. of common salt = 60.

It occurs in great masses as parts of mountainous formations, or is found in deserts, where the whole ground is sometimes covered with crystallized salt. In the deserts of Barun, Darfur, Habesh, in the Highlands of Africa, in Central Asia, near the Caspian Sea, in the Highlands of Thibet, in Peru, and Chili. It is also contained in sea water, from which it is obtained by a variety of processes, but particularly by *boiling* and *evaporating*. It may also be obtained in its purest form, by burning sodium in chlorine; or by heating sodium in muriatic acid gas. (Hence it is by some chemists called *muriate of soda*). It is soluble in water and in most liquids, crystallizes in four-sided pyramids or cubes, and is one of the most indispensable ingredients in the food of man. It is also used for a variety of chemical and medicinal purposes.

Recapitulation of the Principal Binary Combinations of Sodium.

Sodium combines with { *oxygen* to *soda*.
{ *chlorine* to *chloride of sodium* or *common salt*.

3. *Lithium.*

Chemical Equivalent = 10.

§ 157. This substance is likewise obtained by galvanic electricity, from lithia, an alkali which in 1817 has been discovered in several rare metals, in Tourmaline (see Natural Phil. Chap. X), and in some mineral waters. It is a white, solid mass, of a crystalline fracture, and a very caustic taste. It is sparingly soluble in water, and when thrown into alcohol burns with a purple flame. Combined with oxygen it forms the

Oxide of Lithium, or Lithia,

which is composed of 1 equivalent of lithium = 10
1 do. of oxygen = 8

Consequently, chemical equivalent of lithia = 18.

This compound is soluble in water, with evolution of heat, and possesses all the alkaline properties (§ 147, page 179).

4. *Calcium.*

Chemical Equivalent = 20.

§ 158. This is another metal obtained by galvanic electricity, from the well-known substance, *lime.* It is white, solid, inflammable at the atmosphere, and decomposes water by combining with its oxygen, setting the hydrogen free. It combines with oxygen in two proportions. The most remarkable of these combinations,

Protoxide of Calcium, or Lime,

is composed of 1 equivalent of calcium = 20
1 do. of oxygen = 8

Consequently, chemical equivalent of lime = 28.

It is found in great abundance, combined with the acids in all three kingdoms of nature. It is obtained pure by exposing white marble, or calcareous spar to a red heat.

§ 159. *Properties of Lime.* It is a soft, white mass, requiring great degrees of heat for its fusion, but advancing remarkably the fusion of most earthy substances; and is therefore said to be a *flux.* Its taste is caustic and astringent. By absorption of moisture from the atmosphere, or by the process of *slaking* (mixing it with water) it becomes converted into an *hydrate.*

The use of Lime is very general and diversified. In architecture it is used for the preparation of mortar and for whitewashing; in chemistry for the production of hydrate of *potash, soda,* and *ammonia;* in the arts, for bleaching, dyeing, and tanning. It is also used in sugar-refineries, and in the manufactory of glass and parchment. Finally, it is employed in domestic economy to absorb the moisture from fields.

Calcium combines also with *chlorine* to *chloride of calcium.* When this substance is mixed with snow its refrigerating power is so great as to freeze *mercury.*

The chloride of *lime*, which is a combination of the *oxide* of calcium with chlorine, will be described in the 4th chapter among the salts.

Recapitulation of the principal Combinations of Calcium.

Calcium combines with
- *oxygen* to *lime (Protoxide of Calcium).*
- *chlorine* to *chloride of calcium.*

5. *Barium.*

Chemical Equivalent = 70.

§ 160. *Barium* is likewise produced by galvanic electricity from a substance called carbonate of baryta. It is of a dark grey color, has less lustre than cast-iron, is soon oxidised when in contact with the atmosphere, acts violently on water (which is decomposed by it), and burns when heated in the atmosphere, with a dark red flame. It combines with oxygen in two different proportions, producing respectively protoxide and peroxide of barium.

The protoxide of Barium (Baryta), also called Heavy Earth,

is composed of 1 equivalent of barium = 70
1 do. of oxygen = 8

Chemical equivalent of protoxide of barium = 78.

§ 161. *Properties of Baryta.* It is a greyish-white, earthy substance, which does not melt at a common fire, has a burning, caustic taste, and is very poisonous. When thrown into water it becomes heated and deposites a white powder (a hydrate). The solution, which is called baryta water, is colorless, possesses all the alkaline properties, and upon cooling or freezing forms regular crystals.

The peroxide of barium is a dirty-grey mass, suffering great degrees of heat without being decomposed.

Barium combines also with *chlorine*, *sulphur*, and *iodine*, forming respectively *chloride*, *sulphuret*, and *iodide* of Barium.

Recapitulation of the principal Combinations of Barium.

$$\begin{array}{c}\textit{Barium}\\ \text{combines with}\end{array}\left\{\begin{array}{l}\textit{oxygen}\text{ to}\left\{\begin{array}{l}\textit{protoxide}\\ \textit{peroxide}\end{array}\right\}\text{ of }\textit{barium.}\\ \textit{chlorine}\text{ to }\textit{chloride of barium.}\\ \textit{sulphur}\text{ to }\textit{sulphuret of barium.}\end{array}\right.$$

6. *Strontium.*

Chemical Equivalent = 44.

§ 162. Strontium is the last of the six alkaline metals, which, like the rest, has been obtained by galvanic electricity. It has, like barium, a greyish white color, and little metallic lustre. It combines with oxygen in two proportions, forming *Protoxide* and *peroxide of Strontium.*

The *protoxide of Strontium,* — *Strontia,* (so called from the town of Strontia, in Argyleshire, where the native carbonate of strontia — see Chap. IV — was first discovered in 1787) is generally found combined with sulphuric and carbonic acid.

It is composed of 1 equivalent of strontium = 44
1 do. of oxygen = 8

Consequently, chemical equivalent of strontia = 52.

It consists of a greyish white powder, which does not melt at a common fire; has a sharp, caustic taste (less than baryta, but more than lime), and is dissolved in boiling water to a colorless liquid, called strontia water, which possesses all the alkaline properties.

Strontium combines yet with sulphur and chlorine to *sulphuret* and *chloride* of strontium respectively.

Recapitulation.

$$\text{\textit{Strontium} combines with}\left\{\begin{array}{l} \textit{oxygen} \text{ to } \left\{\begin{array}{l}\textit{protoxide}\\ \textit{peroxide}\end{array}\right\} \text{ of } \textit{strontium.} \\ \left.\begin{array}{l}\textit{sulphur} \text{ to } \textit{sulphuret}\\ \textit{chlorine} \text{ to } \textit{chloride}\end{array}\right\} \text{ of } \textit{strontium.}\end{array}\right.$$

B. Of the six Earthy Metals, Magnesium, Yttrium, Alumium, Glucinum (Berilium), Zirconium, and Thorium.

§ 163. The existence of these metals is not so much proved by actual experiment as by strong reasoning and analogy. Their oxides were formerly known by the name of *earths*, but from the experiments which have since been made upon them, and the strong analogy which exists between them and the oxides of the alkaline metals, places their *metallic* origin beyond a doubt or controversy. It is on this account all modern chemists have, without an exception, treated of these substances as the oxides of the metals we have just named, although they cannot be converted to the metallic state by any ordinary process of reduction (§ 146, page 179); nor scarcely by any process of science thus far known. They have all an insipid taste, different from the fixed alkalies, which taste acrid; but neutralize the acids in the same manner as other salifiable bases.

1. *Magnesium.*

Chemical Equivalent = 12, *(doubtful).*

§ 164. Magnesium may be obtained by Voltaic electricity, or by the action of potassium on a substance called chloride of magnesium.

When Voltaic electricity is employed, magnesium in contact with mercury is exposed for a long time to the action of the battery, until an amalgam is formed, which upon dry distillation (secluded from the atmosphere), during which the quicksilver is partly converted into vapor, yields a dark-grey, metallic film. This is the metal magnesium. By the second process, chloride of magnesium, a substance contained in sea and well water, is heated in a platina crucible with about 10 parts of pure potassium. During this process the chlorine combines by elective affinity with the potassium, setting the magnesium free.

Magnesium obtained by either process can only be collected in very small particles, scarcely sufficient for chemical investigation. It has nevertheless been found to be a white, ductile substance, of great metallic lustre, which is infusible in close vessels, at a very high temperature, but burns when heated in contact with atmospheric air with a red light, and with scintillation. It combines but in one proportion with oxygen, the product being the oxide of magnesium, commonly known by the name of

Magnesia,

whose chemical composition is supposed to be

1 equivalent of magnesium = 12
1 do. of oxygen = 8

Consequently, chemical equivalent of magnesia = 20,

although the exact proportion in which it is united with oxygen is not yet ascertained.

§ 165. The oxide of magnesium (Magnesia) is abundantly distributed throughout nature, making part of extensive rock formations, and being also largely contained in sea-water, from which it is obtained for commerce. In its purest state it is best obtained by submitting carbonate of magnesia, a substance with whose properties we shall become acquainted in the 4th chapter, to an intense red heat, and it is on this account, by apothecaries, called calcined magnesia (because the process of calcination consists in burning bodies at an open fire).

Properties. It is a white, soft powder, without smell or taste, infusible and insoluble in water, which is extensively used in medicine.

Chloride of magnesium, which is a combination of magnesium with chlorine, is contained in sea and well water, and it is from this substance that pure magnesia may be obtained through the medium of potassium.

Magnesium combines also with sodium and with fluorine.

Recapitulation.

Magnesium combines with { *oxygen* to *oxide* / *chlorine* to *chloride* } of *magnesium*

Glucinum (Berillium).

Chemical Equivalent = 20, *(doubtful).*

§ 166. *Glucinum* is produced by the action of potassium on a peculiar earth called Glucina (berillious earth).

When potassium is heated with this earth in close vessels, it is changed into potash, and dark-colored globules are discovered disseminated throughout the whole mass, which are the metal *Glucinum.*

To this inference we are naturally led by the impossibility of Potassium being converted into potash without absorbing oxygen (potash being a compound of potassium and oxygen), and the impossibility of its absorbing oxygen from any other substance than from the earth glucina, since it is this substance alone with which it is brought in contact, atmospheric air being excluded by the experiment being performed in close vessels. Thus we have every certainty which reasoning can give, that glucina is a combination of oxygen with some metal which is its basis. This reasoning moreover is corroborated by the fact that metallic globules do actually appear disseminated through its mass when the experiment above alluded to is made; and to all this is yet added the strong analogy which glucina bears to those substances which we *know* to be oxides of metals, and which are reduced to the metallic state *by exactly the same operation,* which alone, if all experiments failed, would be sufficient to place the metallic base of glucina almost beyond a doubt.

Properties. It is a dark-grey, granular powder, which when polished assumes a metallic lustre. It does not become oxydized at the common temperature of the atmosphere; but burns when heated with great splendor.

Oxide of Glucinum, Glucina, Berillia, is known only to exist in a few rare minerals. It is a white, light powder, which adheres to the tongue like clay. It is insoluble in water, but is readily dissolved in liquid potash or soda. Its chemical equivalent is supposed to be 28.

Glucina combines also with sulphur and chlorine.

3. *Yttrium.*

Chemical Equivalent = 34, *(doubtful).*

§ 167. This substance was likewise obtained by the action of potassium on a substance called *chloride of yttrium*, in the same manner as glucinum is obtained from glucina.

Properties. It consists of grey, metallic scales, which, when polished, assume a dark lustre. It does not combine with oxygen at low temperatures, but when heated burns with a dazzling light.

Oxide of yttrium is found in a mineral *(ytterby)* and in several other fossils in Sweden. It is a yellowish white powder, inodorous, tasteless, insoluble in water, and infusible at a common red heat. It combines with most of the acids, forming a class of salts which are all more or less distinguished by a sweetish taste, like sugar. Its chemical equivalent is supposed to be 42.

4. *Alumium.*

Chemical Equivalent = 10, *(doubtful).*

§ 168. This is another mineral, which has been produced by the action of potassium on *chloride of alumium.* It is a grey, granular powder, with a metallic lustre like that of tin; when strongly heated it burns in contact with atmospheric air, the residue being a white clay which scratches glass.

Oxide of Alumium — Alumia.

This compound of alumium with oxygen, is probably
composed of 1 equivalent of alumium = 10
1 do. of oxygen = 8

Chemical equivalent of alumia = 18.

§ 169. *Properties of Alumia.* It is an abundant product of nature, occurring either in its simple form, or as a *hydrate*, or combined with the acids and earths as a constituent part of rocks and alluvial depositions.

In its *pure* state it is contained in some of the gems, viz.: In sapphire (blue); in the red oriental ruby, in topaz (yellow), amethyst (violet), in the emerald (green). The different kinds of clay used in the manufacture of glass and porcelain contain hydrate of alumia in a greater or less proportion. It is a loose, white powder, without taste or smell, infusible at a common red heat, and insoluble in water; but has nevertheless a strong attraction for moisture. It combines permanently with some dyeing stuffs, wherefore it is used in calico printing.

Alumium combines yet with chlorine to *chloride* of alumium, with sulphur to *sulphuret*, and with fluorine to *fluoride* of alumium. Neither of these compounds is of much application in the arts.

Recapitulation.

Alumium combines with
oxygen to *alumia.*
chlorine to *chloride of alumium.*
sulphur to *sulphuret of alumium.*

5. *Zirconium.*

Chemical Equivalent not ascertained.

§ 170. This metal has been obtained (by Berzelius) by heating potassium with a salt called *fluate* of zirconia. It is a black, dry powder, of a dark, metallic lustre, which burns at a heat a little before redness, and is a bad conductor of electricity.

Oxide of Zirconium, zirconia, has been found only in a few minerals, the zircon (a precious stone) of Ceylon, and the hyacinth from France. It is a fine, white powder, without smell or taste, scratches glass, and is insoluble in water.

6. *Thorium.*

§ 171. This metal was produced by the action of heated potassium on a substance called *chloride of thorium*, as glucinum is produced from glucina. It is a grey, heavy powder, which by pressure assumes a metallic lustre, does not become oxidized in water, but burns when exposed to a moderate heat with great splendor. The product of the combustion,

Oxide of Thorium, or *Thoria*, which is also found in nature, is a Norwegian fossil, called thoria, whence its name.

C. OF THE NINE NOBLE METALS, MERCURY, SILVER, GOLD, PLATINUM, PALLADIUM, RHODIUM, IRIDIUM, OSMIUM, AND NICKEL.

1. *Mercury.*

Chemical Equivalent = 200.

§ 172. This metal occurs comparatively but sparingly in the mineral kingdom. But few countries possess quicksilver mines. It is found either native (as *virgin* quicksilver), or combined in sulphur or *mercurial ore.*

This ore is reduced by heating it with iron filings or lime. During the process the sulphur combines by elective affinity with the iron or lime, setting the mercury free, which, by the heat is volatilized, and passes over into a receiver, where in contact with the colder sides of the vessel it is again condensed into the liquid form.

§ 173. *Properties.* It is the *only* metal which is liquid at the common temperature of the atmosphere. It is perfectly tasteless, has a bluish white color and a strong metallic taste. It freezes at 40° below zero of Fahrenheit, and boils at 660° of the same scale. When congealed it is malleable, and may be cut with a knife or hammered into thin plates. It is so extremely volatile that its vapors rise even at low temperatures, especially in a vacuum. On this account all the thermometers and barometers (Natural Phil. Chaps. V and VI), are more or less incorrect by the pressure of the vapors of mercury which rise in the vacuum above it.

§ 174. Mercury has the power of uniting to *amalgams* with most metals, but more especially with *gold, tin, silver, zinc, lead,* and *bismuth,* which it dissolves in minute quantities.

This affords a means of extracting gold from other substances with which it is mixed in small quantities. Thus, gold beaters are in the habit of shaking their dust with mercury, which amalgamate with the gold, from which the gold may afterwards be obtained by heat, the quicksilver being volatilized, while the gold remains in the solid state (compare § 142, page 177). Or it is also customary to press the amalgam thus formed through a buckskin bag, which allows the mercury to go through, but retains the gold.

Another application of the amalgam of gold is made in the process of *water gilding*, which is performed by means of this amalgam. An amalgam of quicksilver with silver is employed in the same way to imitate plated ware.

The amalgam of tin is largely employed in *silvering* the backs of looking glasses. For this purpose the quicksilver is simply poured upon a sheet of tin foil, and the plate afterwards pressed upon it, care being taken to place the plate upon the amalgam in such a way as not to allow any air to remain between it and the metal. The plate remaining in this manner pressed upon the amalgam, for a time not exceeding 48 hours, the process is completed, and the amalgam adheres afterwards to the plate merely by the adhesive attraction which exists between these substances. The amalgam of tin and mercury is also used for electrical machines, Leyden phials, and a number of processes in the arts.

Combinations of Mercury with Oxygen.

§ 175. Mercury combines with oxygen in two different proportions, producing respectively *protoxide* and *peroxide* of mercury.

Protoxide of Mercury

is composed of 1 equivalent of mercury = 200
1 do. of oxygen = 8

Consequently, chem. equiv. of prot. of mercury = 208.

It is obtained when quicksilver is violently agitated in contact with atmospheric air. By this means the quicksilver is converted into a greyish black powder, which is insipid and insoluble in water, and combines with a greater portion of oxygen when gently heated in contact with atmospheric air. The compound then formed is

Peroxide of Mercury,

which is composed of 1 equivalent of mercury = 200
and 2 equivalents of oxygen (each = 8) = 16

Consequently, chem. equiv. of peroxide of mercury = 216.

§ 176. This compound, as we see from its chemical composition, is composed of mercury combined with a double quantity of oxygen, and is most readily obtained by dissolving mercury in nitric acid and applying afterwards a sufficient degree of heat to the solution to expel the acid.

Properties. It is of a dark red color, and but sparingly soluble in water, to which it communicates the property of turning blue vegetable colors into green. When distilled in a glass tube it parts again with its oxygen and the metal is revived.

Both oxides of mercury combine with the acids to salts, wherefore they are called salifiable bases (see Introduction page 38).

Combinations of Mercury with Chlorine.

§ 177. Mercury combines also in two proportions with chlorine, forming *Proto-chloride* and *Perchloride of Mercury.*

Proto-Chloride of Mercury — (Calomel),

is composed of 1 equivalent of mercury = 200
and 1 do. of chlorine = 36

Consequently, chemical equivalent of proto-chloride of mercury = 236.

§ 178. This compound is obtained directly by bringing the *mercury* in contact with chlorine, at the common temperature of the atmosphere. It is also formed when a solution of common salt is poured upon a solution of mercury in nitric acid. The chlorine of which common salt is composed (which is a chloride of sodium) combines then with the mercury to a heavy, white powder which is precipitated; and must afterwards be washed and dried at a gentle heat. The compound thus obtained forms that celebrated medicine, known by the name of calomel, which is now of almost universal application, but was first employed and prepared by Dr Hahneman, late Professor of Medicine in Leipzig.

Per-Chloride of Mercury — (Corrosive Sublimate)

consists of 1 equivalent of mercury = 200
2 equivalents of chlorine (each = 36) = 72

Consequently, chemical equivalent of per-chloride of mercury = 272.

§ 179. This substance affords a powerful illustration of the power of *heat* to increase chemical affinity (see Intro. page 5). We have said in the last section that proto-chloride of mercury is obtained by bringing chlorine and mercury in contact *at the common temperature of the atmosphere*, but if this be done when mercury is *heated*, its affinity for chlorine increases, in which case it combines with a double proportion of chlorine, forming the compound whose chemical composition we have stated at the head of this section. *Corrosive Sublimate* is also prepared for medicinal purposes by subliming a mixture of 73 parts of a salt known by the name of *sulphate of mercury* with 120 parts of common table salt (a chloride of sodium).

(The sulphate of mercury, which is a compound of sulphuric acid with mercury, is obtained by boiling to dryness 50 parts, by weight, of mercury, and 70 of sulphuric acid).

§ 180. *Properties.* Corrosive sublimate thus obtained has a crystalline texture, is perfectly colorless, soluble in water, and has a hot, acrid taste. When taken in its pure state it is highly poisonous. One of the most distressing symptoms accompanying the poisoning by corrosive sublimate is the swelling of the glands and throat, which, if it be taken in large quantities, terminates in suffocation. It is nevertheless much used in medicine.

Combinations of Mercury with Sulphur.

§ 181. Mercury unites yet with sulphur in two different proportions, forming respectively *proto-sulphuret* and *bi-sulphuret* of mercury. The first of these combinations may be obtained by triturating together mercury and sulphur, or by passing a current of sulphuretted hydrogen through water in which powdered chlorine is suspended.

It is composed of 1 equivalent of mercury = 200
1 do. of sulphur = 16

Its chemical equivalent therefore, is = 216.

Bi-sulphuretted Mercury

is composed of 1 equivalent of mercury = 200
and 2 equivalents of sulphur (each = 16) = 32

Consequently, chemical equivalent of bi-sulphuret of mercury = 232.

§ 182. This compound, also known by the name *cinnaber*, is, as we have had occasion to say before, the principal ore from which mercury itself is obtained; but it may also be produced by art, by fusing together mercury and sulphur, and subliming the compound. It is of a beautiful red color, and is employed as a red pigment, known by the name of *vermilion.*

Recapitulation of the principal Binary Combinations of Mercury.

Mercury combines with	*oxygen* to	*protoxide* *per-oxide*	of *Mercury.*
	chlorine to	*proto-chloride* *per-chloride*	of *Mercury.*
	sulphur to	*proto-sulphuret* *per-sulphuret*	of *Mercury.*

2. *Silver.*

Chemical Equivalent = 110.

§ 183. This well-known metal is found native, or mixed with *chlorine*, *sulphur*, *copper*, and other metals, in a great many countries, but particularly in South America and Mexico. It is of a beautiful white color and great lustre, which is only surpassed by polished steel. It is very malleable and possesses very great ductibility. It may be hammered into leaves of not more than one ten thousandth part of an inch in thickness, and drawn out into wire of the breadth of a hair. It is seldom (even by art) obtained in an entirely pure state, being generally alloyed with a small portion of copper. Most silver contains also a small quantity of gold (about $\frac{1}{12}$ per cent), which for the want of a cheap method of refining it, has until of late, been suffered to remain with it*. The uses of silver for coins, ornaments, instruments, vessels, &c, are sufficiently known. It is eminently calculated for all these purposes, on account of its unalterability, being only tarnished by vapors of sulphur, and resisting oxidation even when exposed to moisture in contact with heat.

Combinations of Silver.

§ 184. Silver by uniting with oxygen, chlorine and sulphur, forms the three respective compounds, *oxide*, *chloride*, and *sulphuret* of silver. The first of these combinations,

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* It has lately been extricated from the silver of some of the mines in Saxony.

Oxide of Silver,

is composed of 1 equivalent of silver = 110
and 1 do. of oxygen = 8

Its chemical equivalent, therefore, is = 118

It is obtained by adding lime-water to a solution of silver in nitric acid. It possesses an olive color, is insoluble in water, and perfectly tasteless.

Chloride of Silver

is composed of 1 equivalent of silver = 110
1 do. of chlorine = 36

Consequently, chem. equiv. of chloride of silver = 146.

It is commonly known by the name of *horn* silver, and obtained by adding a solution of common salt to one of silver in nitric acid. The precipitate thus formed is the chloride of silver, which at first is white, but gradually becomes dark, and finally black, when exposed to the rays of the sun. It is insoluble in water, and when heated in a silver crucible, forms upon cooling, semi-transparent crystals, similar to horn (hence the name of horn silver).

A mixture of chloride of silver, chalk and pearl-ash is used for silvering brass. The brass must for this purpose be well cleaned, and the mixture, a little moistened with water, rubbed upon its surface.

Sulphuret of Silver

is composed of 1 equivalent of silver = 110
1 do. of sulphur = 16

Consequently, chem. equiv. of sulphuret of silver = 126.

This compound occurs in silver mines, but may also be produced by art by placing thin plates of silver and sulphur upon one another, and heating them gently at a low red heat. As this compound is much more fusible than pure silver, the pure metal may be extricated from it by heat. Another way of producing it is by passing sulphuretted hydrogen through a solution of silver in nitric acid.

It is of a black color, but when fused is employed in the manufactory of silver ornaments.

Recapitulation of the principal combinations of Silver.

Silver combines with { *oxygen* to *oxide* of *silver*.
chlorine to *chloride* of *silver*.
sulphur to *sulphuret* of *silver*.

3. *Gold.*

Chemical Equivalent = 200.

§ 185. Gold belongs to those metals which on account of their being found in a *native* state, were known to the remotest people of antiquity. It occurs either in its simple form, or combined with *silver*, *tellurium*, *rhodium*, &c. Native gold is found in various shapes in *Europe*, *Asia*, *Africa*, and *America*, in *Ceylon*, *Sumatra*, *Java*, *Borneo* and the *Phillipine Islands*.

Properties. It is of a beautiful yellow color, and about 19 times heavier than water (its specific gravity being 19, that of water taken for 1). Hammered out into thin leaves it transmits the rays of the sun, the light passing through it appearing green. It is more malleable and ductile than any of the metals ; $\frac{1}{10}$ of a grain of it may be hammered out to cover 37 square feet of surface. According to Réaumure, a French philosopher, one grain of gold may be drawn into a piece of wire 500 Paris feet long, and 38 grains of the same metal are sufficient to cover a piece of silver wire upwards of one thousand miles in length ! ! It is perfectly unchangable by *fire*, *moisture*, or *air*, and is only acted upon by *one* solvent, which is a *mixture* of *muriatic* and *nitric* acid (neither of these acids does alone affect gold), which from this property of dissolving gold has been called *aqua regia* (king's water); because the alchymists considered gold as the king of metals.

Gold is used like silver for *coins* and ornaments, and possesses the greatest value of any metal known.

Gold from a state of solution may easily be revived by any substance which has a strong affinity for oxygen, for which gold has but a feeble affinity. Hence if a ribbon or some other substance be moistened with a dilute solution of gold in aqua regia, and afterwards exposed to a current of hydrogen, the gold will be revived and cover the stuff. When the solution is applied in regular figures, by means of a camel's-hair pencil, it will afford a beautiful experiment, particularly to young scholars. An etherial solution of gold, which is formed by pouring sulphurous ether into a solution of gold, is employed for gilding steel instruments, to preserve them from rust or moisture. The solution is easily prepared by adding 2 ounces of ether to one ounce of the solution of gold ; when the vessel is thoroughly shaken and afterwards allowed to stand for a few minutes, the ether which does not mix with the acid, and which, on account of its being specifically lighter, will float on top, may be poured off into another vessel. Any steel instrument dipped into the etherial solution will instantly receive a thin coating of gold.

Combinations of Gold.

§ 186. Gold combines in two different proportions with oxygen. The products are *protoxide of gold,* and *deutoxide of gold,* or *auric* gold. Neither of these combinations is used in the arts, neither is their nature and composition precisely known or understood. The same holds of the combinations of gold with chlorine (see Chloride of Gold, Chap. IV). *Sulphuret of gold* is obtained like that of silver (see § 184, page 201), by passing sulphuretted hydrogen through a solution of the metal.

The principal combinations of gold may therefore be arranged as in the following table :

Gold combines with	*oxygen* to	*protoxide of gold.* *auric gold.*
	chlorine to	*chloride of gold.*
	sulphur to	*sulphuret of gold.*

4. *Platinum.*

Chemical Equivalent = 96.

§ 187. The Spanish philosopher, Antonio d'Ulod, observed the ore of *platinum*, in 1736. An Englishman by the name of *Wood* brought it first to *Europe*, where it was analyzed, and found to contain besides, four different metals, viz. *Palladium*, *Rhodium*, *Iridium*, and *Osmium*. It has since been found in *Russia*, where it is used for coin, for which it is admirably adapted on account of its hardness and unalterability.

Properties. It is of a white color, somewhat resembling steel, but has less lustre than silver. Like gold it is not acted upon either by a common fire, moisture or air; nor by any of the acids alone, but is likewise dissolved by a mixture of nitric and muriatic acid. When very pure it is soft, ductile, and may be hammered out into leaves, but cannot be drawn into such *fine wire* as either gold or silver. It is a good conductor of heat and electricity, exceedingly difficult of fusion, and the heaviest of all substances known (its specific gravity being 21.5, that of water taken for 1).

Besides the coining of money it is yet used for a variety of scientific, particularly chemical purposes. It unites with oxygen, chlorine and sulphur; but the nature of these combinations is not precisely ascertained.

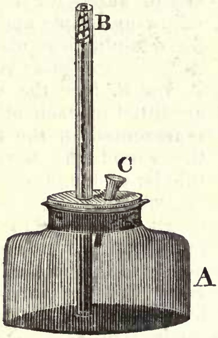
Among the various applications of platinum in chemistry, we will only mention a few, which will sufficiently serve for an illustration.

1st. It is used for crucibles in all such cases where, in the course of a chemical process some acid is to be employed which would corrode or act upon some other metal, or which would operate upon glass.

2d. It is used in the manufacture of a number of chemical and physical apparatus, particularly in electric and galvanic batteries, where it is used as a conducting wire.

3d. In the construction of the flameless or aphlogistic lamp, which is represented in the adjoining figure. It consists principally of a glass tube several inches long, which must be fitted to a small bottle or some other low vessel (as represented in the figure) by means of a wooden cork, which has, besides, another aperture C, for the purpose of feeding the lamp with alcohol. Into the glass tube is inserted a coil of platina wire, wound round a piece of wood, which is shaped somewhat conical (tapering), with its lower end turned upwards. A piece of wick establishes a communication between the alcohol and the platina wire.

Fig. CXIII.

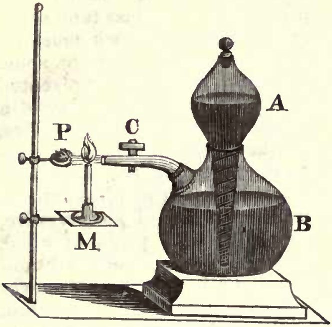


When the lamp is to be used the platina may be ignited by the flame of a candle, which being afterwards blown out, the wire will still remain red hot, and emit a feeble light, as long as there is any alcohol remaining in the vessel.

This phenomenon is explained in the following way. When the wire is ignited, its temperature is sufficiently raised to inflame the alcohol, which as we well know, is a highly combustible substance; but this being once done, the heat given out by the burning alcohol is sufficient to keep the platina wire red hot, even after its flame is blown out.

Another application of platinum is made in the preparation of *platinum-sponge*, for the purpose of producing instantaneous light. Platinum-sponge is a substance which is obtained by dissolving platinum in a mixture of nitric and muriatic acid, and precipitating the metal from this solution by the addition of some muriate of ammonia. This precipitate being afterwards exposed in a crucible to a red heat, the acid and ammonia are evaporated and the metal remains in a spongy mass, which on that account has been called platinum-sponge. Its most remarkable property consists in the manner in which it is affected by hydrogen gas, and which is not yet sufficiently explained. A jet of this gas being directed upon it, in contact with, and at the common temperature of the atmosphere, the platinum-sponge becomes immediately red hot, and ignites the hydrogen.

Fig. CXIV.



Upon this property of platinum-sponge, Professor Döbereiner of the University of Jena, founded the following simple apparatus for obtaining instantaneous light. Two glass vessels, A and B, (see the figure) are fitted to each other as represented in the figure, the vessel A, having a tubular prolongation which is ground air-tight into the mouth of the vessel B. This prolongation, which reaches nearly to the bottom of the vessel B, being surrounded by small strips of zinc, and sulphuric acid being poured into B, hydrogen gas will be evolved, as in the experiment represented in Fig. LXXVIII, page 65, which by its pressure will force part of the liquid through the tube into the upper vessel A. The remainder of the gas being compressed by the weight of the water and the acid, a portion of it will rush forth in a jet from the mouth of the pipe P, when the stop-cock C, is turned open. This jet being directed upon some grains of platinum-sponge, the latter will instantly become red hot and ignite the hydrogen, which in its turn sets fire to the wick of a small candle, which must be placed between the mouth of the pipe and the platinum-sponge.

Besides the applications we have mentioned, platinum admits of many others, in Chemistry and Natural Philosophy, to which the unalterability and ductability of the metal seem to be particularly adapted; and there can be no doubt but that its uses would become as frequent as those of iron, if it were found in larger quantities, and reduced from its ores by a more simple process than is known in the present state of the science.

5. *Palladium.*

Chemical Equivalent = 56.

§ 188. Palladium, as we have observed in the last section, is contained in raw platinum ore. It is also found combined with gold in Brazil. Its color is similar to that of platinum. It is ductile and may be rolled into leaves, or drawn into wire: It is less fusible than gold, tarnishes when heated, but assumes again its original lustre when submitted to higher degrees of temperature. It is acted upon (dissolved) by the nitric, sulphuric, and muriatic acids. It combines with oxygen and sulphur. The product of the last combination, *sulphuret of palladium*, is of a greyish white color, has a metallic lustre, and is brittle and easily fusible.

6. *Rhódium.*

Chemical Equivalent, (not ascertained).

§ 189. This metal (likewise contained in platinum) has but lately been found combined with gold. It is white (like silver), hard, brittle, and infusible at a common red heat. It is not acted upon by any acid, except when alloyed with another metal, but becomes oxydized when calcined with potassium.

The oxide thus obtained is a hydrate of a brown color, and astringent taste, which is dissolved by most acids, and combines with the alkalies and earths in several proportions.

7. *Iridium.*

Chemical Equivalent (not ascertained).

§ 190. Iridium is found united with *osmium* (see next section) in form of small, black globules, from which it is afterwards separated by the action of muriatic acid. It is a white, heavy metal, which is not acted upon by any acid, and is fusible only in small quantities by the agency of powerful galvanic batteries.

8. *Osmium.*

Chemical Equivalent (not ascertained).

§ 191. This metal is obtained by the same process as iridium. It is a greyish, black, or blue powder, which is acted upon by nitric acid; small quantities of it burn when transmitted to a red heat in contact with the atmosphere. The acid which is formed by the combustion of the metal is soluble in water, and emits a peculiar odor (from which the metal derived its name.*)

9. *Nickel.*

Chemical Equivalent = 30.

§ 192. *Nickel* is not an abundant product of nature, and is generally united with *cobalt* or *arsenic* (the latter combination is known in Commerce by the name of *spliss*). It has almost a silver-white color, a strong metallic lustre, is not easily fusible, but ductile (when cold or warm), and may be drawn into wire or rolled and hammered into plates. It does not become oxydized in contact with the atmosphere at common temperatures, but burns in pure oxygen. It is attracted by the magnet, and is itself capable of receiving and exhibiting magnetic power, in a degree less than iron but greater than cobalt (see Nat. Phil. Chap. X). When heated in contact with atmospheric air it is converted into a dark powder, *oxide of Nickel*, which is yet possessed of magnetic properties.

D. OF THE REMAINING METALS, IRON, TIN, LEAD, COPPER, ZINC, BISMUTH, COBALT, ANTIMONY, ARSENIC, MANGANESE, TELLURIUM, TITANIUM, CERIUM, URANIUM, COLUMBIUM, TUNGSTEN, CADMIUM, CHROMIUM, MOLYBDENUM, AND VANADIUM.

1. *Iron.*

Chemical Equivalent = 28.

§ 193. No metal is of such importance to mankind as

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* From a Greek word, signifying odor.

iron; it is almost indispensable to civilization. Neither gold nor silver are so intimately connected with the power and prosperity of a people. By a wise distribution of Providence, it is most abundantly diffused throughout the whole globe, and is found in all three kingdoms of nature. It is generally met with in an oxydized state, native only in *meteor stones*,* and in some of the fossils. It is of a bluish-grey, sometimes white color, and susceptible of the highest polish. It is malleable and ductile, and may be drawn into wire; but cannot be beaten into very thin leaves, like gold or silver. It is very hard and infusible; but when red hot it is soft and capable of receiving any form, by hammering. It is strongly attracted by the magnet, and is itself capable of receiving all magnetic virtues.

The native *magnet* or *load-stone*, is an ore which is known by the name of magnetic iron ore. It occurs crystallized, in regular octahedrons, or in crystalline masses, but sometimes also in an earthy state. When crystallized it has a strong metallic lustre, and a greyish black color. Its peculiar properties have been described in Natural Philosophy, Chapter X.

Combinations of Iron with Oxygen, Chlorine and Sulphur.

§ 194. Iron has a strong affinity for oxygen, and forms with it two definite oxides—*protoxide* and *per-oxide of iron.* The chemical composition of the

Protoxide of Iron

is 1 equivalent of iron = 28
1 do. of oxygen = 8

Consequently, chemical equiv. of protoxide of iron = 36.

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* Meteor stones are such as have come down through the atmosphere. Their origin is not precisely ascertained. Some philosophers believe they are of cosmic origin; that is, so many little globes, revolving like our earth around a common centre, which is the sun. The authorities for this opinion are Biot, Chladni, and all German mineralogists.

Per-oxide of Iron

is composed of 1 equivalent of iron = 28
1½ do. of oxygen = 12

Consequently, chemical equiv. of per-oxide of iron = 40.

The *Per-oxide* is obtained from a solution of iron in nitric acid, which must afterwards be boiled and precipitated by ammonia. It is of a red color and not attracted by the magnet. The *protoxide* may be obtained by separating part of the oxygen from the per-oxide which is done by passing hydrogen over the per-oxide, at a temperature a little below red heat. It is blue, ignites spontaneously when exposed to the atmosphere, and is attracted by the load-stone, though feebler than raw iron. When iron is made red hot in contact with atmospheric air, *black oxide of iron* is formed, which is an indefinite compound of iron with oxygen (a mixture of protoxide and per-oxide) and an abundant product of nature.

§ 195. Iron unites also with chlorine in two proportions. The respective products are *proto-chloride* and *per-chloride of iron.*

Proto-Chloride of Iron

is composed of 1 equivalent of iron = 28
1 do. of chlorine = 36

Consequently, chem. equiv. of proto-chloride of iron = 64.

Per-Chloride of Iron

is composed of 1 equivalent of iron = 28
1½ do. of chlorine = 54

Chemical equivalent of per-chloride of iron = 82.

Proto-chloride of iron is obtained from a solution of iron in muriatic acid, which should be evaporated to dryness and then ignited (secluded from the atmosphere). The product thus obtained is of a grey color, has a metallic lustre and scaly texture. The *Per-chloride of iron* is produced by burning iron wire in chlorine. It is a brown substance, of great lustre. Both chlorides are used in dyeing — the per-chloride is also employed in medicine.

§ 196. The *sulphurets*, *proto-sulphurets* and *bi-sulphuret* of iron are products of nature. The bi-sulphuret, particularly, is an abundant natural product, and is known by the name of *iron pyrites*. It is of a yellow bronze color, somewhat similar to gold (for which it is sometimes mistaken by those unacquainted with mineralogy) and is often found in crystals. It has not as yet been produced by art, and when heated becomes converted into proto-sulphuret of iron, by losing half its proportion of sulphur. The *proto-sulphuret* may also be produced by rubbing sulphur on red-hot iron. The sulphuret will fall down in drops, which upon cooling are slightly attracted by the magnet.

Proto-Sulphuret of Iron

is composed of 1 equivalent of iron = 28
1 do. of sulphur = 16

Consequently, chemical equivalent of proto-sulphuret of iron = 44.

Bi-Sulphuret of Iron

is composed of 1 equivalent of iron = 28
2 do. of sulphur = 32

Consequently, chem. equiv. of bi-sulphuret of iron = 60.

Combination of Iron with Carbon, (Steel).

§ 197. When malleable iron is surrounded by powdered charcoal, and for a length of time exposed to a red heat, part of the carbon, to the amount of about $\frac{1}{150}$ part of the weight of iron, unites with the iron and forms the well-known substance, *steel*. This product of art, which was already known to the ancients,* is by far more elastic, hard and sonorous than iron itself. In order to adapt it to the

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* The Jews, under Moses, knew the manufactory of steel; but in the Trojan war, 1200 years before Christ, copper arms were used.

variety of purposes for which it is used, it must undergo the process of *tempering*, which consists in heating it to a certain point. According to the different manners in which steel is manufactured, and the iron ore employed for that purpose, it is called *rough steel*, *blistered steel*, or *cast steel;* all which are articles of commerce. The uses of steel for the manufactory of surgical instruments, razors, penknives, scissors, knives, forks, small and broad-swords, domestic implements, carpenters' and other tools, pens, balances (of watches), musical instruments, &c, are well known, and justify the assertion made in the beginning of § 193.

Recapitulation of the principal Combinations of Iron.

$$\begin{array}{c}\textit{Iron}\\ \text{combines with}\end{array}\begin{cases} \textit{oxygen} \text{ to } \left\{\begin{array}{l}\textit{protoxide}\\ \textit{per-oxide}\\ \textit{black oxide}\end{array}\right\} \text{ of } \textit{Iron.} \\ \textit{chlorine} \text{ to } \left\{\begin{array}{l}\textit{per-chloride}\\ \textit{proto-chloride}\end{array}\right\} \text{ of } \textit{Iron.} \\ \textit{sulphur} \text{ to } \left\{\begin{array}{l}\textit{sulphuret}\\ \textit{bi-sulphuret}\end{array}\right\} \text{ of } \textit{Iron.} \\ \textit{carbon} \text{ to } \textit{Steel.} \end{cases}$$

2. *Lead.*

Chemical Equivalent = 104.

§ 198. This well known metal occurs abundantly (though not often in a native state) in the mineral kingdom, and was, on account of its easy production from the ores, known to almost all people of antiquity. In its pure state it is of a bluish-grey color, and when recently cut has a strong metallic lustre. It is very soft and ductile, but on account of its small cohesive attraction cannot very well be drawn into wire, but may be hammered out into plates. It leaves a stain on paper or wood, and a faint, disagreeable smell on the fingers. It boils when exposed to a red heat, and emits vapors which are very injurious to health. It is extensively used in the manufacture of shot, *sugar of lead* (see Chap. IV), and in the process of cupellation (see the next section).

Combination of Lead with Oxygen, Chlorine, and Sulphur.

§ 199. Lead combines in four different proportions with oxygen. The products are *sub-oxide of lead* (ashes of lead); *protoxide of lead* (the massicot of commerce); *deutoxide of lead* (red lead); and *per-oxide of lead.*

Chemical Composition of the Oxides of Lead.

Sub-oxide of Lead

is composed of 1 equivalent of lead = 104
½ do. of oxygen = 4
Consequently, chem. equiv. of sub-oxide of lead = 108.

Protoxide of Lead

is composed of 1 equivalent of lead = 104
1 do. of oxygen = 8
Consequently, chem. equiv. of protoxide of lead = 112.

Deutoxide of Lead

is composed of 1 equivalent of lead = 104
and 1½ do. of oxygen = 12
Consequently, chem. equiv. of deutoxide of lead = 116.

Per-oxide of Lead

is a product of 1 equivalent of lead = 104
2 do. of oxygen = 16
Consequently, chem. equiv. of per-oxide of lead = 120.

All these oxides may be obtained, though in an impure state, by heating lead in atmospheric air, or by the action of nitric acid. They have the peculiar property of combining with most metals, except silver, gold, and platinum; and are on this account used for purifying gold and silver.

The metal which is to be purified is wrapped up in a sheet of lead, and melted in a crucible. By this process, which is called cupellation (see § 198), the lead which is melted first sinks to the bottom and carries along with it all the baser metals with which it combines.

The *protoxide* of lead, or *massicot* of commerce, is obtained by fusing lead in open vessels, and continuing the heat until it has assumed a uniform yellow color. When this substance is again partially melted, it is called *litharge*, which however is less pure than the massicot.

The *deutoxide of lead* is known in commerce by the name of *red lead*, and is used as a pigment, and in the manufactory of glass. It is obtained by exposing massicot to a moderate heat, presenting a large surface to the atmosphere. At a temperature equal to red heat it parts again with a portion of its oxygen and is converted into protoxide. When nitric acid is poured upon the deutoxide, it is again partly converted into a protoxide, which is dissolved by the acid, from which it absorbs a further portion of oxygen, and is then precipitated in form of a dark brown powder, which is the per-oxide.

Chloride of Lead is produced by adding common salt to a solution of lead in nitric acid. It has a sweet taste, and when fused has the appearance of horn — wherefore it is called *horn lead.* It is composed of 1 equivalent of lead = 104
1 do. of chlorine = 36

Consequently, chemical equivalent of chloride of lead = 140.

Sulphuret of Lead (galena) is an abundant product of nature. It is less fusible than lead, and constitutes the *ore* from which pure lead is commonly obtained.

Recapitulation of the principal Combinations of Lead.

$$\begin{array}{c}\textit{Lead}\\ \text{combines with}\end{array}\left\{\begin{array}{l}\textit{oxygen}\text{ to}\left\{\begin{array}{l}\textit{sub-oxide}\\ \textit{protoxide}\\ \textit{per-oxide}\\ \textit{deutoxide}\end{array}\right\}\text{ of }\textit{Lead.}\\ \textit{chlorine}\text{ to }\textit{chloride of Lead.}\\ \textit{sulphur}\text{ to }\textit{sulphuret of Lead.}\end{array}\right.$$

3. *Tin.*

Chemical Equivalent = 59.

§ 200. ***Tin*** is also one of the oldest metals. It was known to the Phenicians, who brought it from Spain and England. It was wrought in the times of Moses, although it is not a very abundant product of nature. It occurs either as an oxide or a sulphuret. In its pure state its color resembles that of silver; its hardness is between lead and gold. It may be cut with a knife, is very ductile, may be hammered into leaves or drawn into wire, and leaves, like lead, a faint, disagreeable smell on the fingers. When bent forward and backward it makes a crackling noise; but loses this property when frequently repeated. It is used for the manufactory of vessels, plates, pots, kettles, and for tinning all kinds of sheet-iron ware.

Combinations of Tin with Oxygen, Chlorine and Sulphur.

§ 201. Tin has a strong affinity for oxygen, and combines with it in two proportions, forming *Protoxide* and *Per-oxide.*

Chemical Compositions.

Protoxide of Tin

consists of 1 equivalent of tin = 59
1 do. of oxygen = 8

Consequently, chemical equiv. of protoxide of tin = 67.

Per-oxide of Tin

is composed of 1 equivalent of tin = 59
2 do. of oxygen = 16

Chemical equivalent of per-oxide of tin = 75.

Both products may be obtained by heating tin in contact with the atmosphere, or by the action of nitric acid on the metal.

When tin is fused, and for a long time in the liquid state, exposed to the atmosphere, it becomes converted into a grey powder, which is the protoxide. When this is again heated in contact with air, it combines with a further portion of oxygen, and is changed into the per-oxide.

The Per-oxide has a light yellow color, becomes yellow at a red heat, is infusible, and insoluble in water, and unites by double affinity (see Intro. page 9) with the alkaline earths. Oxide of tin, united with that of lead, is used in the manufactory of brass (see § 203), and for polishing hard substances, such as glass, crystal, stones, &c.

Proto-Chloride of Tin is obtained by dissolving tin-filings in muriatic acid. It is grey, half-transparent, and soluble in water. *Per-chloride* of tin is obtained by heating tin-filings with chlorine. It is a thin, volatile liquid, which inflames oil of turpentine and emits white fumes when exposed to the atmosphere.

Proto-chloride of Tin

is composed of 1 equivalent of tin = 59
1 do. of chlorine = 36

Consequently, chemical equiv. of proto-chloride of tin = 95.

Per-Chloride of Tin

is composed of 1 equivalent of tin = 59
2 do. of chlorine = 72

Consequently, chemical equiv. of per-chloride of tin = 131.

§ 202. Of the two *sulphurets of tin* (Proto-sulphuret and sulphuret) the proto-sulphuret is produced by a fusion of tin and sulphur. It is blue and brittle. The sulphuret is produced by heating per-oxide of tin with sulphur. It is used for giving a beautiful yellow color to gold.

Recapitulation of the principal Combinations of Tin.

$$\begin{matrix}\textit{Tin}\\ \text{combines with}\end{matrix}\begin{cases}\textit{oxygen} \text{ to } \left\{\begin{matrix}\textit{protoxide}\\ \textit{per-oxide}\end{matrix}\right\} \text{ of } \textit{Tin.}\\ \textit{chlorine} \text{ to } \left\{\begin{matrix}\textit{proto-chloride}\\ \textit{per-chloride}\end{matrix}\right\} \text{ of } \textit{Tin.}\\ \textit{sulphur} \text{ to } \left\{\begin{matrix}\textit{proto-sulphuret}\\ \textit{sulphuret}\end{matrix}\right\} \text{ of } \textit{Tin.}\end{cases}$$

4. *Copper.*

Chemical Equivalent = 72.

§ 203. Few metals have so long been known to man, or have been wrought at so early a period, as *copper*. (The ancients brought it from the island of *Cyper*). It is found in a metallic state, connected with other substances, especially sulphur. It is red, elastic, sonorous, and when pure has a strong metallic lustre. It has a faint, disagreeable smell and taste, and is less coherent than iron. It is a good conductor of heat, and the best conductor of electricity. It is less fusible than silver, more so than gold, becomes volatile at high degrees of heat, burns with a green flame, becomes oxidized in contact with a damp atmosphere, and covered with a green crust, which is very injurious to health. It is used for the coverings of roofs, for pans and pipes in breweries, sugar refineries, and soap-manufacturies. It is employed also in the construction of boilers for steam-engines, for fastening vessels, and a variety of other useful purposes. One of its chief applications consists in uniting it with *zinc* in the manufactory of *brass* and *tombac;* and with different proportions of *tin* for the casting of bells, and in the preparation of *gun* and *speculum metal.* (The latter is used for the construction of reflecting telescopes, in the manufactory of optical instruments).

Combinations of Copper with Oxygen, Chlorine, and Sulphur.

§ 204. We know of two combinations of copper with oxygen. Both are products of nature, but may be obtained by burning copper, in a state of minute division, in atmospheric air. The *protoxide* is red and melts at a red heat; the *deutoxide* is black and tasteless.

The protoxide consists of 1 equivalent of copper = 72
and 1 do. of oxygen = 8

Chemical equivalent of protoxide of copper = 80.

The deutoxide is composed of 1 equivalent of copper = 72
2 do. of oxygen = 16

Chemical equivalent of deutoxide of copper = 88.

§ 205. *Proto-chloride* and *per-chloride of copper* are obtained by introducing copper filings into chlorine. The filings will spontaneously take fire, and both compounds are at once produced, the proto-chloride in a solid state, and the per-chloride in form of a powder. The proto-chloride is a yellowish substance, similar in appearance to resin, easily fusible, but insoluble in water. The *per-chloride* is a brown powder, which, when it has absorbed moisture from the air, turns green. Spirits of wine, in which per-chloride of copper has been dissolved, burns with a beautiful green flame, on account of which it is used in fire-works and for theatrical purposes.

Proto-Chloride

is composed of 1 equivalent of copper = 72
1 do. of chlorine = 36

Consequently, chemical equivalent of proto-chloride of copper = 108.

Per-Chloride of Copper

is composed of 1 equivalent of copper = 72
2 do. of chlorine = 72

Chemical eqvivalent of per-chloride of copper = 144.

The Sulphurets of copper (proto-sulphuret, and bi-sulphuret) are abundant products of the mineral kingdom. The former is found combined with other sulphurous metals, the latter has been discovered near the crater of Mount Vesuvius, and in a few rare copper ores.

Recapitulation of the principal Combinations of Copper.

Copper combines with	*oxygen* to	*protoxide* *per-oxide*	of *Copper.*
	chlorine to	*proto-chloride* *per-chloride*	of *Copper.*
	sulphur to	*proto-sulphuret* *bi-sulphuret*	of *Copper.*

5. *Zinc.*

Chemical Equivalent = 34.

§ 206. The ore of this metal was formerly imported into Europe from *China*. In the 16th century it was distinguished as a separate metal, and received its present appellation. It is not found in a native state, but occurs mixed with lead or sulphur. (Most zinc is obtained from an ore called *sparry calamine*, which is a carbonate of this metal). Pure zinc has a bluish-white color and a strong metallic lustre. It is less ductile than lead or tin, but when heated to from 212 to 302° Fahrenheit it may be hammered, or drawn into wire. Of all metals which are used in common life, it is most expanded by heat. It is capable of volatilization and distillation by heat.

Combinations af Zinc with Oxygen and Chlorine.

§ 207. Zinc may be burnt in *atmospheric air* or *chlorine.* In the first case the combustion is accompanied by a most beautiful blue flame, into which the forming *oxide of zinc* is thrown up in form of white flakes, formerly known by the name of *flowers of zinc.* In the second case *chloride of tin* is formed, which is a soft, grey substance, of the consistency of wax, easily soluble in water, and used (in France) in the process of dyeing.

Oxide of Zinc

is composed of 1 equivalent of zinc = 34
1 do. of oxygen = 8

Consequently, chemical equivalent of oxide of zinc = 42.

Chloride of Zinc

is composed of 1 equivalent of zinc = 34
1 do. of chlorine = 36

Consequently, chemical equiv. of chloride of zinc = 70.

Recapitulation of the principal Combinations of Zinc.

$$\textit{Zinc}\text{ combines with }\left\{\begin{array}{l}\textit{oxygen}\text{ to }\textit{oxide}\\ \textit{chlorine}\text{ to }\textit{chloride}\end{array}\right\}\text{ of }\textit{Zinc.}$$

6. *Bismuth.*

Chemical Equivalent = 71.

§ 208. Bismuth is seldom found in its native state; it is more frequently combined with oxygen, sulphur and lead. It has a reddish-white color, and a strong metallic lustre. It is very brittle, so that it may be reduced to a powder, is fusible, volatile, and capable of distillation. It is used for the manufactury of pigments and paints. It combines with oxygen and chlorine to oxide and chloride of bismuth, in a manner similar to zinc (see the last section). Its principal binary combinations may therefore be arranged as follows:

$$\textit{Bismuth}\text{ combines with}\left\{\begin{array}{l}\textit{oxygen}\text{ to }\textit{oxide}\\ \textit{chlorine}\text{ to }\textit{chloride}\end{array}\right\}\text{ of }\textit{Bismuth.}$$

7. *Cobalt.*

Chemical Equivalent not ascertained.

§ 209. The ores of Cobalt were already known in the 15th century, and used in the manufactury of blue pigments. It is however but a few years since cobalt has been entirely separated from nickel, arsenic and iron, with which it is commonly found combined. The purest cobalt is of a greyish-white color (between silver and steel), and possesses considerable splendor. It is malleable and ductile only in an inferior degree (cannot be drawn into wire), is attracted by the magnet, and capable of receiving magnetic properties (Nat. Phil. Chap. X). The oxides of this metal, which are obtained by exposing it to an intense heat in contact with atmospheric air, or by precipitating it from a solution in nitric acid, by the addition of potash, occur in commerce mixed with sand or calcined flint, under the name of *zaffer* and *smalts*. They are fine blue pigments, and are extensively used for dyeing linen, or to stain glass and China.

8. *Antimony.*

Chemical Equivalent = 44.

§ 210. Antimony occurs either native, or in red and grey ore of antimony. It has a dusky white color, considerable metallic lustre and scaly fracture. It is so brittle that it may be reduced to a powder, is fusible and volatile, and burns when heated in the atmosphere. It is used as an alloy in some of the arts, and sometimes it is employed in medicine. Combined with lead it forms the metal of which printers' type is cast.

Combinations of Antimony with Oxygen, Chlorine and Sulphur.

§ 211. Antimony combines with oxygen in three different proportions. The first of these combinations,

Protoxide of Antimony,

is composed of 1 equivalent of antimony = 44
1 do. of oxygen = 8
Its chemical equivalent, therefore, is = 52.

It is a product of nature, but may be obtained also by the combustion of antimony in atmospheric air. It is a greyish white powder, which, when taken into the stomach, operates like an emetic, melts at a red heat, is volatile, and forms, upon cooling, regular crystals. The second,

Deutoxide of Antimony (Antimonious Acid),

is composed of 1 equivalent of antimony = 44
1½ do. of oxygen = 12
Consequently, chem. equiv. of deutoxide of antimony = 56.

It is found in some of the ores of antimony, and may be formed by heating the protoxide in the open air. It is a white powder without smell er taste, insoluble in water, and fusible only when submitted to high degrees of heat. It is used in glass and porcelain painting. The third,

Per-oxide of Antimony,

is a product of 1 equivalent of antimony = 44
and 2 do. of oxygen = 16
whence its chemical equivalent is = 60.

It is formed by pouring a solution of antimony in nitro-muriatic acid, see (§ 185, page 202) upon water; the peroxide is then precipitated. It is of a yellow, straw-color, inodorous and tasteless, and when submitted to a red heat parts with some portion of its oxygen, and is again converted into the deutoxide.

The *Proto-chloride* or *butter of Antimony*, is obtained by the combustion of powdered antimony in chlorine. It is soft, and melts at a gentle heat. The per-chloride is produced by bringing heated solid antimony in contact with chlorine.

Antimony combines yet readily with sulphur. The compound is a grey sulphuret, with metallic lustre, and is, among all the ores of antimony, that which is most abounding in nature.

Recapitulation of the principal Combinations of Antimony.

$$\begin{array}{l}\textit{Antimony}\\ \text{combines with}\end{array}\begin{cases}\textit{oxygen}\text{ to}\begin{Bmatrix}\textit{protoxide}\\ \textit{deutoxide}\\ \textit{per-oxide}\end{Bmatrix}\text{of }\textit{Antimony.}\\ \textit{chlorine}\text{ to}\begin{Bmatrix}\textit{proto-chloride}\\ \textit{per-chloride}\end{Bmatrix}\text{of }\textit{Antimony.}\\ \textit{sulphur}\text{ to }\textit{sulphuret}\text{ of }\textit{Antimony.}\end{cases}$$

9. *Arsenic.*

Chemical Equivalent = 38.

§ 212. *Arsenic** was first obtained from arsenic acid by *Brandt*, a celebrated chemist, in 1733. It occurs combined with various substances in the mineral kingdom. It is of the color of steel, and has a strong metallic lustre, which, however, is easily tarnished. Its texture is lamellar. At 356° Fahrenheit it forms greyish white vapors, which have a strong smell of garlic. It has a strong affinity for oxygen (powdered arsenic moistened with water may be heated to spontaneous combustion). In oxygen gas it burns with a bluish white flame, leaving arsenic acid. It is poisonous, although less so than the acid. Its use in the arts is very limited.

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* What in commerce occurs as *Arsenic*, is *arsenic acid*, or *oxide* of arsenic.

Combinations of Arsenic with Oxygen, Hydrogen and Sulphur.

§ 213. We know of three different combinations of arsenic with oxygen. The first,

Oxide of Arsenic, is an indefinite compound, formed by the contact of the metal with atmospheric air, and consists of a dark grey powder. The second,

Arsenious Acid,

is composed of 1 equivalent of arsenic = 38
and 2 equivalents of oxygen (each = 8) = 16

Consequently, chemical equiv. of arsenious acid = 54.

It is a product of nature. It is white, brittle, and highly poisonous. It tastes sweetish, is sparingly soluble in water, but when heated is easily volatilized. It is used in medicine and in some of the arts; viz: in glass factories, in cotton-printing, and in the preparation of mineral green. It may also be employed to preserve stuffed animals from destructive insects. The third combination of arsenic with oxygen,

Arsenic Acid,

is composed of 1 equivalent of arsenic = 38
3 do. of oxygen = 24

Consequently, chemical equivalent of arsenic acid = 62.

It occurs in some mineral salts. It may be obtained, also, by the action of nitric acid on heated arsenious acid. It is a white, opaque, inodorous mass, with a pungent, sour taste, and still more poisonous than arsenious acid.

Arseniuretted Hydrogen.

Chemical Equivalent not ascertained.

§ 214. A combination of *arsenic* with *hydrogen* is called *arseniuretted hydrogen gas.* It is a colorless gas of a nauseous smell. When taken into the lungs it causes giddiness, oppression, and death.

Sulphuret of arsenic is a product of nature. It occurs in commerce under the name of *Realgar*, and is used in dyeing and calico-printing.

Recapitulation of the principal combinations of Arsenic.

Arsenic combines with
- *oxygen* to
  - *oxide of arsenic.*
  - *arsenious acid.*
  - *arsenicacid.*
- *hydrogen* to *arseniuretted hydrogen gas.*
- *sulphur* to *sulphuret of arsenic.*

10. *Manganese.*

Chemical Equivalent = 28.

§ 215. *Manganese* occurs as an oxide or sulphuret, sometimes also in combination with chlorine or arsenic. It is of a greyish white color, and has a strong metallic lustre. It is hard, brittle, becomes easily oxydized, and falls to powder. It decomposes water at common temperatures, and melts when submitted to superior degrees of heat. Little application is made of this metal in the arts.

Combinations of Manganese with Oxygen and Chlorine.

§ 216. Manganese combines with oxygen in 4 or 5 different proportions. Two of them are indefinite compounds, or mixtures of the protoxide, deutoxide, and peroxide, and neither of them is of much service to the arts. The *per-oxide* is an abundant product of nature, has an earthy appearance (sometimes black, in crystals) and is soluble in water. It is used in the preparation of chlorine for bleaching, and constitutes what is called the *glass-makers' soap.* From the per-oxide the deutoxide and protoxide may be obtained by heat. By mixing it with nitre, and submitting it to red heat, an acid is obtained, which is called *manganesis acid.*

Chloride of manganese is found in some mineral waters and may be obtained by a direct combination of manganese with chlorine. It is a red liquid, which is used for the brown ground in calico printing.

Recapitulation of the principal combinations of Manganese.

Manganese combines with
- *oxygen* to
  - *protoxide*, *deutoxide*, *per-oxide* of *Manganese.*
  - *manganesic acid.*
- *chlorine* to *chloride* of *Manganese.*

11. *Tellurium.**

Chemical Equivalent = 29.

§ 217. Tellurium has but recently been discovered in one of the ores of Transylvania. It occurs seldom, either native or mixed with gold, silver, lead, and bismuth. It possesses a greyish white color, a strong metallic lustre, and a lamellar texture. It is brittle, may easily be reduced to a powder, boils when submitted to superior degrees of heat and is capable of distillation. Of all metals it is the worst conductor of electricity. It combines with oxygen and hydrogen. No use is made of this metal or its compounds in the arts.

12. *Titanium.*

Chemical Equivalent not ascertained.

§ 218. This metal never occurs in its simple form, but is found crystalized in scales of a copper-brown color, in the slags of smelting-furnaces; a small quantity of titanium being often contained in iron. It is hard and brittle, scratches steel, and is capable of a high polish. It is not fusible at a common red heat, and is under common circumstances, not acted upon by any acid. It combines in two or three proportions with oxygen, which are not easily reduced to the metallic state.

13. *Cerium.*

Chemical Equivalent supposed to be = 50.

§ 219. This metal occurs but sparingly in form of an

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* The remaining part of this chapter may be omitted by young pupils until reviewing the book.

oxide from which it has been obtained in exceeding small quantities by the action of very powerful voltaic batteries. It is a chocolate-colored powder, which a little before red heat ignites and burns vividly, the product of the combustion being an oxide of the metal.

14. *Uranium.*

(Not precisely ascertained).

§ 220. Uranium is obtained by the action of hydrogen upon the heated oxide of uranium. It is, like cerium, of rare occurrence, consists of a brown powder, which when polished shows a greyish dark lustre. It combines in two proportions with oxygen. The two products of these combinations, *protoxide and per-oxide* of uranium, are employed in porcelain painting, the first gives it a black, and the second an orange color.

15. *Columbium.*

Chemical Equivalent = 144.

§ 221. This metal was discovered by Hatchet, in an American fossil (wherefore its name), it is found very sparingly in form of an acid, from which it is extracted. It is a black powder, which, when polished, becomes of the color and lustre of iron. In thin leaves it is a conductor of electricity and is acted upon by boiling nitro-muriatic acid. Its only combination with oxygen is, as we have just said, an acid, from which the metal itself is obtained.

16. *Tungsten (Wolfram).*

Chemical Equivalent = 96.

§ 222. Tungsten is obtained from tungstic acid, the only form in which it occurs in some fossils. It is a dark grey powder, which by polishing can be made to assume a weak metallic lustre. It is very infusible. When submitted to red heat in contact with atmospheric air, it becomes oxydized, and, in small portions, is capable of ignition. It combines in two proportions with oxygen, forming an oxide and an acid. The latter is a product of nature; the oxide is obtained by reducing the acid, through the action of hydrogen gas.

17. *Cadmium.*

Chemical Equivalent = 56.

§ 223. This metal is contained in the ores of zinc, from which it is obtained chiefly be distillation. It resembles zinc in color and properties; but is more malleable and ductile. It may be drawn into wire or reduced to thin plates. It melts a little before red heat, and burns to a brown oxide, the only compound of cadmium and oxygen known. A combination of this metal with sulphur, which is not unfrequently found in a natural state, is of a beautiful yellow color (turning into orange), and has lately been employed in oil-painting.*

18. *Chromium.*

Chemical Equivalent = 28.

§ 224. Chromium is found only in an oxydized state, in the red ore of lead and in combination with iron, from which it is extracted by heat. It is of a greyish-white color, very brittle, but sparingly soluble in boiling nitro-muriatic acid, and combines with oxygen in three proportions, forming *protoxide of chromium*, *deutoxide of chromium*, and *chromic acid.*

The protoxide is a product of nature, and may be obtained by heating chromium in contact with air. It is a dark green powder, infusible, and insoluble in water; and is used in porcelain and oil-painting. *Deutoxide of Chromium* is produced by the action of sulphuric acid on chro-

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* An Italian painter by the name of Demin, employed it lately in a painting (Alfresco), and found it very applicable.

mic acid. It is a dark-brown powder of little lustre, which when heated gives off oxygen. *Chromic acid* is a product of nature. It is commonly found combined with lead, from which it is obtained by a somewhat difficult process. It is of a red color (when dissolved in water and distilled, it forms beautiful ruby-colored crystals), has a sharp, sour (rather astringent) taste, stains the skin yellow, and is dissolved in contact with the atmosphere, in water or alcohol.

19. *Molybdenum.*

Chemical Equivalent = 48.

§ 225. Molybdenum occurs only in small quantities, in combination with oxygen, sulphur and lead. It is commonly obtained by reduction of the heated oxide, through hydrogen gas. It is hard and brittle, and burns when heated in the air, to *Molybdic Acid.* It combines yet in two other proportions with oxygen forming an *oxide* and a *Molybdous acid.* No application is made of this metal or its binary compounds in the arts.

20. *Vanadium.*

Chemical Equivalent not ascertained.

§ 226. This metal was discovered (by Sesström) in 1830. It has been found in some of the ores of iron and lead, in Eckersholm in Sweden, and Ximapar in Mexico. The process of procuring it is tedious and difficult. It is obtained in white leaves of a strong metallic lustre. It is so brittle that it cannot be hammered, and does not become oxydized at common temperatures, neither in atmospheric air or in water. It is soluble in muriatic and nitro-muriatic acid, and combines in three different proportions with oxygen, forming two oxides and one acid. It enters also into combinations with sulphur and chlorine.

REVIEW OF THE 54 ELEMENTS TREATED OF IN THE THREE PRECEDING CHAPTERS.

Names of the Elements.	*Color.*	*Specific Gravity.**	*Discovered by*	*Aggregate Form.*
Oxygen	Colorless	1.103	Priestley, 1774	Gaseous (æriform)
Hydrogen	Colorless	0.069	Cavendish, 1776	Gaseous
Chlorine	Greenish yellow	2.422	Scheele, 1774	Gaseous
Nitrogen	Colorless	0.976	Rutherford, 1772	Gaseous
Carbon	Colorless or black	3.5	Known to the ancients	Solid
Sulphur	Yellow	1.98	Known to the ancients	Solid
Selenium	Color of lead or red	4.32	Berzelius, 1817	Solid
Phosphorus	Yellowish	1.77	Brandt, 1669	Solid
Boron	Brownish green (olive)	Not ascertain'd	Gay, Lussac, Thênard, Sir Humphrey Davy, 1809	A Powder
Iodine	Greyish black	4.946	Courtois, 1811	Solid
Bromine	When solid, *color of lead*, when liquid, *dark red*	2,966	Bâlard, 1826	At common temperature, *liquid ;* a few degrees below zero, *solid*
Silicon	Dark brown	Not ascertain'd	Berzelius, 1823	Solid
Fluorine is a hypothetical substance, supposed to be analogous to Bromine and Iodine.				
Potassium	White (tin color)	0.865	Sir Humphrey Davy, 1807	Soft, solid
Sodium	White (like silver)	0.934	Sir H. Davy, 1807	Soft, solid
Lithium	White	Not ascertain'd	Sir H. Davy, 1818	Solid

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* The Specific gravity of the gaseous Elements is determined in reference to *Atmospheric air* ; that of the solid elements in reference to distilled water. (See Natural Philosophy.)

Names of the Elements.	*Color.*	*Specific Grav'ty.*	*Discovered by*	*Aggregate Form.*
Calcium	White	Not ascertain'd	Sir H. Davy, 1808	Soft, solid
Barium	Grey	little heavier than concentr. sulphuric acid	Sir H. Davy, 1808	Solid!
Strontium	Grey	between 4 and 5	Sir H. Davy, 1808	Solid
Magnesium	White (like silver)	Not exactly ascertained	Bassy, 1828	Soft and Ductile
Glucinum	Dark grey	ditto	Wöhler, 1828	Powder
Yttrium	Greyish white	ditto	Wöhler, 1828	Scaly
Alumium	White (like tin)	ditto	Wöhler, 1827	Granular powder
Zircomium	Grey-black	ditto	Berzelius, 1823	Powder
Thorium	Greyish	ditto	Berzelius, 1828	Powder
Mercury	White (like tin)	13.568	Known to the ancients	Liquid
Silver	White	10.474	ditto	Hard but ductile
Gold	Yellow	19.25	ditto	Soft and most ductile
Platinum	White (like steel)	21.25	Wollaston, 1803	Very hard and ductile
Palladium	Greyish-white	11.3	Wollaston, 1803	Soft and ductile
Rhodium	White (like silver)	lit. more than 11	Wollaston, 1803	Hard and brittle
Iridium	Greyish-white	15.588	Tennant, 1803	Hard
Osmium	Greyish-blue	10	Tennant, 1830	Powder

Nickel	Almost like silver, a little more grey	8.279	Cronstädt, 1751	Hard but ductile
Iron	Greyish-black	7.78	Known to the ancients	Hard but malleable and ductile
Lead	Grey	11.325	ditto	Soft and ductile
Tin	White	7.291	ditto	Soft and ductile
Copper	Red	8.878	ditto	Hard and ductile
Zinc	Bluish-white	6.86	(supposed) Paracelsus, 1541	In its common state hard and brittle
Bismuth	Reddish-white	9.822	(supposed) Agricola, 1546	Very brittle
Cobalt	Greyish-white	8.71	Brandt, 1733	Half malleable and ductile
Antimony	Dusky-white	6.702	Valentinus, 16th century	Brittle
Arsenic	Grey (like steel)	5.96	Brandt, 1733	Very brittle (lamellar texture)
Manganese	Greyish-white	8.013	Gahn, 1774	Hard and very brittle
Tellurium	Greyish-white	6.115	Reichenstein, 1782	Lamellar texture and brittle
Titanium	Red (like copper)	5.	Klaproth, 1794	Very hard and brittle (lamellar texture)
Cerium	Chocolate color	not precisely ascertain'd	Berzelius and Heisinger, } in 1803	Powder
Uranium	Brown	9.	Klaproth 1789	Powder
Columbium	Greyish-black (like iron)	Not ascertain'd	Hatchet, 1801	Powder
Tungsten	Dark-grey	17.22	D'Elhuyart	Very hard and infusible
Cadmium	Greyish-white (like zinc)	8.6	Herrman and Stromeyer, } 1817	Malleable and ductile
Chromium	Greyish-white	5.9	Vauquelin & Klaproth, 1797	Hard and very brittle
Molybdenum	White (like silver)	8.6	Fljelm, 1782	Hard and brittle
Vanadium	White	Not ascertain'd	Sesström and Berzelius, } 1830	Very brittle

RECAPITULATION.

Questions for Reviewing the most important Principles contained in the Third Chapter.

1. QUESTIONS ON THE PRELIMINARY REMARKS ON METALS.

[§ 137.] Is it possible to fix with precision upon the general characteristics of metals? By what properties are they, notwithstanding, more or less distinguishable?

Are the metals commonly electro-*positive* or electro-*negative* bodies? Why?

[§ 138.] To what class of bodies do all metals belong, as far as our experience goes in chemistry? What is their number? What are their names?

[§ 139.] For what substance have all metals a greater or less affinity? Under what circumstances do they combine with oxygen?

What change is wrought upon most metals when they are exposed to air or to moisture? By what is this change occasioned? To what is the increase of weight proportional? Which metal, more than all others, attracts oxygen from the air and from moisture? What is the friable substance called, which collects on the surface of iron? How are metals prevented from rusting? What was Davy's proposition for preventing metals from rusting? Why are steel instruments kept in silver paper?

[§ 140.] Is oxygen the only substance with which metals combine? Into what other combinations do the metals yet enter? What are the products of these respective combinations called?

[§ 141.] What do you understand by *alloys of metals?* What by *amalgams?* What properties do the alloys of metals generally possess?

[§ 142.] What may be done with two metals possessing different degrees of fusibility? Why is fusion a means of refining ores?

[§ 143.] What are metals which easily melt capable of advancing in others? What process is founded upon this property of the metals? In what consists the process of *soldering*?

What solder is employed for tin ware?
What, for cast iron?
What, for copper and brass?
How is zinc soldered?
How, platinum?
How, gold?
What solder is used for silver?

[§ 144.] What other process of art is founded upon the natural attraction which exists between some of the metals?

Give examples.

[§ 145.] In what state are the metals generally found? What are they then called? Where do they occur? In what are they generally bedded? What are those substances called with which the metals are commonly found combined? What substance is most abundantly found combined with the metals? What is it therefore called? What are those metals called which occur in their simple form? Where is native gold and silver principally found?

[§ 146.] What is the process called by which the pure metal is extracted from the ore? What means are particularly resorted to for this purpose?

In what consists the *roasting* of ores?
In what the *smelting* of ores?
In what the *refining* of metals?

[§ 147.] What do the similar properties which some metals possess enable us to do?

To what class of metals belong *potassium*, *sodium*, *lithium*, *calcium*, *barium*, and *strontium*?

What is the name applied to the metals, *magnesium*, *yttrium*, *alumium*, *glucinum*, *zirconium*, and *thorium*?

What are the names of the nine *noble* metals?

What metals are most useful to man?

A. Questions on the six Alkaline Metals.

[§ 148.] What is the chemical equivalent of potassium? How may this metal be obtained?

How large a galvanic battery is required for the decomposition of hydrate of *potash*? Describe the process by which Thénard and Gay-Lussac decomposed hydrate of potash in a bent gun-barrel. (Explain Fig. CXII).

[§ 149.] What are the characterizing properties of potassium?

[§ 150.] In how many different proportions does potassium combine with oxygen? Which is the most remarkable of these combinations? What is its chemical composition? Where does it occur? How may it be obtained pure, by art?

How is the potash of commerce obtained? What does potash form when united with water? What substance does this hydrate form in combination with the fat oils?

[§ 151.] What are the properties of the *hydrate of potash*? How is it obtained?

[§ 152.] What is the name given to a solution of hydrate of potash? What are its properties?

[§ 153.] To what compound does potassium unite with chlorine? What is the chemical composition of chloride of potassium? Where is it found? How may it be produced by art? What are its properties?

What are the principal binary combinations of Potassium?

[§ 154.] What is the chemical equivalent of sodium? In what manner is sodium obtained? What are its properties? For what substance has sodium a strong affinity?

[§ 155.] What is the chemical composition of *soda*? In how many different proportions does sodium combine with oxygen? Where does protoxide of sodium, or soda occur? How is the purest soda obtained? What are its properties?

[§ 156.] What is the chemical composition of chloride of sodium, or common salt? Where does it occur? In what is it also largely contained? By what means may it be procured in its purest state? In what form does it crystalize? What does it constitute?

What are the principal binary combinations of Sodium?

[§ 157.] What is the chemical equivalent of lithium? How is lithium obtained? What are its properties? What is the chemical composition of the oxide of lithium, or *lithia*?

[§ 158.] What is the chemical equivalent of calcium? By what means is calcium obtained? What is the protoxide of calcium called? What is the chemical equivalent of lime? Where does it occur? How may it be obtained pure?

[§ 159.] What are the principal properties of lime? Why is lime said to be a *flux?* What is the taste of lime? Into what does it become converted by the process of *slaking*?

What are the principal uses of lime?

What substance does calcium form in combination with chlorine?

What are the two principal binary combinations of Calcium?

[§ 160.] What is the chemical equivalent of barium? By what process is barium produced? What are its properties? In how many different proportions does it combine with oxygen? What is the protoxide of barium called? What is its chemical composition?

[§ 161.] What are the leading properties of baryta? What are the properties of baryta-water?

What kind of substance is the per-oxide of barium?

With what other substances is barium known to combine?

What are the principal binary combinations of Barium?

[§ 162.] What is the chemical equivalent of strontium? How is it procured? What are its properties? In how many proportions does it combine with oxygen? In what state, and where is the protoxide of strontium, or strontia, generally found? What is its chemical composition? What are its properties? With what other substances does strontium yet combine?

What are the most remarkable binary combinations of Strontium?

B. QUESTIONS ON THE SIX EARTHY METALS, MAGNESIUM, YTTRIUM, ALUMIUM, GLUCINUM, ZIRCONIUM, AND THORIUM.

[§ 163.] Is the existence of the six earthy metals proved by actual experiment? Under what names were the oxides of these metals formerly known? What do the experiments which have been made upon them, together with the strong analogy which exists between them and the alkaline metals prove them to be? By what particular test are all of them distinguished? How do they all act upon the acids?

[§ 164.] What is the chemical equivalent of magnesium? By what means may magnesium be obtained?

Explain this process by galvanic electricity. Explain the process in which the metal is obtained from the chloride of magnesium.

What are the properties of magnesium, obtained by either of these processes? In how many proportions does it combine with oxygen? What is the compound called? What is its chemical composition?

[§ 165.] Where does the oxide of magnesium occur? From what substance is magnesia obtained for commerce? By what means is it obtained in its purest state?

What are the properties of magnesia?

What sort of substance is chloride of magnesium?

What are the principal binary combinations of Magnesium?

[§ 166.] What is the chemical equivalent of glucinum? How is this metal produced?

Explain the process.

By what sort of reasoning are we led to the inference that the dark colored globules which in your experiment appear disseminated throughout the whole mass, are actually the metal glucinum? What strong analogy does glucina bear to those substances which we *know* to be oxides of metals?

What are the properties of glucinum?

Where does the oxide of glucinum, or glucina occur? What sort of substance is it? What is its chemical equivalent supposed to be?

[§ 167.] What is the chemical equivalent of yttrium? How is this substance obtained?

What are its properties?

Where is the oxide of yttrium found? What is it called? By what peculiarity are all the salts of yttria distinguished?

[§ 168.] What is the chemical equivalent of alumium? What are its properties?

What is the chemical composition of alumia?

[§ 169.] Where does alumia occur? In what substances is it contained in its simple form? What are its properties? For what purposes is it used? With what substances does alumium yet combine?

What are the principal binary combinations of Alumium?

[§ 170.] By what means has zirconium been obtained in its simple form? What are its properties?

Where has the oxide of zirconium, or zirconia been found? What are its properties?

[§ 171.] By what means was thorium produced? What are its properties? Where is the oxide of thorium found?

C. QUESTIONS ON THE NINE NOBLE METALS, MERCURY, SILVER, GOLD, PLATINUM, PALLADIUM, RHODIUM, IRIDIUM, OSMIUM, AND NICKEL.

[§ 172.] What is the chemical equivalent of mercury? Where does mercury occur?

How is mercury obtained from the ore?

[§ 173.] What are the characterizing properties of mercury?

[§ 174.] What peculiar power does mercury possess? How is this property of mercury taken advantage of? What other application is made of the amalgams of gold? What application is made of the amalgam of silver? For what particular purpose is the amalgam of tin used?

[§ 175.] In how many different proportions does mercury combine with oxygen? What is the chemical composition of protoxide of mercury? By what means is it obtained? What is the composition of per-oxide of mercury?

[§ 176.] How is *per-oxide* of mercury obtained?

[§ 177.] In how many proportions does mercury combine with Chlorine? What is the composition of protochloride of mercury? By what name is this compound generally known?

[§ 178.] How is calomel obtained?

[§ 179.] How is per-chloride of mercury formed? How is corrosive sublimate prepared for medicinal purposes?

[§ 180.] What are the properties of corrosive sublimate?

[§ 181.] In how many different proportions does mercury unite with sulphur? What is the chemical composition of proto-sulphuret of mercury? How is it obtained?

[§ 182.] What is the chemical composition of bi-sulphuret of mercury? By what other name is this compound known? Is it a product of nature? How may it be produced by art? For what purposes is it employed?

What are the principal binary combinations of Mercury?

[§ 183.] What is the chemical equivalent of silver? and in what state found? Where is this metal principally found? What are its properties? With what substance is silver generally alloyed? What other metal does it often contain in minute quantities? For what purposes is it used?

[§ 184.] With what substances does silver combine? What are the names of the products thus formed?

What is the chemical composition of oxide of silver?

How is it obtained?

What is the chemical composition of chloride of silver? By what other name is this substance known? How is it formed? What are its properties?

For what purposes is a mixture of silver, chalk, and pearl-ash used?

What is the composition of sulphuret of silver? Where does this compound occur? What are its properties? For what is it used?

What are the principal binary combinations of Silver?

[§ 185.] What is the chemical equivalent of gold?

In what state is gold found? Where does it principally occur?

What are its properties? By what mixture of acids is gold operated upon? What, therefore, has this mixture been called?

By what means may gold be revived from a solution in nitro muriatic acid? What beautiful experiment may on this account be made with it? For what purpose is the etherial solution of gold used? How is it prepared?

[§ 186.] In how many different proportions does gold combine with oxygen? With what other substances does it yet combine?

What are the principal binary combinations of Gold ?

[§ 187.] What is the chemical equivalent of platinum ? Who first analyzed the ores of platinum ? What other substances (besides platinum) does the ore of platinum generally contain ? For what purposes is platinum used in Russia ? What are the properties of platinum ? With what substances does platinum unite ?

For what two purposes is platinum used in chemistry ? In what cases is it well adapted to the manufacture of crucibles ? How is the flameless or aphlogistic lamp constructed ? (Explain Fig. CXIII). How is this phenomenon explained ?

How is platinum-sponge prepared ? How does hydrogen gas act upon platinum-sponge ? Explain Prof. Döbereiner's apparatus for producing instantaneous light. (Explain Fig. CXIV).

[§ 188.] What is the chemical equivalent of palladium ? Where does it occur ? With what other substance is it found combined in Brazil ? What are its properties ? By what acids is it operated upon ? What are the properties of sulphuret of palladium ?

[§ 189.] What are the properties of rhodium ?

How is the oxide of rhodium obtained ? What are its properties ?

[§ 190.] What is the chemical equivalent of iridium ? Where is it found ? What are its properties ?

[§ 191.] What is the chemical equivalent of osmium ? How is this metal obtained ? What are its properties ?

[§ 192.] What is the equivalent number of nickel ?

With what substances is nickel generally united ? By what name is the latter of these combinations known in commerce ? What are the properties of nickel ? How is it acted upon by the magnet ? Into what does it become converted when heated ?

D. QUESTIONS ON THE REMAINING METALS, IRON, TIN, LEAD, COPPER, ZINC, BISMUTH, COBALT, ANTIMONY, ARSENIC, MANGANESE, TELLURIUM, TITANIUM, CERIUM, URANIUM, COLUMBIUM, TUNGSTEN, CADMIUM, CHROMIUM, MOLYBDENUM, AND VANADIUM.

[§ 193.] What is the chemical equivalent of iron? In what state is iron generally found? What are its properties.

What sort of ore is the native magnet? In what state does it occur? What are its chemical properties?

[§ 194.] In how many proportions does iron combine with oxygen? What is the chemical equivalent of protoxide of iron?

What, that of the per-oxide of iron?

How is the per-oxide of iron obtained? What are its properties? How is the protoxide obtained? What are its properties? How is the black oxide of iron formed? What sort of compound is it?

[§ 195.] In how many proportions does iron combine with chlorine? What are the names of the compounds? What, their composition? How is proto-chloride of iron produced? What are its properties? How is per-chloride of iron obtained? What are its properties?

[§ 196.] What sort of product are the sulphurets of iron? By what name is the *bi-sulphuret* known? Of what color is it; and in what state is it found? How may the proto-sulphuret of iron be produced?

What is the chemical composition of proto-sulphuret of iron? What, that of the bi-sulphuret?

[§ 197.] In what manner is steel formed? What peculiar properties does it possess in a higher degree than iron? What process must steel undergo in order to become adapted to the different uses for which it is destined? In what does the process of tempering consist?

What are the principal binary combinations of iron ?

[§ 198.] What is the chemical equivalent of lead ? What are the principal properties of lead ? For what purposes is it extensively used ?

[§ 199.] In how many different proportions does lead combine with oxygen ? What are the names of the products ? What is the chemical composition of the sub-oxide of lead ? What, that of the protoxide ? What, that of the deutoxide ? What, that of the per-oxide ?

By what means may all these oxides be obtained ? What peculiar property do they possess ? For what purpose, therefore, are they used ?

Explain the process of cupellation.

How is the protoxide of lead (or massicot of commerce) obtained ? What is this substance called when partially melted ?

By what name is the deutoxide of lead known in commerce ? What are its properties ?

How is chloride of lead produced ? What are its properties ? What is its chemical composition ?

What sort of product is the sulphuret of lead ? What kind of ore does it constitute ?

What are the principal binary combinations of Lead ?

[§ 200.] What is the chemical equivalent of tin ? To whom was this metal already known ? In what state does it commonly occur ? What are its properties in a pure state ?

[§ 201.] In how many different proportions does tin combine with oxygen ? What is the chemical composition of the protoxide of tin ? What that of the per-oxide ? How may both products be obtained ?

What becomes of tin, when fused, and in this state for a long time exposed to the atmosphere ? What becomes of the protoxide when again exposed to heat in contact with air ?

What are the properties of the per-oxide of tin ? For what purposes are the oxides of tin used ?

How are proto-chloride and per-chloride of tin obtained ? What are the properties of the proto-chloride ? What, those of the per-chloride ?

What is the chemical composition of proto-chloride of tin? What is the chemical composition of the per-chloride?

[§ 202.] How are the two sulphurets of tin produced? What are their properties?

What are the principal binary combinations of Tin?

[§ 203.] What is the chemical equivalent of copper? How long is it since this metal has been wrought? In what state is it found? With what substances is it commonly connected? What are its properties? For what purposes is it used? In what consists one of its chief applications?

[§ 204.] In how many proportions does copper combine with oxygen? Of what color is the protoxide? Of what the deutoxide? What is the chemical composition of these substances?

[§ 205.] How is proto-chloride and per-chloride of copper obtained? What are the properties of the proto-chloride? What those of the per-chloride? What property does per-chloride of copper communicate to spirits of wine in which it is dissolved?

What is the chemical composition of proto-chloride of copper? What is the chemical composition of the per-chloride?

What products are the sulphurets of copper? Where does the proto-sulphuret of copper occur?

What are the most important binary combinations of Copper?

[§ 206.] What is the chemical equivalent of zinc? In what state is zinc found? What are its properties? How is zinc acted upon by heat?

[§ 207.] How are the oxides and chlorides of zinc formed?

What are the properties of the oxide of zinc? What those of chloride? What is the chemical equivalent of oxide of zinc? What that of the chloride?

[§ 208.] What is the chemical equivalent of bismuth?

Where does this metal occur? What are its properties? For what purposes is it used? What are its principal binary combinations?

[§ 209.] With what substances is cobalt generally found combined? What are the properties of pure cobalt? How are the oxides of this metal obtained? Under what name do they occur in commerce? For what purposes are they used?

[§ 210.] What is the chemical equivalent of antimony? Where does it occur? What are its properties? For what purposes is it used?

[§ 211.] In how many different proportions does antimony combine with oxygen? What is the chemical composition of the protoxide? How may it be obtained? What are its properties?

How may the deutoxide be obtained? What are its properties? What is the chemical composition of per-oxide of antimony? By what means is it formed? What are its properties?

How is the *Proto-chloride* or *butter* of antimony obtained? What are its properties? With what other substances does cobalt yet combine?

What are the principal binary combinations of Antimony?

[§ 212.] What is the chemical equivalent of arsenic? By whom was arsenic first obtained? Where does it occur? What are its properties?

[§ 213.] In how many proportions does arsenic combine with oxygen? What sort of compound is oxide of arsenic? What are its properties? What is the chemical composition of arsenious acid? What are its properties? For what purposes may it be used?

What is the composition of arsenic acid?

Where does it occur? How may it be obtained by art?

[§ 214.] What is a combination of arsenic with hydrogen called? What are its properties?

Under what name does the sulphuret of arsenic occur in commerce? For what is it used?

What are the principal binary combinations of Arsenic?

[§ 215.] What is the chemical equivalent of manganese? Where does manganese occur? What are its properties?

[§ 216.] In how many proportions does manganese combine with oxygen? For what purposes is the per-oxide used? Where does the chloride of manganese occur?

What are the principal combinations of manganese?

[§ 217.] What is the chemical equivalent of tellurium? Where does this metal occur? What peculiar property has it, among the metals?

[§ 218.] In what state does titanium occur? What are its properties?

[§ 219.] What is the chemical equivalent of cerium? Where does it occur? What are its properties?

[§ 220.] How is Uranium obtained? What are its properties? In how many proportions does it combine with oxygen?

[§ 221.] What is the chemical equivalent of columbium? By whom was it discovered? In what? What are its properties? In how many proportions does it combine with oxygen?

[§ 222.] What is the chemical equivalent of tungsten? Where does it occur? What are its properties? In how many different proportions does it combine with oxygen?

[§ 223.] What is the equivalent number of cadmium? By what means is this metal obtained? What metal does it resemble in color and properties? What are its other properties? What combination of this metal has lately been employed in oil-painting?

[§ 224.] What is the chemical equivalent of chromium?

In what state is this metal found? What are its properties? In how many different proportions does it combine with oxygen? How may the protoxide be obtained? What are its properties? How is the deutoxide produced? What are its properties? What sort of product is chromic acid? What are its properties?

[§ 225.] Where does molybdenum occur? How is it obtained? What are its properties?

[§ 226.] By whom was vanadium first discovered? Where has it been found? What are its properties? In how many proportions does it combine with oxygen?

CHAPTER IV.

OF THE QUARTERNARY COMBINATIONS OF BODIES, OR SALTS.

General Remarks on the Acids.

§ 227. The general characteristics of those binary compounds (combination of one element with another) called *acids,* have already been enumerated in the introduction, page 38. It will be well now to draw a few general inferences from the properties of these substances, as far as we have become acquainted with them in the three preceding chapters.

Among the different elements, oxygen and hydrogen are by far the most powerful agents in nature. They enter into almost every composition of organic or inorganized matter; and although marked by the most distinguishing properties which can possibly designate two heterogeneous bodies, the product of their union—*water*—is the most indifferent (neutral) substance known; and so perfect and compact is this compound, that it occupies less than one two thousandth part of the volume which its two constituent gases (hydrogen and oxygen) occupy before their combination (Chap. I, § 27). But although oxygen and hydrogen are capable of thus neutralizing *each other*, their relation *to other substances* is quite different. For it may be said that all bodies, in relation to these two are merely passive, and receive as it were their characterizing properties from the proportion in which they combine with either oxygen or hydrogen.

As an instance we may take the different properties of the combinations of nitrogen with oxygen (see Chap. I, § 46,) which seem solely to depend on the proportion in which the latter substance combines with the former. And so entirely are the original characteristics of nitrogen changed by its union with oxygen, that 4 volumes of it, mixed with 1 volume of oxygen, form a respirable gas, eminently calculated to support animal life, while a combination of one volume of nitrogen with five volumes of oxygen, constitutes a body in the highest degree destructive to all organic formation.

§ 228. The most remarkable products obtained by the combination of oxygen and hydrogen with other substances, are the *acids*. The body which in combination with oxygen or hydrogen forms an acid, is called the *radical*, and the oxygen or hydrogen with which it unites is termed the *acidifying principle*. Thus, in nitric acid (see § 56), oxygen is the acidifying principle; but in *muriatic acid* and prussic acid it is *hydrogen*.

It is here important to observe that every acid may be considered as the union of an *electro-positive* with an *electro negative body**; the radical being always the electro-*positive*, and the acidifying principle the electro-*negative* factor.

It was formerly believed that oxygen was the acidifying ingredient of every acid, but the discovery of the acidifying qualities of hydrogen has sufficiently corrected that error. (Compare the note at the bottom of this page).

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* The ancient divisions of bodies into *acidifying substances* or *supporters of combustion*, and such as are capable of being *acidified* or *burnt (combustibles)*, is vague and no longer applicable. For it has been proved that one and the same substance may in one instance be capable of *combustion* with oxygen, and in another be the *acidifying* principle in combination with a different substance.

To give an example: *Hydrogen* combines with oxygen to combustion, the product being *water* (see Chap. I, § 23), while on the other hand it communicates the acid qualities to muriatic, iodic, and fluoric acid (§ 67, § 124, § 133). Thus, hydrogen would belong to both the *combustible* and the *acidifying* substances. There are, moreover, but few substances, besides oxygen, capable of supporting combustion (only a small number of bodies burn in chlorine, iodine, and fluorine). All ordinary processes of combustion result from a combination of oxygen with a combustible basis; and most acids are supporters of combustion only by virtue of the greater or less quantity of oxygen which enters into their composition.

§ 229. Those acids in which hydrogen enters as the acidifying principle, are called *hydro acids.* To these belong

The *Muriatic acid,* composed of chlorine and hydrogen (see Chap. I, § 67).

The *Hydro-bromic acid,* composed of bromine and hydrogen (see Chap. II, § 129).

The *Hidriotic acid,* composed of iodine and hydrogen (see Chap. II, § 125).

The *Hydro-fluoric acid,* composed of fluorine and hydrogen (see Chap. II, § 134).

The *Sulphureted hydrogen,* composed of sulphur and hydrogen (see Chap. II, § 106).

The *Hydro-cyanic,* or *prussic acid,* composed of cyanogen and hydrogen (see Chap. II, § 90).

Many other acids, however, require water (consequently also hydrogen, which is an ingredient of water) for their solid or *liquid* form. These acids are termed *hydrates,* and have likewise the word *'hydro'* prefixed to their names. Thus, we speak of *hydro-nitric acid, hydro-sulphuric acid,* &c. Those acids in which water does not enter as an essential ingredient are called *an-hydrous.* (Compare the remark § 58, page 99).

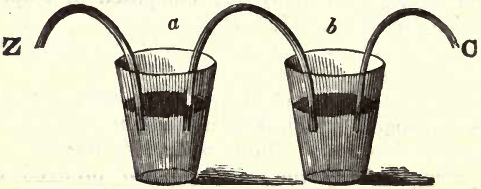
§ 230. The acids combined with those substances called *bases* (see Intro. page 38) form a new class of bodies designated by the name of *salts. A salt, therefore, is a combination of a basis with an acid.*

When a salt is again decomposed by the almost universal agency of galvanic electricity, the acid adheres invariably to the positive pole, while the basis is attracted by the negative pole of the battery. Hence from the law of electricity we may infer *that the acids are electro-negative, and the bases electro-positive substances.*

This is a remark we have already had occasion to make in the Introduction, pages 38 and 39, where we have stated that galvanic electricity is by far the best criterion of an acid or a basis. Neither the sour taste nor the changing of vegetable colors can be relied upon as infallible characteristics.

We have already stated in the Introduction that some chemists of distinction, at the suggestion of Sir Humphrey Davy, are inclined to believe that all chemical phenomena are the result of electrical attractions, either in the same or in opposite directions. This theory has lately been supported by some of the most distinguished English chemists, and is indeed so strongly corroborated by facts that it must at least be considered an ingenious hypothesis, which in course of time may perhaps arrive at greater perfection. We will now only mention a few facts attending the decomposition of salts by galvanic electricity, which are in themselves highly interesting, and may serve to explain why the *bases* are called electro-positive, and the *acids* electro-negative bodies.

Fig. CXV.



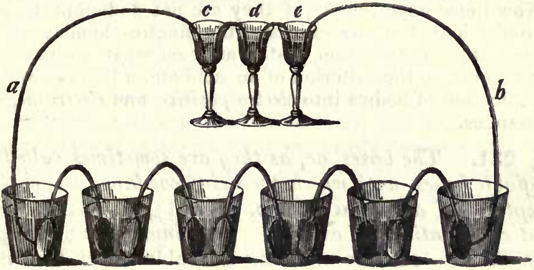
Experiment I. When a solution of a salt is made in water, and placed in two cups, *a* and *b*, of which one is connected with the positive or zinc pole, and the other with the negative or copper pole of a galvanic battery, and a communication is established between the two cups by a wet conductor (which may be a piece of cotton or some other moistened substance); then after the battery has been for some time in motion, the acid of which the salt is composed will pass into the cup connected with the positive or zinc pole and the basis will be transferred to the cup which is connected with the negative, or copper pole — so that after some time the solution in the cup *a*, will have acquired a *sour* taste, and that in the cup *b*, will taste alkaline.

Now this phenomenon is easily accounted for by the electric attraction of the battery. The salt which, as we have said, is always a compound of an acid with a basis, is by the opposite electric attraction of the battery decomposed into its two constituent principles; because the positive pole of the battery attracts the acid, and the negative pole the basis, more strongly than these substances attract each other; their combinatory attraction therefore is overcome or destroyed, which enables each of them to follow the impulse received by the attractive force of electricity, and it is on this account, the acid, which is the electro-negative substance, collects (by the law of opposite attraction, Natural Philosophy, Chap. X) in the cup near the negative pole, and the alkali, or basis, passes over into the cup connected with the positive pole, because it is an *electro-negative* body.

A still more striking instance, showing the decomposing power of galvanic electricity, is the following

Experiment II. Place a saline solution in the middle cup *d*,

Fig. CXVI.



and pure water in the two cups *c* and *e*. Connect the water in the cups *c* and *e*, respectively with the positive and negative poles of the battery, and establish a direct communication between the three cups *c*, *d*, *e*, as in the last experiment, by means of some wet conductor. After the battery has for some time been in motion, the saline solution contained in the cup *d*, will not only be decomposed, but will absolutely have disappeared from this cup — the acid being transferred to the cup *c*, connected with the positive pole, and the alkaline basis to the cup *e*, connected with the negative pole of the battery, while the liquid in the cup *d*, will have acquired a pure taste, like water.

We see from this expperiment that the attractive force of galvanic electricity has not only the power of decomposing a saline solution, but is actually capable of acting through the medium of another substance. But what is still more surprising, it is even capable of suspending the laws of affinity which one body has for another, as is proved by the following fact.

If in the last experiment a solution of sulphate of soda is put in the cup connected with the negative or copper pole, and in the other two an infuson of red cabbage, (which is a strong test of the presence of an acid, because most acids change its color), then after the galvanic battery has been for some time in motion, the sulphate of soda becomes decomposed, and the sulphuric acid of which it is composed is transferred to the cup which is connected with the positive pole of the battery, without changing in the least degree the color of the infusion in the middle cup, through which it is obliged to pass. If the middle cup is filled with an alkaline solution, the acid is still transferred to the positive pole of the battery, without combining in the least with it, and in the same manner may an alkaline solution be transferred through an acid.

Now these experiments, if they are not sufficient to *prove* beyond a doubt the correctness of the electro-chemical theory, given in the introduction, justify at least what we have said in reference to the criterion of an acid and a basis — and the classification of bodies into *electro-positive* and *electro-negative* substances.

§ 231. *The bases, or, as they are sometimes called, the salifiable bases, with which the acids combine, are, with the exception of ammonia* (Chap. I, § 61), *all* OXIDES, *or at least combinations of oxygen.* Both *inorganic* and *organic bodies* are capable of being salifiable bases, that is, or to combine with the acids to salts.

They are therefore divided into

I. Bases from the Mineral Kingdom.

A. Soluble in water.		B. Insoluble in water.	
a. Easily soluble.	*b. Not easily soluble.*	*a. Earths.*	*b. The remaining* METALLIC *bases.*
Potash,	Baryta,	Alumine,	
Soda,	Strontia,	Berillia,	
Lythia,	Lime,	Yttria,	
Ammonia,	Magnesia,	Zirconia,	
		Thoria.	

II. Organic Bases.

A. Vegetable Bases. B. Animal Bases.

The different properties of these bases, with the exception of those from the animal and vegetable kingdoms (which will be treated of in animal and vegetable chemistry, (see Chapters V, and VI), have already been described in the preceding sections.

Remark. Since all the bases here enumerated are already binary combinations of an element with oxygen, and the acids with which they combine are likewise composed of *two* principles, it follows that we may consider a salt as a combination of *two binary* compounds — or, which is the same, as a *Quarternary compound.*

Nomenclature of Salts.

§ 232. Each of the acids we have become acquainted with in the preceding chapter, is capable of uniting with all the bases just enumerated ; each, therefore, forms a distinct class of salts, which is generally denominated after the acid which enters into its composition. The way in which this is done is easily understood : The termination of the acid ending in *ic* is changed into *ate;* that which ends in *ous* into *ite;* to which is added the name of the base, in the genitive case. Thus, the salts which are formed by the combination of sulphur*ic* acid with the different salifiable bases, are called sulph*ates;* those in which sulphur*ous* acid is an ingredient are called sulph*ites;* and so of the rest. Now if, for example, we wished to denote the salt arising from the combination of sulphur*ic* acid with *soda,* we should call it sulph*ate of soda;* if we wished to denote the salt in which sulphur*ous* acid is united with ammonia, we say sulph*ite of ammonia,* &c.

This nomenclature of the salts is of immense advantage to the memory, and infinitely preferable to the arbitrary names by which they were formerly designated. Thus, instead of *Glauber's salts, butter of antimony,* &c, we say now *sulphate of soda, muriate of antimony,* &c, by which appellations we cannot but recollect their constituent principles, viz.: *sulphuric acid* and *soda, muriatic acid* and *antimony,* &c.

It will therefore be unnecessary to describe the elementary ingredients of the salts, as their appellations sufficiently indicate their composition.

Neutral, sour, and basic Salts.

§ 233. The salts have yet been divided into *neutral, sour,* and *basic* salts. By a neutral salt is meant one in which the properties of the acid and the base of which it consists are neutralized; *sour* are those salts in which the acid properties are prevalent; and *basic* those in which the properties of the basis are yet distinguishable.

Decrepitation of salts.

§ 234. All salts which are obtained from crystals, contain a certain proportion of water either *mechanically* entangled — in which case it is called *water of crystalization* — or chemically combined — as an essential principle to their formation. Those which contain water *mechanically* entangled, easily *decrepitate*, that is, fly off in small particles when thrown into fire. This is owing to the expansion of steam, into which their water of crystalization is converted by exposure to heat. Those salts in which water is a *chemical* constituent hardly ever decrepitate.

Phenomena of efflorescence and deliquescence.

§ 235. Some salts lose their water either at common temperatures of the atmosphere, in which case they become a shapeless powder, and are said to *effloresce*, or they *absorb* moisture from the atmosphere, and melt, which process is called that of *deliquescence*. But there are others which may be melted in a strong *heat*, without being decomposed; and there are salts which melt in their own water, when its solving power is increased by heat. The first process is called *igneous fusion;* the second is termed *aqueous fusion.*

Crystalography.

Before entering on the description of the chemical properties of salts, we must here mention some highly interesting peculiarities in their chemical conformations which were first noticed by Haüy, a celebrated French philosopher, and have since occupied much of the time and researches of many distinguished chemists.

We have already stated (in the first chapter of Nat. Phil.) that whenever a body passes from the liquid to the solid state, or, in other words, whenever a body from a state of solution is converted into a solid, so that its particles are capable of following their own mutual attractions, they arrange themselves in regular mathematical forms, in which state they are called *crystals.* These crystals are of various shapes, according to the different substances of which they are formed, and it even happens that the crystals of one and the same substance are capable of assuming different geometrical forms. Now it was reserved for Haüy first to show by a series of the most beautiful experiments, that all crystals are more easily divided in certain directions than in others, so that if a portion be cut off in one of these directions, the surface will be perfectly smooth and regular, whereas, in every other direction we obtain a rough surface or a common fracture. By continuing the division of a crystal, following always the direction in which it is most readily divided, and presents a regular, smooth surface, Haüy finally arrived at certain geometrical forms, which were then no longer divisible without fracture. This geometrical form, which is, as it were, the nucleus of the crystal, he called the *primitive form of the crystal*, and the shape which it had before the division he called the *secondary form.*

By a long and painful investigation of a great variety of crystals he found that their primitive forms were all reducible to six regular, geometrical solids, which are,

1st. The *parallelopiped*, which form includes *the cube* (Fig. CXVII), the *four-sided prism* (Fig. CXVIII), and the *rhomboid* — three solids which are bounded by six quadrilateral faces.

Fig. CXVII.

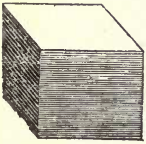


Fig. CXVIII.

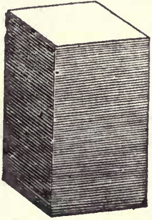
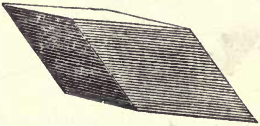
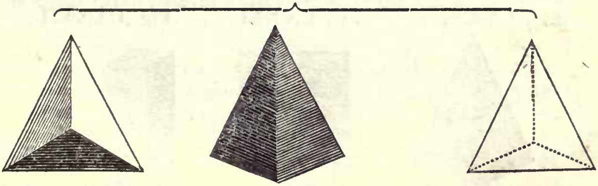


Fig. CXIX.



2d. The *tedrahedron*, of which three different views are given in Fig. CXX, and which is bounded by four triangular surfaces

Fig. CXX.



3d. The *octahedron*, of which two differest views (in outline, and shaded) are given in Fig. CXXI, bounded by eight triangular sides, or which may also be conceived as formed by joining the bases of two triangular pyramids.

Fig. CXXI.

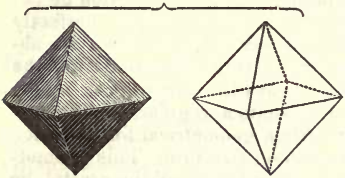
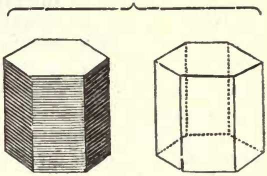


Fig. CXXII.



4th. The *six-sided* prism, represented in Fig. CXII, bounded by six parallelograms, and two parallel bases.

5th. The *rhombic dodecahedron*, represented in Fig. CXXIII, bounded by twelve rhomboidical surfaces, and

Fig. CXXIII.

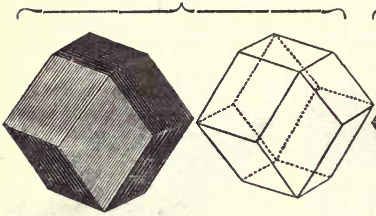
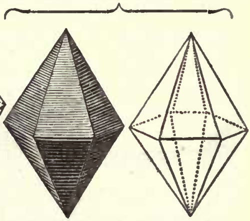


Fig. CXXIV.



6th. The dodecahedron, represented in Fig. CXXIV, which is a solid, bounded by twelve triangles, and which may be conceived to be formed by the junction of the bases of two six-sided pyramids.

These six forms being not so simple as we might expect from a pure *mathematical* investigation of their formation, it is highly probable that the more complicated of them are themselves composed of the more simple ones, which, according to the

Fig. CXXV.

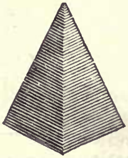


Fig. CXXVI.

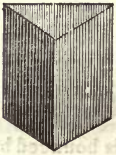
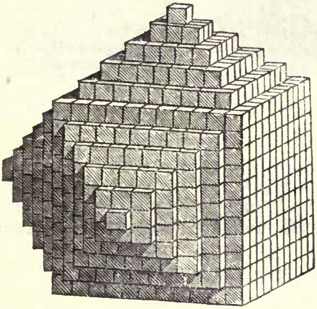


Fig. CXXVII.

opinion of some philosophers, are the tedahedron (Fig. CXXV), the triangular prism (Fig. CXXVI), and the *parallelopiped* (Fig. CXVII), because it may be proved mathematically that the six primitive forms may be produced by a proper combination of these three. On this account the three solids which we have just named, are called *integrant molecules*, because they are conceived to be the constituent geometrical forms from which the secondary shape and even the primitive forms of all crystals are derived.

As an example we will only mention the six-sided prism, or in fact any prism whatever, which may evidently be divided into as many triangular prisms as it has sides, by drawing from all the corners straight lines to the centre of the bases and passing planes in the direction of these lines; and the rhombic dodecahedron, which it is easily perceived may be formed by integrant cubes, as represented in the figure, by placing rows of them upon all the sides of the cubical nucleus, making each row recede one step further, until regular pyramids are formed, of which two and two form a rhombical surface. (This is shown in the figure, which is taken from Haüy's Philosophy, plate II, fig. 12.) Three sides of the cubic nucleus are purposely left remaining to exhibit the gradual formation of a rhombic surface upon two contiguous sides.

Fig. CXXVIII.



This theory, however ingenious, does not quite satisfy the demands of strict mathematical reasoning. The secondary form of some crystals, particularly, cannot very well be accounted for on the supposition that they are formed by the piling upon one another of the integrant molecules, although the objections made against it by some philosophers, that the molecules would in this case have spaces between them, can be but of little avail; because there is no geometrical figure that the molecules could possibly assume, which would not be more or less objectionable on this account. To wave these objections, Dr Wollaston, one of the most ingenious philosophers of the present age, has improved the theory of integrant molecules, by showing the possibility of constructing both, the primitive and secondary forms of crystals, by means of small integrant spheres, as may be seen from the adjoining figures.

Fig. CXXIX.

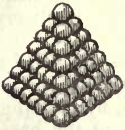


Fig. CXXX.

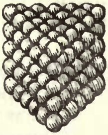


Fig. CXXXI.

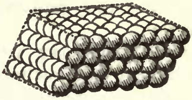


Fig. CXXXII.

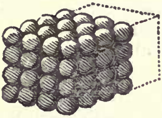


Fig. CXXXIII.

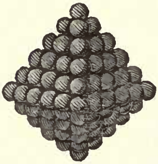
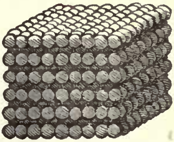


Fig. CXXXIV.



He supposes the intergant molecules of crystals to be spheres, and the six *primitive* and all *secondary* forms of bodies, produced by the piling upon one another of these spheres. This theory is in many respects superior to Haüy's, and although, as yet, far from being satisfactorily demonstrated, deserves to be preferred to Haüy's for the following reasons:

1. On account of its greater simplicity (adopting but *one* from for all integrant molecules).

2. Because it seems to agree better with the general laws of nature — the spherical form being the most perfect of all, containing (as may be proved mathematically) the greatest quantity of matter, or space, bounded by the smallest surface; and it being the form which all bodies in nature *spontaneously* assume, when solely acted upon by the cohesive attraction of their particles.

3. Because all crystals are formed by bodies passing spontaneously from the liquid into the solid state; and it is therefore highly probable that the particles will adopt that arrangement which is most natural. Moreover, it can be proved geometrically, that if they are solely impelled by their *gravitation towards each other*, they must arrange themselves round

their common centre of gravity, and consequently form spheres.

Whichever theory we adopt, we must not forget that it is but an ingenious hypothesis, which, although serving our imagination, is as yet far from being established by actual experiment; and it is more than probable that we shall never be able to lift the veil with which nature covers all her works. We can only worship and wonder at the simplicity of the means which she adopts to produce the greatest ends; but of her secret operations we know nothing, either in this or any other of the natural sciences.

We shall now proceed to describe the composition and principal properties of those salts which are useful in common life, and of some application in the arts. A *comprehensive treatise* on this subject would fill volumes, and far exceed the limits proposed in a work of an elementary nature.

§ 236. The principal salts obtained from the combination of the acids with the different salifiable bases, are, according to the nomenclature, explained in § 232, the *Nitrates*, *Chlorates*, *Chlorides*, *Muriates (chlorides)*, *Sulphates*, *Carbonates*, *Phosphates*, *Chromates*, *Arseniates*, *Cyannites*, and *Fulminates*.

A. NITRATES.

§ 237. *Properties of the Nitrates.* The combinations of nitric acid with the various salifiable bases gives rise to a class of salts extensively used in the arts. The general properties by which they are distinguishable *as a class*, are the following:

1. They are all decomposed by heat.
2. They are acted upon by all simple combustible substances.
3. They decompose the fixed acids.
4. They are soluble in water.

1. *Nitrate of Potash (Nitre, Saltpetre).*

Chemical Composition: 1 equiv. of nitric acid = 54
1 equiv. of oxide of potassium, or potash = 48

Consequently, chem. equiv. of nitrate of potash = 102.

§ 238. This salt occurs in nature in the mineral and vegetable kingdoms. It collects on damp walls, in subterraneous places, in cellars, dirty lanes, and wherever lime, potash, or decayed animal substances abound. It is also obtained by neutralizing nitric acid with potash.

The nitre which occurs in commerce and which is used in the manufacture of gunpowder, is obtained by throwing in heaps the remains of decayed vegetable matter. Nitric acid is by this means spontaneously generated by the decomposition of these substances, which as we shall see hereafter, are principally composed of nitrogen. Such heaps are called *nitre-beds.* They must from time to time be sprinkled with water, when after remaining in this state for several months, nitre will be formed, in combination with nitrate of lime and of magnesia. From these, and the earth with which it is mixed, it is freed by dissolving it in water, and adding to the solution a small quantity of potash, which decomposes the nitrates of lime and magnesia, and leaves the nitrate of potash pure. The solution is afterwards evaporated and the nitre obtained in crystals.

This mode of treating nitre is much resorted to in France and particularly in Germany, for the manufacture of gunpowder; but in England and this country nitre is imported from the East Indies, where it is found already formed in a state of efflorescence, particularly after heavy rains.

§ 239. *Properties of Nitre.* It has a bitter (somewhat sour,) cooling taste, is perfectly inodorous, becomes liquid by *igneous* fusion (§ 236), at a red heat, and becomes decomposed at a still higher degree of temperature (its acid being reduced to its elements, oxygen and nitrogen). It crystalizes in 6 sided prisms. When mixed with common salt (Chloride of soda) it becomes partly decomposed, and nitrate of soda and chloride of potassium are formed. Thrown upon red coals, it promotes their combustion by giving off oxygen. A mixture of sulphur and nitre thrown into a red hot crucible will immediately burn with a vivid light. A mixture of phosphorus and nitre may be inflamed by the stroke of a hammer, with great detonation.

Uses of Saltpetre. Nitre, or saltpetre is used principally,

1. In the preparation of fulminating powder.
2. In the manufactory of gunpowder.
3. In the manufactory of sulphuric acid.
4. In the manufactory of glass.
5. In medicine.
6. In domestic economy (for corning beef and preserving grain).

Three parts of nitre, two of potash, and one of sulphur, when mixed together and heated, explode with a loud noise, on account of the great quantity of nitrogen which is suddenly given off. Hence the name *fulminating* powder.

§ 240. *Gunpowder.* The most remarkable application of nitre is in the manufactory of *gunpowder.* This is a mixture of *nitre, charcoal,* and *sulphur.* The proportions of these ingredients vary according to the purpose for which the powder is to be used. It consists generally of five parts of nitre, one part of sulphur, and one of charcoal. These are moistened and finely powdered, either by wooden pestles, or, in modern times, by marble rollers, and the paste thus obtained is then granulated and dried.

Table exhibiting different sorts of Powder.

	INGREDIENTS.		
	nitre,	*sulphur,*	*charcoal.*
Prussian military powder,	75	11.5	13.5
French and English,	75	12.5	12.5
English Dartfort,	79.7	7.82	12.48
Swedish,	76	9	16
Austrian musket powder,	72	16	17

Properties of good powder. It must have a bluish slate-color (a dark or black color shows too great a proportion of charcoal, or dampness). The grains must be round and even, and not too readily crumble between the fingers. When ignited, the *whole* must be quickly inflamed, without a crackling noise, and without singing the surface on which it is placed. A yellow or black residue after combustion is a proof of too great a proportion of sulphur or charcoal, and a crackling noise during combustion shows that the powder is either damp or that there are other salts mixed with the nitre. In order that gunpowder shall retain its qualities, it must be protected from dampness. For this purpose it is best kept in leather bags.

Gunpowder ignites at a temperature of 419° Fahrenheit, and its subsequent expansion and propelling power is owing to a prodigious quantity of *nitrogen, carbureted hydrogen,* and sulphurous acid gas in connection with a large proportion of steam, which are given off instantaneously during its combustion. The use and effect of powder are sufficiently known.

The powder contained in the cartridges of common fire-arms is never wholly ignited; part of it is always expelled without adding to the effect of the piece. By the use of percussion-caps (see Fulminates) a more powerful stream of fire is created, in consequence of which the powder ignites more thoroughly, and it has been found upon experiment that a percussion-gun produces the same effect with only four fifths of the quantity of powder which is needed for the charge of a musket with a common lock.

2. *Nitrate of Soda.*

Chemical Composition: 1 equiv. of nitric acid = 54
1 equiv. of soda (oxide of sodium) = 32

Consequently, chemical equiv. of nitrate of soda = 86

§ 241. *Nitrate of soda*, also under the name of *cubic nitre,* is found among native nitre in Spain, India, and America, particularly in Peru, where layers of more than two miles in length have lately been discovered. It may also be produced artificially by saturating *nitric acid* with *soda.* Its taste is cooling, pungent, and bitter, though less so than that of nitrate of potash. It burns with an orange-colored light, three times slower than powder, wherefore it is used in fire-works. (Pyro-technia).

3. *Nitrate of Ammonia.*

Chemical Composition: 1 equiv. of nitric acid = 54
1 do. of ammonia = 17
to which is added 1 do. of water = 9

Consequently, chem. equiv. of nitrate of ammonia = 80.

§ 242. This is a salt produced by dropping a solution of ammonia into dilute sulphuric acid. It crystalizes in needles (four or six sided prisms) which have a lustre like silk. They are colorless, have a bitter, cooling, pungent taste, attract easily moisture from the atmosphere, explode when thrown on burning coals, and produce great cold when dissolved in water. There is but little or no use made of this salt in the arts.

4. *Nitrate of Lime.*

Chemical Composition: 1 equiv. of nitric acid = 54
1 do. of lime = 28

Consequently, chemical equiv. of nitrate of lead = 82.

§ 243. *Nitrate of lime* occurs in small quantities in well and pump water, and among the nitre which collects on walls or on the surface of the earth. It is also produced by dissolving a salt called carbonate of lime in nitric acid (the lime combining with the nitric acid and the carbonic acid being set free). It crystalizes in colorless, six-sided prisms, attracts moisture from the air, and deliquesces (see § 235). It is dissolved by one fourth its weight of cold water, (in warm water it melts sooner) and by equal parts of hot alcohol. Its taste is bitter, sharp and cooling. When heated, it gives off oxygen gas, and the residue emitting in the dark a white, beautiful light, is known by the name of Baldwin's Phosphorus. It detonates weakly when thrown on burning coals, and is chiefly used in the preparation of saltpetre.

5. *Proto-nitrate and Per-nitrate of Mercury.*

Chemical Composition. Proto-nitrate of mercury is composed of 1 equivalent of nitric acid = 54
1 equivalent of protoxide of mercury = 208

Consequently, chem. equivalent of proto-nitrate of mercury = 262.

Per-nitrate of Mercury

is composed of 1 equivalent of nitric acid = 54
2 equiv. of per-oxide of mercury (each = 216) = 432

Consequently, chemical equivalent of per-nitrate of mercury = 486.

§ 244. The proto-nitrate of mercury is a salt, which, as we may suppose from its name, is composed of protoxide of mercury and nitric acid. It is obtained by pouring quicksilver upon weak dilute nitric acid, kept at a low temperature. Oxide of nitrogen is slowly given off, and a colorless solution formed, which deposites colorless, transparent crystals, of a sharp, pungent taste. When exposed to daylight they become yellow, and stain the skin with a purple color.

The per-nitrate of mercury is a combination of the peroxide of mercury with nitric acid. It is obtained in the same manner as the proto-nitrate, only that the solution must be heated and boil for some time. When the liquid evaporates, long, prismatic crystals are formed, which have a pungent, sharp taste, attract moisture, and become yellow by exposition to day-light. Both nitrates of quicksilver are used in medicine. They are also employed in the art of gilding by means of gold amalgams.

6. *Nitrate of Silver.*

Chemical Composition: 1 equiv. of nitric acid = 54
1 do. of oxide of silver = 118

Chemical equivalent of nitrate of silver = 172.

§ 245. This salt, fused and cast into small bars, forms the well known *lunar caustic,* extensively used in surgery. It is obtained from a solution of fine silver in nitric acid. Deutoxide of nitrogen is given off, and the nitrate shoots into colorless, transparent crystals, which have a sharp, bitter, metallic taste, and upon being exposed to light, turn dark. It is dissolved in equal parts of cold water, and in 4 parts of boiling alcohol. A number of bodies have the power of decomposing it, and when mercury is poured upon it, the silver is precipitated in form of a tree, which affords one of the most beautiful and striking experiments that can be made, to beginners. It destroys speedily all vegetable and animal formations (hence its use in surgery), or stains them first with a white, but upon exposition to light, with a permanent black color. The latter property is taken advantage of in the preparation of *indelible* or *marking ink.*

The linen or cotton which is to be marked is first moistened with a solution of carbonate of soda, upon which, when perfectly dry, the letters are written with a solution of nitrate of silver, mixed with gum arabic, and a little India ink. Upon exposition to light, the letters turn permanently black.

7. *Nitrate of Lead.*

Chemical Composition: 1 equiv. of nitric acid = 54
1 equiv. of protoxide of lead = 112

Consequently, chemical equiv. of nitrate of lead = 166.

§ 246. This salt is quickly obtained from a solution of oxide of lead in nitric acid. It crystalizes in colorless, transparent (sometimes white, opaque) octahedrons, which have a pungent, cooling, sweetish taste. It is dissolved in seven times its weight of cold water (much less *boiling* water is required), melts when heated, gives off oxygen and leaves oxide of lead. It is used in cotton-printing. With *Chromate of potassium* it produces a beautiful orange color.

8. *Nitrate of Copper.*

Chemical Composition : 1 equiv. of nitric acid = 54
1 equiv. of per-oxide of copper = 80

Consequently, chem. equiv. of nitrate of copper = 134.

§ 247. Nitrate of copper is obtained by dissolving copper in dilute nitric acid. The salt crystalizes in prisms of a beautiful sapphire-blue color, has a sharp, caustic taste ; deliquesces (§ 235) easily, and dissolves readily in water. It is used in the preparation of blue colors in cotton printing, and as a means of oxydizing metals.

B. CHLORATES.

§ 248. *Properties of the chlorates.* These salts are in their properties similar to the nitrates. They are all *products of art*, and are easily decomposed by heat. They give off part of their oxygen and are totally consumed when thrown upon burning coals. We shall only describe a few of them.

Chlorate of Potash.

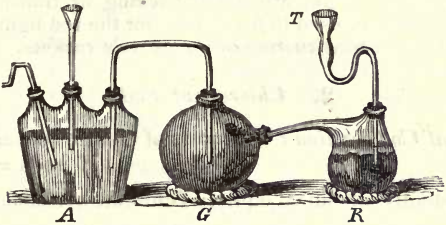
Chemical Composition : 1 equiv. of chloric acid = 76
1 do. of potash = 48

Consequently, chem. equiv. of chlorate of potash = 124.

§ 249. This salt is produced by conducting as much chlorine into a solution of pure potash as the latter is capable of taking up. The solution is then suffered to cool and evaporate, when the salts will shoot in crystals similar in appearance to mother of pearl.

The solution of potash is placed in a three-necked bottle A, shaped as represented in the adjoining figure. This bottle communicates by means of a pipe, with the globe G, and the retort R, into which some black oxide of manganese is introduced in a state of fine powder. The apparatus being thus arranged, muriatic acid is poured upon the oxide of manganese through the safety tube T, which to prevent the immediate escape of the chlorine gas must be shaped as represented in the figure, and a gentle heat applied to the retort. Chlorine will be given off and pass over into the solution of potash, until the solution is saturated, after which the excess of gas will escape through the safety tube. When the saturated solution is afterwards evaporated at a low heat, small shining crystals are obtained, which are the pure chlorate of potash.

Fig. CXXXV.



§ 250. *Properties.* Its taste is cooling but nauseous. It is besides, inodorous, sparingly soluble in cold water, becomes liquid by a gentle heat, but gives off its oxygen and becomes decomposed by high temperatures. When mixed with combustible substances a smart stroke or percussion may inflame it, and a violent detonation takes place. (Half a tea-spoon full wrapt in a piece of paper and briskly struck with a hammer, gives a report like a gun). It is used in the comstruction of instantaneous light matches.

Instantaneous light matches. The ends of the matches are covered with a red mass, consisting of 30 parts of chlorate of potash, 10 of sulphur, and a little gum water. When these matches are dipped in a little bottle, filled with concentrated sulphuric acid, enough heat is produced for the sulphur to ignite, that is, to combine with the oxygen which is given off.

Remark. *Bertholet*, a French chemist, endeavored to use chlorate of potash instead of nitre in the manufactory of gunpowder. The powder thus obtained is very powerful, but so highly inflammable that many people lost their lives during its preparation, or in the attempt of packing or transporting it. It is nevertheless used in fire-works, for the red light in theatres, and in the construction of Congreve's rockets.

2. *Chlorate of Soda.*

Chemical Composition : 1 equiv. of chloric acid = 76
1 do. of soda = 32

Consequently, chemical equiv. of chlorate of soda = 108.

§ 251. *Chlorate of soda* is obtained in the same manner as chlorate of potash (taking soda instead of potash). It crystalizes in cubes, tastes almost like chlorate of potash, is soluble in three parts of cold (much less of warm) water, but is more easily dissolved in spirits of wine. Its other properties resemble those of nitrate of potash.

3. *Hydro-chlorate (Muriate) of Ammonia.*

Chemical Composition : 1 equiv. of muriatic acid = 37
1 do. of ammonia = 17
To this must yet be added, 1 equiv. of water = 9

Consequently, chemical equiv. of hydro-chlorate of ammonia = 63.

§ 252. This salt, commonly called *sal-ammoniac*, is found in all volcanic countries, in hair-like crystals, or spherical; also in form of a powder, colored by an admixture of sulphur or oxide of iron. It is manufactured on a large scale from the refuse of animal substances, (such as hoofs, horns, claws, &c), and may also be obtained by neutralizing a solution of ammonia with muriatic acid. When the liquid is evaporated, the salt shoots in colorless crystals, of a sharp, pungent, saline taste. It is easily volatilized, emits white vapors, and is very soluble in water. It is used for a variety of purposes in the arts, particularly in tinning copper ware, to prevent the oxidation of that metal.

C. CHLORIDES.

§ 253. *Pure chlorine* combines with potash, soda and other oxides of metals. All these combinations have powerful bleaching powers and smell after chlorine. The most remarkable and useful of them is

Chloride of Lime.

Chemical Composition: 1 equivalent of chlorine = 36
2 equivalents of lime (each = 28) = 56

Consequently, chemical equiv. of chloride of lime = 92.

§ 254. This compound is manufactured upon a very extensive scale. For this purpose chlorine is passed into rooms in which fine-powdered, fresh-slacked lime is submitted to its action. The gas combines quickly with the lime; but as this combination is accompanied by an evolution of heat, through which chlor*ate* of lime would be formed, it is necessary to let the gas *slowly* into the room, commonly two days in succession) or to surround the room with cold water. It is calculated that 1 cwt. of *lime* yields commonly 1½ cwt. of *chloride of lime.*

§ 255. *Properties. Dry chloride of lime* is a white powder with a faint smell of chloric acid (not chlorine) and a strong, pungent taste. By long keeping, especially when moist, it absorbs carbonic acid gas from the atmosphere, whereby it becomes converted into carbonate of lime.

Applications of Chloride of Lime. It is extensively used in the process of bleaching, on which account it is commonly called bleaching powder, and possesses the remarkable property of cleansing the atmosphere from the infective effluvia and exhalation of putrefying substances, and communicating to it a pleasant freshness. For this purpose fumigation and sprinkling with chloride of lime cannot be too strongly recommended, in case of contagious diseases in hospitals, prisons, alms-houses, and all places of public assembly.

D. MURIATES, (OR CHLORIDES).

§ 256. *Properties of the Muriates, or Chlorides.* The salts belonging to this class are all distinguishable by the following characterizing properties:

1. They remain all unaltered by the admixture of combustible substances (such as hydrogen, sulphur, carbon, &c), to whatever degree of heat they may be exposed. Common salt, for instance, which is a chloride of sodium, may be mixed with charcoal and heated, without changing in the least, its properties.

2. They are all decomposed by sulphuric acid, giving off muriatic acid, &c.

3. They are all soluble in water.

REMARK. It is to be remarked that in regard to the combinations of *muriatic acid* with the different salifiable oxides of metals, there are two different opinions entertained by modern chemists. Some of them believe that when muriatic acid is poured upon an oxide of a metal, a mutual decomposition takes place; the chlorine of the acid combines with the metal and forms a *chloride*, while the hydrogen of the muriatic acid combines with the oxygen of the oxide to *water*, in which the chlorine is afterwards dissolved. Hence the appellation of *chlorides*. Others, however, take the solution of a metallic oxide in muriatic acid, for a *hydrate*: believing the water *chemically* combined with the solution. For this reason they call the salts thence obtained, *muriates*. It is, of course, indifferent for practical purposes, to which of these two opinions we adhere, and we shall therefore distinguish these salts in future by the name of *chlorides*.

1. *Chloride of Silver.*

Chemical Composition: 1 equivalent of chlorine = 36
1 do. of oxide of silver = 110

Consequently, chem. equiv. of chloride of silver = 146.

This salt has already been described in Chapter III, § 184, page 201, among the binary combinations of silver.

2. *Chloride of Gold.*

Chemical Composition not precisely understood.

§ 257. Chloride of gold is prepared from a solution of gold in nitro-muriatic acid. The solution has commonly a strong sour taste, has a beautiful yellow color, and leaves upon evaporation a reddish-yellow, saline mass, which still contains some muriatic acid, and is soluble in water. If this salt be gently heated, chlorine is given off, and its yellow color is changed into red. Both the yellow and the red salt deliquesce, have a sour, astringent, nauseous taste, and are highly poisonous. They are easily soluble in water, ether and alcohol. These solutions become decomposed by exposition to daylight, (still better by solar light) whereby gold is precipitated. The salts themselves are likewise decomposed by light and heat, (chloride of gold, and finally simple gold remains). The pure chloride of gold is used in several preparations of gold; in the manufactury of gold-purple, a precious, beautiful color, employed in glass and porcelain painting, and particularly in the gilding of steel, for which purpose it is extensively employed.

3. *Chloride of Platinum.*

Chemical Composition: 2 equivalents of chlorine
(each = 36) = 72
1 equivalent of platinum = 96

Consequently, chem. equiv. of chloride of platinum = 168.

§ 258. A DOUBLE *Chloride (bi-chloride) of platinum* may be obtained by the solution of platinum in nitro-muriatic acid. When the solution is carefully evaporated a blackish brown mass is obtained (as long as it contains water it appears red) which has a nauseous, metallic, sharp taste, acts as a poison on the animal body, and is easily soluble in water, ether and alcohol. It communicates to organic substances a purple color, and when heated gives off part of its chlorine, by which means a *simple chloride of* *platinum* remains. This is a greyish powder, which is soluble only in concentrated muriatic acid.

4. *Chloride of Copper.*

Chemical Composition: 2 equiv. of chlorine (each = 36) = 72
1 equiv. of copper = 64
Consequently, chem. equiv. of chloride of copper = 136.

§ 259. ***Double chloride of copper*** is obtained as a hydrate by a solution of oxide of copper in muriatic acid. In an *an-hydrous* state it may be obtained by being gently heated. If the temperature be still further increased, part of the chlorine is given off and the *simple chloride of copper* remains. *(An-hydrous chloride of copper* may also be obtained at once by heating thin plates of copper, and immersing them in chlorine. The copper does then burn with a green light, and the product of the combustion is the an-hydrous chloride). The an-hydrous combination has a yellowish brown color, but absorbs moisture so rapidly from the air that its color becomes soon changed into green. Mixed with 35 per cent of water it crystalizes in beautiful green needles, which have a sharp metallic taste, deliquesce, and are easily dissolved by spirits of wine. Such a solution burns with a beautiful green flame, and is used in fire-works and for theatrical purposes.

5. *Chloride of Lead.*

This salt has already been spoken of, among the binary combinations of lead, on page 214.

6. *Chloride of Tin.*

§ 260. *Chloride of Tin, (Tin salt)* is obtained in an an-hydrous state; when tin-filings are heated with muriatic acid gas; the hydrogen of the muriatic acid gas is given off, and the chlorine combines with the tin. It is a grey, half-transparent substance, of a glassy fracture, which melts and becomes volatilized at a red heat. *Chlo-*

ride of tin combined with water (muriate of tin), is obtained from a solution of tin-filings in muriatic acid. The solution has a brown color, which upon cooling and concentrating, forms colorless, transparent crystals of a disagreeable taste and smell, and highly poisonous. They deliquesce, and are easily soluble in water. Chloride of tin is used in cotton and silk dyeing.

Per-chloride of tin is obtained by a distillation of one part of tin-filings with four parts of corrosive sublimate. It is a colorless, transparent liquid, of a very disagreeable smell, which, in contact with atmospheric air, emits dense white vapors. It absorbs water rapidly. By adding to it one third of its weight of water it becomes converted into a thick, white substance, known by the name of tin-butter.

7. *Chloride of Cobalt.*

§ 261. This chloride is produced by boiling a solution of cobalt in concentrated muriatic acid. The solution has a beautiful red color (when concentrated and warm it is blue), and crystalizes with water in dark red prisms, which have an astringent taste, and are soluble in water and alcohol.

A dilute, weak solution of chloride of cobalt, which is almost colorless, is used for a sort of sympathetic ink. The characters written with it, when dry are invisible; but when the paper is held before a *fire* they become blue. Upon cooling, the color disappears again; but may again be produced by exposition to heat. When the experiment is often repeated, the characters become finally fixed with a dark red color.

Chlorine combines yet with *iron*, *nickel*, *cerium*, and most of the other metals.

E. SULPHATES.

§ 262. *Properties of the Sulphates.* These salts are formed (as the name indicates) by the combination of *sulphuric acid* with the different salifiable bases. Many of them are products of nature, and are of great usefulness to the arts. They may be marked, as a class, by the following properties:

1. When an acid is poured upon them, at common temperatures, they neither effervesce nor give off any vapors.
2. They are all decomposed by high temperatures, with the exception, however, of the sulphates of potash, soda, lithia, baryta, strontia, lime, magnesia, and lead.
3. They are all decomposed by carbon under the influence of an intense heat.

1. *Sulphate of Potash.*

Chemical Composition: 1 equiv. of sulphuric acid = 40
1 do. of potash = 48

Consequently, chem. equiv. of sulphate of potash = 88.

§ 263. This salt occurs in common stone or table salt, in alumine, and in many vegetables. It is obtained, as a secondary product in salines, and in the preparation of nitric and sulphuric acid. It crystalizes in prisms, has a sharp, bitter, saline taste, remains fixed in fire, and is soluble in 12 parts of cold water. It is used in medicine, and in the preparation of alum, glass, and saltpetre.

2. *Sulphate of Soda.*

Chemical Composition: 1 equiv. of sulphuric acid = 40
1 do. of soda = 32

Consequently, chem. equiv. of sulphate of soda = 72.

§ 264. This sulphate (known in medicine by the name of Glauber's salts) occurs in all three kingdoms of nature. It is sometimes (for instance, in Spain) found on the surface of the earth, and adheres to damp walls. It is also found in mineral waters, and in lakes. It is obtained in large quantities by the decomposition of common salt by means of sulphuric acid (whereby muriatic acid is given off). It crystalizes in colorless, transparent prisms, which have a bitter, cooling taste, and when exposed to the atmosphere, changes into a white powder, and deliquesce at a gentle heat. This salt is not soluble in alcohol. It is used in the artificial preparation of carbonate of soda and in the manufactury of glass; but particularly in medicine.

3. *Sulphate of Lime.*

Chemical Composition: 1 equiv. of sulphuric acid = 40
1 do. of lime = 28
to which are added 2 equiv. of water (each = 9) = 18

Consequently, chem. equiv. of sulphate of lime = 86.

§ 265. *Sulphate of lime* occurs abundantly in the mineral kingdom, as *gypsum*, *selenite*, *alabaster*, and *plaster-stone;* more rarely in vegetable and animal substances. *Selenite* crystalizes in right or oblique prisms, which are transparent, and either colorless, or grey, yellow, or brown, and have a lustre between glass and mother of pearl.

Alabaster has more of a lamellar texture, and a white, yellowish-grey, or reddish color. The most compact kind of gypsum,

Plaster-stone, contains often remains of animal and vegetable substances. It is very liable to destruction, and crumbles easily into dust.

Gypsum may be produced by the action of sulphuric acid on lime, in which case it is obtained in white, silky crystals, which are not easily soluble in water. By burning, it becomes reduced to a white powder, called *Plaster of Paris.* The uses of this salt are manifold. It serves to polish precious stones and pearls, and is used for various ornaments (tables, clocks, &c), for taking casts and moulds, for cements and stuccos in architecture, in the manufactory of porcelain, and in domestic economy as a manure for meadows and clover fields. Mixed with animal glue, and polished with sand-stone, it resembles marble.

4. *Sulphate of Magnesia.*

Chemical Composition: 1 equiv. of sulphuric acid = 40
1 do. of magnesia = 20

Consequently, chemical equivalent of sulphate of magnesia = 60.

§ 266. Sulphate of magnesia *(bitter salt, Epsomsalt)* is contained in sea and mineral waters, which on that account have a bitter taste (Epsom, in England, whence the name of the salt). It is also found in small quantities on the surface of the earth and in the ashes of burnt vegetables. It may likewise be obtained by the action of strong sulphuric acid on magnesia, by which much heat is evolved (sometimes enough to cause ignition). It crystalizes in colorless, four-sided prisms, which are capable of aqueous and igneous fusion, but forms, when exposed to very high temperatures, a kind of enamel. This salt is extensively used in medicine.

5. *Sulphates of Mercury.*

Sulphuric acid combines with the *protoxide* and *per-oxide* of mercury (see Chap. III, § 175, and § 176) to *proto-sulphate* and *per-sulphate of mercury*, respectively.

The Proto-sulphate of Mercury

is composed of 1 equivalent of sulphuric acid = 40
1 equivalent of protoxide of mercury = 208

Consequently, chemical equiv. of proto-sulphate of mercury = 248.

Per-sulphate of Mercury

is composed of 1 equivalent of sulphuric acid = 40
1 do. of per-oxide of mercury = 216

Consequently, chemical equivalent of per-sulphate of mercury = 256.

§ 267. *Per-sulphate of mercury* (from per-oxide of mercury, is obtained by boiling 4 parts of quicksilver with 5 parts of concentrated sulphuric acid. Sulphurous acid gas is given off, and the liquid upon cooling deposites a saline mass, in form of prismatic crystals. This salt has a sharp, metallic taste, and is by the agency of water, immediately separated into two distinct salts; in a *sour salt*, which remains in a state of solution, and in a *basic*, which is precipitated. The basic salt has a yellow color, but becomes black when exposed to solar light in a state of moisture, on which account it cannot be used as a dyeing stuff.

The proto-sulphate of mercury is obtained by gently heating one part of mercury, with one and a half parts of sulphuric acid. It is but sparingly soluble even in warm water.

6. *Sulphate of Silver.*

Chemical Composition: 1 equiv. of sulphuric acid = 40
1 do. of oxide of silver = 118

Consequently, chem. equiv. of sulphate of silver = 158.

§ 268. This salt is immediately obtained by a solution of silver in concentrated sulphuric acid. It is with difficulty soluble in water, crystalizes in small white needles, has a metallic, disagreeable taste, and melts when heated, by which means oxygen and sulphurous acid gas are given off, and pure metallic silver remains. Sulphate of silver is formed whenever silver is separated from gold and copper by means of sulphuric acid. The gold is not touched by this acid and is therefore obtained in form of a powder. The silver is recovered from the sulphate by the action of copper, which combines with the acid and sets the silver free.

7. *Per-sulphate of Copper.*

Chemical Composition: 2 equiv. of sulphuric acid (each = 40) = 80
1 equiv. of per-oxide of copper = 80
to which is added 10 equiv. of water (each = 9) = 90

Consequently, chem. equiv. of per-sulphate of copper = 250.

§ 269. *Per-sulphate of copper (blue vitriol)* occurs, in a state of solution, in copper-mines. It may be obtained also from a solution of copper in sulphuric acid. It forms crystals of a beautiful azure color, which have a disagreeable metallic taste, cause nausea and vomiting when taken into the stomach, and become converted into a white powder by exposure to heat. *Blue vitriol* is soluble in water (not in spirits of wine). Various mixtures of vitriol are used in the dyeing of wool, in the bronzing of iron ware, in the coloring of gold, in medicine, &c.

8. *Sulphate of Iron.*

Chemical Composition: 1 equiv. of sulphuric acid = 40
1 equiv. of protoxide of iron = 36

Consequently, chem. equiv. of sulphate of iron = 76.

§ 270. *Sulphate of iron (green vitriol)* is a product of nature, which is found in coal and other mines. It may also be obtained from a solution of iron in dilute sulphuric acid. It crystalizes in green, transparent rhombs, which have a sour, astringent taste (like ink), and become quickly oxidized in contact with atmospheric air. At high temperatures it falls into a white powder. On account of its great affinity for oxygen it is used for the desoxidation of indigo.

9. *Sulphate of Baryta.*

Chemical Composition: 1 equiv. of sulphuric acid = 40
1 do. of baryta = 78

Consequently, chem. equiv. of sulphate of baryta = 118.

§ 271. *Sulphate of baryta* (heavy spar) is found crystalized in various shapes and forms. Its color is a yellowish-white, grey, red, or blue, with a strong lustre (like fat or glass). When heated with charcoal it fuses at a high temperature into a white, opaque enamel. It is used as a permanent white pigment, in the manufactory of Wedgwood's jasper ware.

10. *Sulphate of Ammonia.*

Chemical Composition: 1 equiv. of sulphuric acid = 40
1 do. of ammonia = 17
to which is added 1 do. of water = 9

Consequently, chem. equiv. of sulphate of ammonia = 66.

§ 272. This salt is obtained by neutralizing ammonia with sulphuric acid. It has a sharp, bitter taste, is soluble in water, and is used in the manufacture of *sal-ammoniac*, which may be prepared by subliming sulphate of ammonia with common salt. It crystalizes in small prisms by taking up an additional equivalent of water, by which means its chemical equivalent is increased from 66 to 75.

11. *Sulphate of Alumine.*

Chemical Composition: 1 equiv. of sulphuric acid = 40
1 do. of alumine = 17

Consequently, chem. equiv. of sulphate of alumine = 57.

§ 273. This salt is a product of nature, and occurs in America, in Guadaloupe, &c; but is also obtained by art, when pure alumine is dissolved in sulphuric acid. The liquid, when evaporating, forms colorless, semi-transparent, lamellar crystals, with an appearance like mother of pearl. It has a sweet, astringent taste, is easily soluble in water (not in alcohol), and gives off its acid when exposed to heat. It combines with the sulphates of the alkalies, and forms thereby a class of salts with double bases, well known by the name of *alum.* Thus, sulphate of alumine combines with sulphate of potash, and forms a salt which has two bases, *alumine* and *potash.* Again, sulphate of alumine combines with sulphate of soda, the product being a salt with the two bases, *alumine* and *soda*, and so of the rest.

§ 274. *Alum.* The two kinds of salt which we have just chosen for an example, viz: *sulphate of alumine and potash*, and *sulphate of alumine and soda* are by far the most important kinds of alum. Both are products of nature; but the former (sulphate of alumine and potash) is met with in much greater abundance, particularly in the neighborhood of volcanos. They may also be obtained respectively by pouring sulphate of potash or soda into a solution of sulphate of alumine. The salts thence precipitated crystalize in octahedrons, have a sweet, astringent taste, and are easily soluble in water. The acid of the first salt becomes decomposed by heat, whereby it becomes light and spongy, and is distinguished by the name of *burnt alum.* The second salt is by heat entirely decomposed into its elements.

Alum is an important article of commerce. It is used in dyeing and calico printing, in tanneries and paper manufactures; for the sizing of paper. It is also extensively used in medicine.

The *sulphites* are here omitted, because they are of less importance to the arts, and their properties are not yet sufficiently examined.

F. CARBONATES.

§ 275. *Characteristics of the Carbonates.* The salts of this class may be known by the following properties:

1. They lose their acid by exposition to heat (the carbonates of potash, soda and lithia alone excepted).
2. When mixed with charcoal they are all decomposed by a high heat.
3. They are all decomposed by the acids, with strnog effervescence of carbonic acid.

1. *Carbonate of Ammonia.*

Chemical Composition: 1 equiv. of carbonic acid = 22
1 do. of ammonia = 17

Consequently, chem. equiv. of carbonate of ammonia = 39.

§ 276. Two volumes of dry *ammonia* combine directly with one volume of carbonic acid gas. The product is *carbonate of ammonia*, a white, crystaline substance, which has a strong odor of ammonia, and is readily soluble in water. In contact with the atmosphere part of the volatile alkali (ammonia) escapes, whereby the remainder contains a greater portion of the acid, and is therefore changed into bi (double) carbonate of ammonia.

Smelling Salts. Sesqui-carbonate (1½ carbonate) of ammonia, also called smelling salts, is an important article of commerce. It is obtained on a large scale by subliming a mixture of muriate of ammonia and chalk, or a mixture of the well-known salt of *hartshorn* with animal charcoal (see Chap. II, page 124). From these mixtures it is produced in semi-transparent lumps, which have a pungent, penetrating taste and smell, and are used in medicine.

A mixture of carbonate of ammonia and rancid mineral oil or fat is obtained by dry distillation of animal substances, such as bones, horns, hoofs, dried manure, &c, (all of which contain, as we shall see hereafter, a great proportion of nitrogen). The product thus obtained is called *salts of hartshorn*, and is a yellowish brown salt of a penetrating, highly disagreeable smell, which is used in medicine.

2. *Carbonate of Potash.*

Chemical Composition: 1 equiv. of carbonic acid = 22
1 do. of potash = 48

Consequently, chem. equiv. of carbonate of potash = 70.

§ 277. This salt is obtained from the ashes of plants growing remote from the sea-shore, which for this purpose are dissolved in water, boiled, and afterwards calcined. It constitutes the pot-ash and pearl-ash of commerce, and is a solid, white mass, which is easily soluble in water, melts at a red heat, and evaporates at a white heat. Its taste is alkaline, but very little caustic. It is extensively used in the manufactory of soap, in bleaching and dyeing, and in glass making.

If carbonic acid gas is passed through a solution of carbonate of potash, a *bi-carbonate of potash* is obtained, which crystalizes in great colorless crystals, and tastes yet a little alkaline, but not caustic. By boiling and heating it part of the acid is given off, and the product is a *sesqui*-carbonate of potash.

3. *Carbonate of Soda.*

Chemical Composition: 1 equiv. of carbonic acid = 22
1 do. of soda = 32

Consequently, chem. equiv. of carbonate of soda = 54.

§ 278. *Carbonate of soda (soda-salt)* is found, in a state of solution, in some minerals. It is prepared on a large scale, from the ashes of plants which grow *near* the sea-shore, in a manner similar to that in which carbonate of potash is obtained from the ashes of plants growing *remote* from it. (§ 277). It is a white, solid mass, similar to carbonate of potash, only its taste is milder, and it is more easily fusible in water. It forms colorless, transparent crystals which effloresce and undergo aqueous fusion. It is used in the manufactory of glass, in dyeing, in calico-printing, and in medicine.

The *bi-carbonate* and *sesqui-carbonate of soda* are obtained from the carbonate in the same manner in which the bi-and sesqui-carbonate of potash are respectively obtained from carbonate of potash. The sesqui-carbonate of soda is an abundant product of nature, occurring particularly in Egypt, Hungary, and South America.

4. *Carbonate of Magnesia.*

Chemical Composition: 1 equiv. of carbonic acid = 22
1 do. of magnesia = 20

Consequently, chem. equiv. of carbonate of magnesia = 42.

§ 279. This salt occurs in large lumps in the East Indies. It is also (though not so pure) obtained by adding carbonate of potash to sulphate of magnesia, at a high temperature. It is a white, inodorous, tasteless powder, which is but sparingly soluble in water, but readily dissolved by the acids. When a solution of it in dilute carbonic acid, is suffered to evaporate, it crystalizes in small prisms, which effloresce, are easily soluble in water, and are extensively used in medicine. Sir Humphrey Davy, mixed this salt with flour to make the bread lighter and healthier (40 grains of carbonate of magnesia to one pound of bread).

5. *Carbonate of Lime.*

Chemical Composition: 1 equiv. of carbonic acid = 22
1 do. of lime = 28

Consequently, chem. equiv. of carbonate of lime = 50.

§ 280. *Carbonate of lime* occurs native in huge masses, forming whole chains of mountains. It is either crystalized, as *spar*, or in a crystaline state, as *white mar-*

ble; hard, as *lime-stone*, or earthy, as *chalk.* It is also found in the animal kingdom, in the shells of oysters, snails, eggs, &c. That which is prepared by art is obtained from a solution of burnt oyster-shells in muriatic acid. It consists generally of a white powder, which is inodorous, tasteless and insoluble in water; but soluble in very dilute carbonic acid, forming with it *bi-carbonate of lime.* By a red heat it becomes decomposed, gives off its acid, and becomes changed into lime. (This explains the burning of chalk and lime-stone to lime). The stones used in *lithography* are also a carbonate of lime.

6. *Carbonate of Baryta.*

Chemical Composition: 1 equiv. of carbonic acid = 22
1 do. of baryta = 78

Consequently, chem. equiv. of carbonate of baryta = 100.

§ 281. *Carbonate of baryta* is likewise a product of nature, and occurs as a distinct fossil in England (in the the counties of Lancashire, Durham, Cumberland, &c), in Hungary, and particularly in Siberia. It crystalizes in semi-transparent, greyish white, sometimes greenish prisms, but is also precipitated as a white, insoluble powder, from a solution of baryta water, and carbonate of potash. It has neither taste nor smell; but is very poisonous. Mixed with charcoal and exposed to a red heat; it becomes decomposed, whereby carbonic acid is given off, and caustic baryta remains.

7. *Carbonate of Lead.*

Chemical Composition: 1 equiv. of carbonic acid = 22
1 do. of oxide of lead = 112

Consequently, chem. equiv. of carbonate of lead = 134.

§ 282. This is a metallic ore, commonly called *white lead.* It is manufactured on a large scale by exposing *sheet lead* to the action of vinegar. In modern times it has also been obtained as a precipitate, by adding carbonate of potash (§ 277) to *nitrate of lead.* It has a beautiful white color, is insoluble in water, but readily dissolves in a solution of carbonic acid. It is extensively used as a paint, on which account it is an important article of commerce.

8. *Carbonate of Iron.*

Chemical Composition: 1 equiv. of carbonic acid = 22
1 equiv. of protoxide of iron = 36

Consequently, chem. equiv. of carbonate of iron = 58.

§ 283. This salt occurs as a natural product in some of the iron ores, but may also be obtained as a precipitate from a solution of sulphate of iron with carbonate of potash. The *native* carbonate forms white crystals; that which is produced by art is a greenish white powder, which in contact with the atmosphere gradually loses its acid, and changes its color into brown. It is inodorous, tasteless, and insoluble in water, and is used in the manufactory of steel, and in the preparation of some artificial mineral-waters.

9. *Carbonate of Copper.*

Chemical Composition: 1 equiv. of carbonic acid = 22
1 equiv. of per-oxide of copper = 80
to which is added 1 equivalent of water = 9

Consequently, chem. equiv. of carbonate of copper = 111.

§ 284. This carbonate occurs likewise native, as *Malachite*, a beautiful green mineral, which is principally used in the preparation of green and blue pigments. It is also obtained, as a precipitate, from a mixture of sulphate of copper with carbonate of potash. The green substance which is formed in copper and bronze vessels, when exposed to a damp atmosphere, is a carbonate of the same metal.

G. PHOSPHATES.

§ 285. *General characteristics of the Phosphates.*

The salts belonging to this class are formed by the union of phosphoric acid with the different salifiable bases, and may easily be marked by the following characteristics:

1. They are not decomposed by a red heat, but melt at higher temperatures.

2. They are, with the exception of the phosphates of potash, soda, and ammonia, but sparingly soluble in water.

3. They are all dissolved without effervescence, by phosphoric and nitric acid, from which they may again be precipitated by an addition of ammonia.

1. *Phosphate of Ammonia.*

Chemical Composition: 1 equiv. of phosphoric acid = 28
1 do. of ammonia = 17

Consequently, chem. equiv. of phosphate of ammonia = 45.

§ 286. This salt occurs in some of the liquids of carnivorous animals, and may be prepared from carbonate of ammonia and phosphate of lime. It has a pungent but cooling taste, and is easily soluble in water. It is used for the preparation of phosphoric acid.

2. *Phosphate of Soda.*

Chemical Composition: 1 equiv. of phosphoric acid = 28
1 do. of soda = 32

Consequently, chem. equiv. of phosphate of soda = 60.

§ 287. *Phosphate of soda* occurs likewise in animal liquids. It may be obtained by neutralizing phosphoric acid with carbonate of soda; crystalizes in colorless, transparent rhombs, has a cold, saline (not bitter) taste, effloresces in contact with the atmosphere, and when exposed to an intense heat, undergoes first aqueous and afterwards igneous fusion (see § 235). Combined with phosphate of ammonia (§ 286), it forms a salt with double bases, known by the name of *microcosmic salt*, which may be procured by dissolving muriate of ammonia and phosphate of soda in boiling water, and is used instead of borax

(§ 120) for a variety of technical purposes. Phosphate of soda is also used in medicine.

3. *Phosphate of Lime.*

Chemical Composition: 1 equiv. of phosphoric acid = 28
1 do. of lime = 28
to which is added 2 equiv. of water (each = 9) = 18

Consequently, chem. equiv. of phosphate of lime = 74.

§ 288. Phosphate of lime is a principal ingredient of the bones of animals, but is also contained in other solids, and in some of the liquids of their bodies, as, for instance, in milk, in the white of eggs, &c. It is generally procured by the calcination of bones, and consists of a greyish white powder, which soon dries to a hard lump. It is easily soluble in nitric, muriatic, and phosphoric acid and melts, when heated, to a mass which bears a strong resemblance to porcelain. It is used for cleansing brass, as a tooth powder, and in the manufactory of milk-glass and porcelain.

Bi-phosphate of lime is obtained from a solution of phosphate of lime in any strong mineral acid. It forms crystals of a lamellar texture, has a sour taste, deliquesces, is easily soluble in water, and is used in the manufactory of phosphorus and phosphoric acid.

The phosph*ites* created by the union of phosphor*us* acid with the different salifiable bases are here omitted; because they are of very little application in the arts or in medicine.

H. CHROMATES.

§ 289. *Properties of the Chromates.* The salts formed by *chromic acid* in combination with the bases have all a yellow orange-color, and afford, when mixed with potash or soda through the influence of the blow-pipe, (see chemical apparatus, page 26), a beautiful, green-colored glass.

1. *Chromate of Potash.*

§ 290. This salt is manufactured on a large scale in *Manchester* and *London*, by heating one of the iron ores, called chromate of iron, with an equal weight of nitre and carbonate of potash. 1 equivalent of the chromic acid which is thus formed, combines with 1 equivalent of potash to a salt which crystalizes in yellow, six-sided prisms, has a bitter, disagreeable taste, melts at a red heat and becomes green. It is used in the preparation of chromic acid, in the manufactory of several paints and pigments, in calico printing, &c.

2. *Chromate of Lead.*

§ 291. 1 equivalent of chromic acid, combined with 1 equivalent of lead, occurs crystalized in the red ore of lead. It is semi-transparent, and of a beautiful red (seldom yellow) color. It may be produced by art, by precipitating nitrate of lead with chromate of potash (§ 290). It is a tasteless, inodorous powder, which is in soluble in water and unchangeable by light or air. It may be used as a pigment, in calico-printing and in oil-painting.

3. *Chromate of Mercury.*

§ 292. Chromate of mercury is obtained by precipitating nitrate of mercury with chromate of potash. It possesses a beautiful orange-color, is insoluble in water, but readily dissolved in nitric acid, and is used as a red pigment.

I. ARSENIATES AND ARSENITES.

§ 293. *Characteristics of the Arseniates and Arsenites.* These salts possess the following general properties :

1. They are insoluble in water (the arseniates of potash, soda, and ammonia alone excepted).
2. They are all decomposed when heated with charcoal
3. They are all readily dissolved in arsenic and nitric acid.

1. *Arsenite of Potash.*

§ 294. This combination of *arsenious acid* with potash is produced by boiling until neutralization a solution of carbonate of potash with powdered *arsenious acid.* The salt thus obtained deliquesces so easily that it has not as yet been obtained in crystals. A thick solution of it is yellow, has a disagreeable smell, and is highly poisonous. It is used in calico-printing, and in small quantities even in medicine.

2. *Arsenite of Cobalt.*

§ 295. Arsenite of cobalt occurs as a red ore of cobalt, or may be prepared by the action of double affinity (see Introduction XVIII), from arsenite of potash (§ 294) on any salt of cobalt. (The cobalt of the salt separates the arsenious acid from the potash and combines with it to a neutral salt). It is a red powder which gives a blue color to glass or clay, is decomposed by heat, and dissolves in ammonia to a liquid of a dark red color.

K. CYANITES AND FULMINATES.

§ 296. *Cyanites and Fulminates.* We have already spoken of the combinations of cyanogen with oxygen (Chap. II, § 89), the products of which are cyanous and fulminic acid.

Fulminic acid (only discovered in 1824) occurs no where in nature, but may be formed by mixing nitrate of mercury or silver with alcohol at a high temperature. Alcohol and nitric acid are given off, and the remaining nitrogen, oxygen, and carbon form fulminic acid. This, however, is mixed with other substances, and all attempts to isolate the acid, or to obtain it in a pure state have hitherto failed. The salts of this acid, which are called *fulminates*, have the remarkable property, not possessed by the cyanates or cyanites, of detonating and exploding at the slightest friction, or in contact with concentrated sulphuric or nitric acid. These salts are now used in the manufactory of percussion caps, instead of the locks of firearms.

The *cyanous* acid forms with the different bases *cyanites*, which, by heat, are easily decomposed into ammonia and carbonic acid.

Remark. The *cyanic* acid is composed of the same elements and united in the same proportion as those of *fulminic* acid, and yet the properties of its salts (the fulminates) are entirely different from those of the fulminates (formed by fulminic acid). The reason of this difference is not sufficiently accounted for.

We might speak of the bromates, sodates, hydro-bromates, and almost an infinite number of other salts; but we have proposed only to treat of those which are of frequent application in common life, and with which it is absolutely necessary to be acquainted, to understand even the most ordinary processes of the arts.

RECAPITULATION.

Questions for Reviewing the most important Principles contained in Chapter IV.

A. QUESTIONS ON THE GENERAL REMARKS ON THE SALTS.

[§ 227.] What two elements are by far the most powerful agents in nature? What is the product of their union? What are all bodies in relation to oxygen and hydrogen?

Give examples.

[§ 228.] What are the most remarkable products obtained by the combination of oxygen and hydrogen with other substances? What is the body called which in combination with oxygen or hydrogen forms an acid? What is the oxygen or hydrogen called? What is the acidifying principle in nitric acid? What is the acidifying principle in muriatic acid?

What is the electro positive, and what the electro-negative factor in an acid?

[§ 229.] What are those acids called into whose composition hydrogen enters as the acidifying principle? What acids belong to this class?

What do many other acids require for their liquid form? What are those acids called? What word have they prefixed to their names? What are those acids called in which water does not enter as an essential ingredient?

[§ 230.] What class of bodies do the acids form when combined with those substances called *bases*? How then is a salt defined?

What occurs when a salt is decomposed by the agency of the galvanic pile? What do we infer from this fact?

What is the opinion of some philosophers in reference to all chemical phenomena? By whom is this theory supported? Can you state any facts which may serve to corroborate this theory?

Explain experiment I, represented in Fig. CXV.

How is this phenomenon accounted for by the electric attraction of the battery?

Explain experiment II, represented in Fig. CXVI.

What do we see from this experiment?

What takes place, if, in your last experiment, a solution of sulphate of soda is placed in the cup connected with the negative or copper pole, and in the other two a solution of red cabbage? Is the result different if the middle cup be filled with an alkaline solution?

Now what do these experiments prove?

[§ 231.] What sort of bodies are all the salifiable bases with the exception of ammonia? Are organic bodies capable of becoming salifiable bases? How are the bases therefore divided? What bases in the mineral kingdom are easily soluble in water? Which are not easily soluble? Which bases are insoluble in water? How are the organic bases again divided?

Why may the salts be considered as quarternary combinations of the elements?

[§ 232.] What does each of the acids form, in union with the salifiable bases? After what are the different salts thus produced, commonly denominated? Into what is the denomination of the acid in *ic* changed? Into what is that terminating in *ous* changed? *Give examples.* What do you call the salt which arises from the combination of sulphuric acid with soda? What, that which is formed by sulphur*ous* acid with ammonia?

Is the nomenclature of salts advantageous or not? What does the appellation of each salt show?

[§ 233.] How have the different salts yet been divided. What do you understand by a *neutral* salt? What by a *sour;* what by a *basic* salt?

[§ 234.] What do all salts which are obtained in form of crystals contain? What is the water called, which is mechanically entangled? What that which is chemically combined? What do all salts which contain water mechanically entangled, when thrown into fire? What is this owing to? Does the same happen with the salts which contain water as a chemical ingredient?

[§ 235.] What do some salts lose at common temperatures of the atmosphere? What are they then said to do? What do you understand by the phenomenon of deliquescence? What do you call the process by which a salt is melted by heat, without being decomposed? What, that, when a salt melts in its own water, if the solving power of the water is increased by heat.

Questions on Crystalography.

What takes place when a body, from a state of solution, is converted into a solid, so that its particles are capable of following their own mutual attractions? What is it then called? What important discovery did Haüy make, with regard to the division of crystals? What peculiar geometrical forms did he discover were no longer divisible without fracture? What is this geometrical form called, which is, as it were, the nucleus of the crystal? What is the shape called, which the crystal has before the division?

To how many regular geometrical solids are the primitive forms of all crystals reducible? (Call the different geometrical solids, represented in Figs. CXVII, CXVIII, CXIX, CXX, CXXI, CXXII, CXXIII, CXXIV).

To what three solids are these six, again reducible by mathematical division? What, therefore, is the opinion of some philosophers respecting the primitive form of crystals? What are these three solids called?

By what means may any prism whatever be divided into triangular prisms? How may the rhombic dodecahedron be formed by integrant cubes? (Explain Fig. CXXVIII). What is Dr Wollaston's theory respecting the integrant molecules of crystals? (Explain Figs. CXXIX, — CXXXIV).

In what respect is this theory superior to Haüy's?

[§ 236.] What are the names of the principalsalts according to their nomenclature after the acids?

A. QUESTIONS ON THE NITRATES.

[§ 237.] What are the principal properties of the nitrates?

[§ 238.] What is the chemical composition of nitrate of potash? Where does this salt occur? By what means may it be obtained artificially?

How is nitre produced in France and Germany for the manufacture of gunpowder?

[§ 239.] What are the principal properties of nitre? In what consists the chief use of nitre?

[§ 240.] What is the most remarkable application of nitre? Of what ingredients does gunpowder generally consist?

What are the properties of good gunpowder?

At what temperature does gunpowder ignite? To what is its subsequent expansion and propelling power owing?

[§ 241.] What is the chemical composition of nitrate of soda? Where does this salt occur? How may it be produced artificially? What are its properties? For what purposes is it used?

[§ 242.] What is the chemical composition of nitrate of ammonia? How is this salt produced? What are its properties?

[§ 243.] What is the chemical composition of nitrate of lime? Where does it occur? How may it be produced? What form does it assume by crystalization? What are its properties?

[§ 244.] What is the chemical composition of proto-nitrate of mercury? What, that of per-nitrate of mercury? How is the proto-nitrate of mercury obtained? How is the per-nitrate obtained? For what purposes are both nitrates used?

[§ 245.] What is the chemical composition of nitrate of silver? By what other name is this salt known, when fused and cast into small bars? How is it obtained? What are its properties?

How is nitrate of silver used as indelible or marking ink?

[§ 246.] What is the chemical composition of *nitrate of lead?* How is this salt obtained? What are its properties? For what purposes is it used?

[§ 247.] What is the chemical composition of nitrate of copper? How is it obtained? What are its properties?

B. Questions on the Chlorates.

[§ 248.] What are the principal properties of the chlorates?

[§ 249.] What is the chemical composition of the chlorate of potash? How is this salt produced?

Explain the experiment represented in Fig. CXXXV.

[§ 250.] What are the characterizing properties of chlorate of potash? For what is it used?

How are instantaneous light-matches constructed? For what purposes did Bartholet, a French chemist, endeavor to use this salt? For what purposes is it, nevertheless, used?

[§ 251.] What is the chemical composition of chlorate of soda? How is it obtained? What are its properties?

[§ 252.] What is the chemical composition of hydrochlorate of ammonia? What is this salt commonly called? Where is it found? From what is it manufactured? By what means may it also be obtained? What are its properties?

C. QUESTIONS ON CHLORIDES.

[§ 253. What property have all the salts belonging to the class of chlorides?

[§ 254.] What is the chemical composition of chloride of lime? How is this salt manufactured?

[§ 255.] What are the properties of chloride of lime? What are the applications of chloride of lime?

D. QUESTIONS ON THE MURIATES (CHLORIDES).

[§ 256.] By what properties are the muriates distinguished?

What different opinions exist with regard to the muriates?

What is the chemical composition of chloride of silver?

[§ 257.] How is chloride of gold prepared? What are its properties? For what purposes is it used?

[§ 258.] What is the chemical composition of chloride of platinum? How is the double chloride (bi-chloride) of platinum obtained? What are its properties? How is the simple chloride of platinum obtained?

[§ 259.] What is the chemical composition of chloride of copper? How is double chloride of copper obtained? How is the simple chloride of copper obtained from the double chloride? How may the *an-hydrous* chloride of copper be obtained? What are its properties?

[§ 260.] By what means is chloride of tin obtained? What are its properties? For what purposes is it used?

How is the per-chloride of tin obtained? What are its properties? Into what does it become converted when mixed with one third of its weight of water?

[§ 261.] How is chloride of cobalt produced? What are its properties?

For what may a weak solution of chloride of cobalt be used?

E. Questions on the Sulphates.

[§ 262.] By what characterizing properties are the sulphates distinguished, as a class of salts?

[§ 263.] What is the chemical composition of sulphate of potash? Where does this salt occur? How is it obtained? What are its properties?

[§ 264.] What is the chemical composition of sulphate of soda? By what other name is this salt yet known in medicine? Where does it occur? By what means is it obtained in large quantities? What form does it assume by crystalization? What are its properties? Where is it used?

[§ 265.] What is the chemical composition of sulphate of lime? Where does it occur? In what form does it crystalize?

What are the properties of alabaster? What is the most compact kind of alabaster?

What are the properties of plaster-stone?

How may gypsum be produced? By what process does it become reduced to plaster of Paris? What are the uses of this salt?

[§ 266.] What is the chemical composition of sulphate of magnesia? In what is this salt contained? Where is it also found in small quantities? By what means may it be produced by art? What are its properties?

[§ 267.] What is the chemical composition of proto-sulphate of mercury? What that of per-sulphate of mercury? How is the per-sulphate of mercury obtained?

What are its properties? Into what two salts is this salt decomposed by the agency of water? What are the properties of the basic salt? As what is it used?

How is *proto-sulphate* of mercury obtained?

[§ 268.] What is the chemical composition of sulphate of silver? How is this salt obtained? What are its properties?

[§ 269.] What is the chemical composition of per-sulphate of copper? Where does it occur? From what may it be obtained? What properties do the crystals possess which it forms? For what purposes are they used?

[§ 270.] What is the chemical composition of sulphate of iron? Where is this salt found? What are its properties?

[§ 271.] What is the chemical composition of sulphate of baryta? Where is it found? What are its properties?

[§ 272.] What is the chemical composition of sulphate of ammonia? How is this salt obtained? What are its properties?

[§ 273.] What is the chemical composition of sulphate of alumine? What sort of product is it? How is it obtained by art? What are its properties? With what substances does it combine? What class of salts does it thereby form? Give an example.

[§ 274.] What two salts are the two most important kinds of alum? What sort of products are they? Which of the two is met with in greatest abundance? By what other means may they be obtained? What are its properties? How is *burnt alum* obtained?

For what purposes is alum used in the arts?

F. QUESTIONS ON THE CARBONATES.

[§ 275.] What are the general characteristics of the carbonates?

[§ 276.] What is the chemical composition of carbonate of ammonia ? What is the product of the combustion of two volumes of dry ammonia with one volume of carbonic acid called ? What properties does it possess ?

By what name is the sesqui-carbonate (1½-carbonate) of ammonia known in commerce ? How is it obtained ? In what shape ? What properties does it possess ? From what substances is salts of hartshorn obtained ? What are its properties ?

[§ 277.] What is the chemical composition of carbonate of potash ? How is this salt obtained ? What are its properties ?

How is bi-carbonate of potash obtained ? What are its properties ? Into what does it become converted by boiling and heating ?

[§ 278.] What is the composition of carbonate of soda ? Where is it found ? How is it prepared by art ? What are its properties ? What sort of crystals does it form ? For what purpose is it used ?

How are the bi-carbonate of sesqui-carbonate of soda obtained ? What sort of product is the sesqui-carbonate of soda ?

[§ 279.] What is the chemical composition of carbonate of magnesia ? Where does this salt occur ? By what means may it be obtained by art ? What are its properties ? By what process can it be made to crystalize ? For what purpose did Sir Humphrey Davy use this salt ?

[§ 280.] What is the chemical composition of carbonate of lime ? Where, and in what quantities does it occur ? In what animal substances is it also found ? How is it prepared by art ? What are its properties ? Into what does it become converted by a red heat ? What sort of compound are the stones used in lithography ?

[§ 281.] What is the chemical composition of carbonate of baryta ? What sort of product is it ? Where does it occur ? What are its properties ? What becomes of it when mixed with charcoal and exposed to a red heat ?

[§ 282.] What is the chemical composition of carbonate of lead ? By what other name is this salt yet known ?

How is this compound manufactured? What are its properties? For what purposes is it extensively used?

[§ 283.] What is the chemical composition of carbonate of iron? Where does this salt occur? How may it be obtained by art? What are the properties of the natural product? What those of the product of art?

[§ 284.] What is the chemical composition of carbonate of copper? Where does it occur? How may it be produced by art? Of what consists the green substance formed on the surface of copper and bronze vessels when exposed to a damp atmosphere?

G. Questions on the Phosphates.

[§ 285.] What are the general characteristics of the phosphates?

[§ 286.] What is the chemical composition of phosphate of ammonia? Where does it occur? What are its properties?

[§ 287.] What is the chemical composition of phosphate of soda? Where does it occur? What are its properties? What does it form in combination with phosphate of ammonia? How may microcosmic salt be produced?

[§ 288.] What is the chemical composition of phosphate of lime? Where does it occur? How is it generally produced? For what purposes is it used?

How is the bi-phosphate of lime obtained? What are its properties?

H. Questions on the Chromates.

[§ 289.] What are the characterizing properties of chromates?

[§ 290.] How is the chromate of potash manufactured in Manchester and London? What are its properties? for what purposes is it used?

[§ 291.] What salt does 1 equivalent of chromic acid, combined with 1 of lead, form? How may the same salt be produced by art? What are its properties?

[§ 292.] How is the chromate of mercury obtained?

I. Questions on the Arseniates ard Arsenites.

[§ 293.] By what characteristics are the arseniates and arsenites distinguished?

[§ 294.] How is arsenite of potash produced? What are its properties? For what is it used?

[§ 295.] Where does arsenite of cobalt occur? What are its properties?

K. Questions on the Cyanites and Fulminates.

[§ 296.] Does fulminic acid occur in nature in its simple form? How then may it be produced? What are the salts, formed by this acid in combination with the different salifiable bases called? What remarkable property do all these salts possess? For what particular purpose are these salts now used?

What kind of salts does cyanous acid form when combined with the different salifiable bases?

Of what elements is cyanic acid composed?

CHAPTER V.

VEGETABLE CHEMISTRY.

General Remarks on the Difference between Organic and Inorganic Matter.

§ 297. In *animated* nature — *plants* and *animals* — the elements of matter seem to obey different laws from those to which they are subjected in *dead* matter; the products of their combinations bearing little resemblance to those which are obtained in inorganic chemistry. Every living body may be considered as a laboratory, in which a variety of chemical processes serve to support life, in such a manner that from a simple atom, it is gradually developed to its highest perfection; after which these processes begin to be carried on more slowly, and finally cease entirely. From that moment the body obeys all the laws of inanimate matter. Such is the *life* and *death* of every plant and animal. The time from the beginning to the cessation of life (death) is various; but *all bodies endowed with life, in whatever shape they may appear to us, go through the two periods of gradual perfection and decay.*

§ 298. *Difference between organic and inorganized matter.* The difference between organic and inorganic nature consists, therefore, principally in this: *The organized body has a definite beginning and developement, after which it is subject to decay and death; inorganic matter, on the contrary, continues to exist (although sometimes in different shapes) in whatever situation it may be placed.*

It is true, the INorganic elements of plants, and elements (with which we shall presently become acquainted) are not perishable; but the particular *nature* of these bodies is, through death, irrecoverably destroyed, and returns no more. The life of the plant or animal is, consequently, not seated in the organic elements; but in something higher, in a *directing agent*, which is altogether different from, and superior to chemical affinity, or any other attribute of matter. This inconceivable agent — *the vital principle of nature* — is, by the divine wisdom of the Creator, distributed throughout our globe with such wonderful diversity, and so eminently well calculated for the support of man, that the destroyed organization of one being gives birth and support to another; by which means they are able to succeed each other with infinite order and regularity; each fulfilling the end for which it was created.

§ 299. In *in*organic chemistry, we are generally able to produce substances from their elements — we can produce water from oxygen and hydrogen, the acids from a combination of the acidifying principle with the radicals, the salts from the acids and the salifiable bases; — but this is totally impossible with regard to plants or animals. No one has, as yet, succeeded, and certainly never will succeed, to form a plant or an animal from its chemical elements. These bodies need even for their support, products of organized matter, as proper materials for the chemical processes subservient to their existence. The vegetable creation of one year subsists on the residue of vegetable matters from the preceding year; grass-eating animals need plants, carnivorous animals meat of other animals, for their nutriment, or food.

§ 300. *Organs — origin of the appellation of organized bodies.* The chemical processes of plants and animals take place in certain *vessels* which seem to be created for that purpose. These vessels are called *organs*, whence the bodies themselves are said to be organized.

Of the manner in which these processes are carried on, we are, with a few exceptions, almost entirely ignorant. Neither do we know if the different elements, which we have discovered in plants and animals, are actually *chemically combined* with each other, or whether they exist in them only in a state of *mixture*.

§ 301. The products of *vegetables* which are used in domestic economy and in the arts, are either situated in particular organs, or are diffused throughout the whole plant. When they are seated in particular organs, (as, for instance, in the root, stalk, leaves, husk, seeds, &c), they may easily be collected ; but when they are diffused throughout the whole plant, certain processes — such as washing, drying, distilling, &c, — are required to separate them from the substances with which they are mixed. More than thirty different vegetable products have in this manner been obtained ; the most important of which we shall speak of in the course of this treatise.

§ 302. *Immediate ingredients of Plants.* The immediate ingredients, which are obtained by the chemical analysis of plants, are

1st. Certain *gaseous* substances, such as oxygen, hydrogen, nitrogen, carbonic acid gas, &c. These substances have already been described in the preceding chapters.

2d. Substances which partake more or less of the *liquid state.* To these belong mucilage, vegetable extract, resin, &c.

3d. *Solid* substances, as, for instance, woody fibre, farina, fruit, &c.

§ 303. The liquid and solid parts of plants may again be decomposed by the action of water, the acids, and the oxides of the mineral kingdom, or by exposure to a high heat. The elements resulting from their decomposition, which may be considered as the *more remote ingredients of plants* (see Introduction, VII), are either *entirely combustible*, that is, such as become, by heat, entirely converted into gases, or *fixed vegetable alkalies*, which, when ignited and submitted to the highest temperatures, leave still a certain quantity of ashes, which is no longer reducible by heat.*

For an illustration of what has just been advanced, we will give but two examples : *The juice*, which is the first *liquid*

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* This property they share with some of the oxides and salts ; hence the name *vegetable alkali.*

ingredient of grapes, may be decomposed into *mucilage, sugar, extract, coloring matter, tanning principle*, and *vegetable acid. Farina*, which is the immediate ingredient of wheat, may be further reduced to *starch, sugar, mucilage and woody fibre, vegetable extract, oxide*, and *salt.* These are, therefore, the more remote ingredients of wheat.

A knowledge of both kinds of ingredients, but more especially of the *combustible* ones, is indispensable to a correct understanding of the nature of plants, as well as their application to chemical, technical and medicinal purposes.

§ 304. But the more remote ingredients of vegetables, decomposed into their *ultimate* principles exhibit but three or four elements, of which, then, the whole infinite variety of plants is composed !! These are *oxygen, hydrogen, carbon*, and *nitrogen* (in a few cases only, phosphorus, *sulphur, iodine*, and *bromine) ;* and from the different proportions in which these few substances unite and combine with each other, result the infinite variety of taste, smell, color, &c, in the products of the vegetable kingdom.

§ 305. All vegetable matters may, with regard to their composition, be divided into four great classes :

1. Into *unsalifiable vegetable substances ;* that is, such as do not combine with the acids to form salts (see Chap. IV).
2. Into *salifiable bases ;* that is, substances which, like the oxides of metals, form salts in combination with the acids.
3. *Vegetable acids.* These affect vegetable colors like the mineral acids (see Introduction, 38) ; change blue litmus paper into red, and with the *mineral oxides* or *vegetable bases* form *salts.*
4. *Substances of an undetermined nature*, which are not comprised by either of the three preceding classes.

I. UNSALIFIABLE VEGETABLE SUBSTANCES.

§ 306. The unsalifiable vegetable substances may again be divided into *neutral* and *watery. Neutral* are those in which the hydrogen is to the oxygen as in water; that is, in the proportion of one to eight (see Chap. 1, § 25). *Watery*, on the contrary, are those which possess a greater quantity of hydrogen than, in combination with the oxygen they contain, is necessary to form water. Their hydrogen, therefore, is to their oxygen in a larger proportion than one to eight.

A. Neutral Unsalifiable Vegetable Substances.

§ 307. The most remarkable neutral unsalifiable substances in the vegetable kingdom are the *woody fibre*, *starch*, *gum* or *mucilage*, and *sugar*. When perfectly pure they are all white, inodorous, and, with the exception of sugar, tasteless. They are all solid, insoluble in *pure* alcohol, and burn with an acid smoke, which reddens litmus paper.

1. *Woody Fibre.*

§ 308. This principal ingredient of all plants, but more especially of trees, is obtained by removing all soluble parts from wood; which is done by boiling it for a considerable time in water, and then exposing it with alcohol to a gentle heat.

Properties. It is white, inodorous, tasteless, and specifically lighter than water. It is insoluble in water, alcohol, or any *diluted* acid. Hence the fitness of hemp, flax, and cotton to be bleached with water and chlorine. *Concentrated* nitric, sulphuric, or muriatic acid destroys it or gives it a yellowish brown color. Concentrated sulphuric acid blackens it, and with the assistance of heat converts it into *charcoal*. When burnt in close vessels (dry distillation) it affords *tar* and vinegar or acetic acid.

2. *Starch.*

§ 309. *Starch* is obtained principally from all kinds of grain; but also from roots and a variety of other vegetable substances (particularly from potatoes), by grinding them to powder, and washing them frequently with cold water. When dissolved in *hot* water it forms a kind of glue or paste, used by bookbinders. It is soluble also in the acids, and when boiled in a solution of sulphuric acid, a sort of sugar (sugar of starch) is obtained.* Heated in close vessels it yields a sort of vinegar, similar to, though not exactly the same as that obtained from the dry distillation of woody fibre (§ 308).

3. *Gum or Mucilage.*

§ 310. *Mucilage or gum* occurs in different plants and their organs, and is used for technical and pharmaceutical purposes. When the substance is *fluid,* it is termed *mucilage;* when it occurs in a solid state it is called *gum.*

Properties. Both are easily soluble in water, in solutions of pure alkalies, and in diluted acids. *Gum,* however, is much harder and more brittle than mucilage. By strong sulphuric acid it may be decomposed into water, acid and charcoal. By the action of nitric acid it is converted into *Mucous acid,* an acid peculiar to mucilaginous substances, (which has not, as yet, been obtained from any other body in nature), hence the name. When distilled in a retort it yields, likewise, a sort of vinegar (acetous acid).

4. *Sugar.*

§ 311. This substance, which is known by its sweet taste, solubility in water, and capacity of yielding (when properly treated) spirituous liquors, may be obtained from several plants, from fruit, carrots, raisins, liquorice, manna, honey, &c; but more especially from the sugar-cane. The pithy substance of this well known plant of southern climes contains a sweet juice, which, with a small addition of slaked lime, is evaporated in copper vessels until it be-

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* The same sugar is obtained spontaneously in the germination of grains.

comes thick and tenacious. This mass, upon cooling, shoots into white crystals, which are afterwards separated from the liquid. The crystals occur in commerce as *raw sugar;* the remaining liquid is filled in hogsheads and sold as *molasses*. The raw sugar is afterwards again dissolved in lime-water and *refined* by bullocks' blood, which, in the process of boiling, floats on top and draws all impurities with it. The liquid is then cast into moulds, and upon cooling, forms the *loaf-sugar* of commerce. *Sugar* obtained in this manner is easily soluble in cold, but much better in warm water; from a solution of which it crystalizes in prisms, which are called *candied sugar.* Distilled with nitric acid, it becomes converted into *oxalic acid* (which will be described hereafter); but when strongly heated with it, into acetic acid and charcoal. Its application in domestic economy and medicine is sufficiently known.

B. Watery Unsalifiable Vegetable Substances.

§ 312. These occur either already formed by nature, or are prepared by a process of art. To the former belong the *volatile* or *essential oils*, the *fat oils*, wax, resin, &c; to the latter, *alcohol* and the various kinds of *ether*. All these substances are more or less fusible and soluble in *pure* alcohol. On *account of the great quantity of hydrogen which they contain, they are highly combustible, and serve, on this account, for fuel and light.*

1. *Volatile or Essential Oils.*

§ 313. These oils are distinguished by a strong, penetrating smell, and an acrid taste. They are obtained from the greatest variety of vegetable organs, viz: from flowers, fruits, wood, leaves, roots, &c, and differ much from each other in color, taste, smell, fluidity, and combustibility (as, for instance, the oils of camomile, of cloves, of peppermint, of wax, of cinnamon, &c); most of them, however, possess the following *properties:* They have generally a yellow color and a sharp taste; they boil more easily than water, are readily soluble in *alcohol*, (less so in water), burn spontaneously when mixed with nitric acid; and yield, as the product of their combustion, a resinous substance, or an acid. They thicken, when exposed for a long time to the atmosphere, on account of the oxygen which they absorb. By dry distillation in close vessels they are decomposed, and yield principally *carburetted hydrogen* and *charcoal* (see § 84 and § 73). They are used for the preparation of odoriferous waters, for spice, essences, drinks, &c.

Camphor, which, although in a solid state, belongs likewise to the essential oils, is not inflamed by nitric acid, but is converted into a distinct acid, which is called *Camphoric acid.* It is capable of crystalization; burns with an aromatic smoke, and in combination with the alkalies and oxides, forms a class of salts, which have received the appellation of *Camphorates.*

2. *Fat or Fixed Oils.*

§ 314. These oils, which are obtained by mechanical pressure, from certain vegetables, differ from each other according to the nature of the plant from which they are procured; hence the different properties of olive-oil, linseed-oil, nut-oil, oil of almonds, &c. With the exception of *cocoa-butter*, they are all *liquid*, have a yellow color, a faint, sweetish taste, and when perfectly pure, are destitute of smell. They are all specifically lighter than, and insoluble in water. They are decomposed by dry distillation, and combine with the alkalies to *soap.* All of them are highly inflammable, and eminently calculated for combustion. On account of the two last mentioned properties they are valuable articles of domestic economy.

When the fixed oils are mixed with lamp-black, charcoal, cotton, flax or wool, enough heat is given off to produce, in some instances, spontaneous combustion. The greatest precaution therefore ought to be used in cotton-mills, and in all other machineries where oil comes in contact with charcoal or oil.

3. *Resins.*

§ 315. The name of *resins* has been applied to the thickened juices of trees, which exude from the incisions or apertures made in their bark. To this class of bodies belong the gum-resins,* *asafœtida*, *gum-ammoniac*, *aloes*, *gamboge*, *myrrh*, *copal*, *dragon's blood*, *sandarach*, *turpentine*, *common resin*, *caoutchouc* or *India rubber*, *amber*, and a variety of other substances.

Most resins have a yellow color, and are, in a pure state, perfectly inodorous. Their taste is bitter ; they are easily fusible; but not soluble in water, although readily dissolved in spirits of wine, naphta, the fixed oils and the alkalies. They burn with a dense smoke, emitting a very disagreeable odor, and possess the remarkable property of becoming electric by friction. (These phenomena have been treated of in Natural Philosophy, Chapter VIII). The gum-resins are extensively used in medicine. Common resin is employed for physical and technical purposes, viz : for varnishes, electrical machines, salves, balsams, &c.

India rubber or *gum elastic* is obtained principally from two trees (the Hoevea Caoutchouc and Satropha Elastica) which grow in Brazil. When an incision is made in the bark of these trees, a milky juice exudes, which, in contact with the atmosphere, becomes soon changed into a solid, elastic substance, in which state it occurs in commerce. It is supposed to contain a considerable quantity of nitrogen, burns with a bright flame, is insoluble in water, but dissolves in ether and the volatile oils. It possesses the invaluable property of rendering cloth, leather, and other substances used as wearing apparel, impervious to water. It is on this account used for over-shoes, for water-proof boots, and such similar purposes. It absorbs also the marks made with lead-pencil upon paper, and is on this account an indispensable article to the artist and draftsman.

Remark. But few of the resinous substances have as yet been thoroughly examined ; their ingredients and the proportion in which they are combined are, therefore, far from being satisfactorily known.

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* So called from their apparent similarity to gum.

4. *Wax.*

§ 316. This substance is obtained from vegetable matter (berries, leaves, &c), as well as from bees. It differs from resin by its greater fusibility, ductibility, and peculiar smell. It is not so easily soluble in ether, or alcohol, as resin. It melts at about 150° Fahrenheit, and forms a transparent fluid, which, as it cools, gradually acquires consistency, and finally returns to the solid state. Upon decomposition it is found to contain 82 per cent of carbon, and 13 per cent of hydrogen; consequently, 95 per cent of combustible elements. This circumstance accounts sufficiently for the pure, bright flame of wax candles, preferred, sometimes, even to those of the fixed oils.

5. *Alcohol.*

§ 317. This substance, the product of fermentation of all sugary parts of plants, is contained in a greater or less quantity in all spirituous liquors, and produces their well-known intoxicating effects. It is considerably lighter than water, and its specific gravity affords a proof of its rectification, and the rectification of other spirits. (The lighter they are the less water is contained in them; the greater, therefore, is the quantity of water they contain).*

Alcohol, when pure, is perfectly colorless, has a peculiar strong, penetrating smell, a burning taste, and is easily volatilized. It boils at a much lower temperature than water (at 176° Fahrenheit), but has not, as yet, been made to congeal by any known method of producing artificial cold. Even mixed with water it requires several degrees below zero (over 35° below the freezing point of water) to freeze it. It unites *chemically* with water, evolving considerable heat during the combination. It is highly inflammable, absorbs most of the gases, and dissolves many of the vegetable acids, volatile oils, resins and bal-

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* Upon this principle are founded the wine, beer and brandy scales (see chemical apparatus, Fig. LVI and LVII, pages 33 — 35) which exhibit the strength of these liquors by the depth to which they immerse in them. Hence the appellation of 1st, 2d, 3d, 4th, and 5th proof.

sams. It acts also on iodine, sulphur, phosphorus, some of the alkalies, and some of the salts (chloride of lime, sulphate of iron, and some of the nitrates). *It preserves vegetable and animal substances from putrefaction;* but is itself decomposed, when passed through a red hot copper tube, into a fine, light soot, resembling lamp-black, and a great quantity of carbureted hydrogen, (one ounce of alcohol yielding several cubic feet of carbureted hydrogen).

Uses of Alcohol. Alcohol is used in a great number of preparations for domestic, technical, and medicinal purposes; and yet this highly important substance is composed of the same elements, as all vegetable matters we have thus far described; which proves how much depends upon the *proportion* in which simple bodies combine. Thus, while *woody fibre* consists of 4 equivalents of carbon and 4 of water; *starch* of 4 equivalents of carbon and 6 of water, and *sugar* of 4 equivalents of carbon and 8 of water, *alcohol* consists of 4 equivalents of carbon and 12 of water. The ratio, therefore, in which carbon unites with water in these four substances is as 1 to 1, 1 to 1½, 1 to 2, and 1 to 4; and in these different proportions alone lies the reason of the immense difference in the properties of *woody fibre*, *starch*, *sugar*, and *alcohol!!*

The process of Fermentation will be described hereafter (Chap. VII), under the head of spontaneous decomposition of organic substances.

6. *Ether and Naphta.*

§ 318. When alcohol is distilled with the different acids, it becomes converted into *Ether*, a liquid which is lighter than alcohol, mixes in all proportions with the volatile oils, and dissolves wax, resin, vegetable extracts and acids, and some of the alkalies. After distillation a yellowish liquid remains, which, when purified with a solution of potash, will float on top, and is called *oil of wine.* This combines again with the acids, and forms a class of substances known by the name of *Naphtas.* Both products, the *ethers* and *naphtas*, are strongly odoriferous, extremely volatile, similar to the volatile oils, but more easily converted into vapor, more inflammable, and specifically lighter than alcohol. The different kinds of ether are distinguished from each other by prefixing the name of the acid from which they are derived. Thus, the ether prepared from alcohol and sulphuric acid is called *sulphuric* ether; that which is obtained from muriatic acid and alcohol, is called *muriatic ether*, and so of the rest. A similar nomenclature has been adopted for the naphtas.

Sulphuric ether is by far the most important substance of them all, and extensively used in medicine. It is obtained by distilling together equal volumes of alcohol and sulphuric acid.

II. SALIFIABLE VEGETABLE BASES.

§ 319. This class of vegetable substances, the result of the discoveries of modern chemists, contains about 30 different bodies, extracted mostly from narcotic and medicinal plants, by the action of magnesia.* They are generally white, have a sharp, bitter taste, may be obtained in crystals or as a powder, and change, when burnt or in a state of moisture, red vegetable colors into blue. They are not easily soluble in water, better in ether, but most readily in alcohol. With the acids, (particularly the sulphuric, nitric, and muriatic acids) they form salts which are soluble in water, and easily decomposed by potash. Their ultimate principles are oxygen, hydrogen, carbon, and nitrogen; the latter element only in a proportion of from 4 to 8 per cent. Many of them are poisonous or affect the animal body.

The salts which these bases form in combination with the acids, are denominated after the acids according to the rules laid down in Chapter IV, § 232.

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* The names are, *Nicotine*, *Chinine*, *Cinchonine*, *Gentianine*, *Daphnine*, *Corydaline*, *Zanthopicrite*, *Hesperidine*, *Guaranine*, *pure bitter extract*, *Morphium*, *Opium* (*Narcotine*), *Picrotoxine*, *Strychnine*, *Brucine*, *Solanine*, *Coffeeine*, *Narcotic extract*, *Delphinine*, *Veratrine* (*Sabadilline*), *Emetine*, *Piperin*, *Plumbagin*, *Jamaicin*, *Surinamin*, *Asparagin*, *Olivil*, and several other organic bases, whose existence, however, is not yet sufficiently proved.

III. VEGETABLE ACIDS.

[In these substances the hydrogen is to the oxygen in a less proportion than is necessary to form water; that is, in a less proportion than 1 to 8. (Compare § 25, page 75).]

§ 320. *Characteristics of vegetable acids.* The vegetable acids are easily distinguished from the neutral or salifiable vegetable substances, by their sour taste, by changing the blue colors of vegetables into red, and by their combination with the oxides of the mineral and vegetable kingdoms. They are either capable of crystalization *(fixed)*, of distillation *(liquid)*, or of sublimation *(volatile)*. They occur either already formed, in particular organs of plants, or as salts, combined with inorganic or organic bases, and are of great application in domestic economy, in medicine and in the arts.

A. FIXED VEGETABLE ACIDS.

§ 321. The vegetable acids belonging to this class are generally white, and easily soluble in water. The most remarkable among them are *Tartaric acid*, *Citric acid*, *Malic acid*, *Gallic acid*, *Vegetable jelly* and *humous acid*, (in several roots, berries and in potatoes).

1. *Tartaric Acid.*

§ 322. This acid occurs, in its simple form, in tamarinds, in grapes, pine-apples and pepper. It may also be obtained from the well-known salt, *cream of tartar* (tartarate of potash) by boiling it with an admixture of chalk, white marble or oyster-shells. The tartarate of lime thence obtained as a precipitate is gently heated with oil of vitriol, the liquid afterwards evaporated to thickness, and decanted from the sulphate of lime (gypsum) which falls to the bottom. This liquid, upon further evaporation, or upon cooling, forms regular, prismatic crystals, of a strong acid taste, which are easily soluble in water, and fusible. They unite with the different alkaline and earthy bases, and form a class of salts known by the name of *tartrates*. The most remarkable among them is the *tartrate of potash* or *vegetable salt*, which is formed by neutralizing tartar with carbonate of potash ; and the

Bi-tartrate of potash or *tartar* is a solid substance, spontaneously deposited by all kinds of wine, which by being dissolved, filtered, and treated with clay, yields the cream of tartar, from which tartaric acid is prepared.

2. *Citric Acid.*

§ 323. This occurs in its simple form, or mixed with *malic* acid (see the following section) in a variety of fruits. It may also be procured by the action of *nitric acid* or chlorine on many organic compounds. The way in which it is commonly obtained is by saturating boiling lemon or lime juice with carbonate of lime (see Chap. IV, § 280). To the citrate of lime thus obtained, boiling water and oil of vitriol is added, and the liquid afterwards filtered and evaporated until the acid is obtained in form of crystals. Citric acid becomes spontaneously decomposed and covered with a scum, even in closed vessels, and slowly heated with alcohol it becomes converted into vinegar.* The salts formed by the combination of citric acid with the different salifiable bases are called citrates.

3. *Malic Acid.*

§ 324. This acid is next to acetic acid, and oxalic acid (see § 334 and § 325) most generally distributed in the vegetable kingdom, and occurs in the roots, stalks, blossoms, and fruits of a great many plants. It is generally extracted from the berries of the *sorb* or *service tree.* It is liquid, soluble in water, but crystalizes only with great difficulty. It undergoes spontaneous decomposition, and is by nitric acid converted into *oxalic* acid. The salts of this acid are called *malates.*

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* Gmehlen's Chemistry, Heidelberg, 1830.

4. *Oxalic Acid.*

§ 325. The mode of obtaining oxalic acid has already been described in § 324. It has a strong, sour taste, changes blue vegetable colors into red, and forms, upon evaporation, regular crystals, which by a red heat are again decomposed, and leave nothing but charcoal. They are soluble in water and boiling alcohol. With the different mineral bases they form a class of salts, which are distinguished by the name of *oxalates*. The principal ones are *oxalate of potash, soda, lime, strontia, ammonia, baryta,* and *magnesia.*

5. *Gallic Acid.*

§ 326. *Gallic acid* is contained in all astringent vegetable substances, particularly in the bark of trees; and is chiefly obtained by dissolving powdered gall-nut in water, at a gentle heat; when the liquid is filtered and exposed to the atmosphere it is covered with a thin scum, which from time to time must be removed. When evaporated to about half its volume it is decanted. The sediment is then again digested with water and the same process is repeated several times. The residue is afterwards dissolved in *hot* water, from which, upon cooling and filtering, the acid shoots in regular crystals.

Gallic acid has a sharp, sweetish (not sour) taste. When sublimed it reddens litmus paper; melts, at a gentle heat, to a colorless oil, and evaporates, when heated, with white fumes and a faint smell, leaving nothing but a little charcoal. When saturated with *carbonate of potash* or *muriate of tin* a yellowish precipitate is formed, which is known by the name of *tan*, and is used in the preparation of leather. Gallic acid is a principal ingredient of writing ink.

6. *Vegetable Jelly, or Pectic acid.*

§ 327. This acid is obtained from the tremulous, soft substance deposited by the juice of certain fruits. It may be purified by decanting the juice and washing it with a little cold water. It appears, when dry, in transparent leaves, which do not adhere to the sides of the vessel — has, when moist, a decidedly sour taste, and reddens litmus paper. It combines readily with the alkalies and other salifiable bases.

7. *Bitumous Acid.*

§ 328. Bitumous acid is produced from turf, mineral pitch, bituminous wood, mold and such similar substances, by dissolving them in liquid potash and precipitating the solution by the addition of some other acid. The acid thus obtained appears in brown flakes, but when perfectly dry it is a brown, brittle mass, of great lustre. By dry distillation it becomes decomposed into carbonic acid, carbureted hydrogen gas, water, oil, and acetic acid.

The same acid is also produced spontaneously during the putrefaction of a great many vegetable substances, particularly of that of the *woody fibre.* (See Chap. VII, spontaneous decomposition of vegetable substances).

B. Vegetable Acids, Capable of Sublimation.

§ 329. The most important acids belonging to this class are the *benzoic, succinic,* and *boletic acids,* which are found, already formed, in many plants, but may be obtained also by the combustion of a number of vegetable substances.

1. *Benzoic Acid.*

§ 330. Benzoic acid occurs in *dragons' blood, Peruvian balsam,* and a gum (found at Botany Bay) called *Benzoïn* (hence its name); also in a variety of volatile and essential oils; in cloves, and in some of the liquids of quadrupeds. It is now generally obtained by heating benzoïn with dilute sulphuric acid, or by melting it at a gentle heat. It crystalizes in white, soft needles of the appearance of mother of pearl, reddens blue vegetable colors, melts at a gentle heat, like fat, and evaporates at its melting point in form of a white smoke. It combines with the mineral alkalies and oxides, and forms a kind of salts called benzöates.

2. *Succinic Acid.*

§ 331. This acid occurs, already formed, in *amber*, and is obtained from it by slow distillation. It is also procured by boiling powdered amber in water. It forms white, transparent crystals, melts at a gentle heat, and becomes converted into white, sharp vapors, which condense into flakes, and finally into long, crystaline needles. It combines with the mineral and volatile alkalies (ammonia). The salts which it forms are called *succinates.*

3. *Boletic Acid.*

§ 332. This acid is obtained from the juice of a particular plant, called Boletus Pseudoignarius. It crystalizes in four-sided prisms. Its taste is similar to tartaric acid. In fire it becomes converted into white, suffocating vapors.

C. LIQUID VEGETABLE ACIDS (CAPABLE OF DISTILLATION).

§ 333. To this class belong *acetic acid*, from which vinegar is obtained, *Prussic acid*, and *cyanic acid.* The two last have already been described in mineral chemistry (§ 89, — § 92); because they can be produced by *art* from the chemical combination of their elements. But they occur also in vegetables, and seem, indeed, to be an intermediate link between mineral and vegetable formation.

It will appear from reviewing § 89 — § 92 that Prussic and cyanic acids are *ternary* combinations of *carbon*, *nitrogen* and *oxygen*, and on this account already exceptions to other *in*organic formations, which are generally products of two and two elements. (Compare the remark, page 253).

1. *Acetic Acid (Vinegar).*

§ 334. This acid occurs either in its simple form, or mixed with potash and lime in the juice of a great many plants, particularly in the sap of trees, and in some mineral waters. It is also formed at the spontaneous decomposition of vegetable substances, especially such as contain more or less alcohol — in grapes, fruits, &c, (see Chap. VII, *acetous* fermentation) — and at the dry distillation or imperfect combustion of plants. It is the principal ingredient of common vinegar, which consists chiefly of *acetic acid, mucilage, coloring matter* and *water.*

Acetic acid is commonly prepared by mixing wine, cider, beer, or dilute spirit of wine with vinegar, and exposing the mixture in an open vessel (for several weeks) to a heat of about from 80 to 90° Fahrenheit. If vinegar be distilled to thickness, the residue is almost pure acetic acid, mixed with a small quantity of water. If distilled vinegar be exposed to severe cold, part of its water freezes, and the remaining vinegar is much stronger than before.

Properties of acetic acid. Acetic acid in a pure state, as *radical vinegar*, is colorless, possesses a well-known, strong smell, a *very* acid taste, and is capable of being entirely volatilized. It boils a little above 212°, and freezes at about 27° below the freezing point of water. It acts speedily on all oxidable metals, such as iron, lead, tin, copper, &c, and combines with them, as well as with other mineral oxides, and forms with them a distinct class of salts — the *acetates.* The most remarkable among these are the *acetates of potash* (arcanum tartari), of *soda, baryta, magnesia, copper,* and *lead.* The acetate of lead is produced in great abundance at the manufacture of *sugar of lead.* Most of the other acetates are used in medicine, and for technical purposes.

Acetic acid combines also with sugar, gum, the essential oils, alcohol and other organic substances. When, in form of vapors, it is passed through a red-hot iron tube, it is decomposed into carbonic acid and carbureted hydrogen gas, which proves that acetic acid differs in its composition from alcohol, only in the greater proportion of its oxygen.

2. *Prussic Acid.*

§ 335. This volatile and most poisonous acid is found in several plants, particularly in almonds, in the stones of peaches, plumbs, cherries, &c, also in the leaves and bark of trees, &c; but is generally obtained by the combustion with potash of several *animal* substances; for instance, the blood, which contains its elements, carbon, nitrogen, and oxygen. When Prussic acid is treated with blood, alum, and vitriol of iron, it yields the celebrated ***Berlin*** or ***Prussian blue***, which is an extensive article of commerce. The other properties of Prussic acid have already been described in Chapter II, § 91 and 92. The same holds of

3. *Cyanic Acid,*

which has been spoken of in Chap. II, § 89.

REMARK. Besides the vegetable acids here described, there are yet a number of others, which have not, however, been sufficiently examined, and are not yet extensively used in the arts; on this account it may perhaps be well to omit them in an elementary treatise.

IV. VEGETABLE SUBSTANCES OF AN UNDETERMINED NATURE.

§ 336. The vegetable substances belonging to this class and their chemical composition are far from being satisfactorily known. But few of them have been obtained in their simple forms, and there is hardly one among them, the proportion of whose elements is accurately determined. They are nevertheless of great importance to the arts, with regard to which they may be divided into three classes: *coloring matters*, *vegetable extracts* and *fermentous principles.*

1. *Coloring Matters.*

§ 337. Of these, a great number is contained in the most heterogeneous plants, and it may, perhaps, be said that not half of them are as yet sufficiently employed in the arts. The following are the most remarkable :

1. The RED color of *alizarine, lac-lake, cam-wood, safflower* (carthamus seed), sanders (red) wood, *amatto*, and *dragons' blood.*

2. The BLUE color of *litmus, indigo,* and *woad.*

3. The YELLOW color of *Fernambucco-wood, zaffer, saffron, dyer's weed (weld), fustic, turmeric, gamboge,* and *rhubarb.*

4. The GREEN color of the *black-thorn berry*, of the leaves of trees ; and

5. The FALLOW color of *Venice-sumac* and *sanders.*

Some of these dyeing stuffs are soluble in water or dilute spirits of wine, and are called *coloring extracts ;* others, on the contrary, are only entirely dissolved in alcohol, like the red-color of safflower, of gamboge, &c. These are called *resinous colors.* They are all bleached by chlorine and muriatic acid (indigo not excepted). Most of them exhibit a different color when dissolved with the alkalies, ammonia, potash, or soda ; the violet becomes violet-green ; the yellow becomes brown, &c. Concentrated acids destroy most of them, as we have seen in treating of the different acids. When heated they burn with a sour smoke, and leave, after combustion, a small portion of ashes.

Some of the *salts,* when mixed with different solutions of coloring matters, part with the oxides of which they are composed, and leave them to unite with the vegetable substances, the color of which is by this means, materially changed. The salts most liable to this decomposition are *alum, muriate (chloride) of tin,* acetate of lead), and vitriol of iron. Hence their use in dyeing.

§ 338. *Indigo* belongs to the few coloring matters, which are obtained from vegetables in a *pure* state. There are various kinds of indigo, viz : red-indigo, green-indigo, blue-indigo, &c. The elements of those which are best known are oxygen, hydrogen, carbon and nitrogen. Indigo is extensively used in dyeing, on which account it is a valuable article of commerce.

2. *Vegetable Extracts.*

§ 339. These were formerly divided into sweet, sour, coloring, resinous, glutinous, narcotic, and bitter extracts. most of them, however, have, of late, been found to belong to other classes of vegetable matter; wherefore those only are, properly speaking, *vegetable extracts, which are soluble in water and dilute spirits of wine, incapable of crystalization, and a solution of which, when exposed to the atmosphere, precipitates in brown flakes.*

The bitter taste which most of them possess, is more or less variable; but all agree in the following properties:

1. When recently extracted from the plant they are brown, brittle, transparent, and specifically lighter than water.
2. They absorb moisture from the atmosphere, and leave, when shaken with water, a scum at the surface.
3. They are soluble in liquid potash; but not in pure alcohol, ether or the essential oils.
4. They become soft by heat, burn (at least, some of them) and leave a small portion of ashes.

None of them have, as yet, been obtained in their simple form.

3. *Fermentous Principles.*

§ 340. To this class of bodies belong those vegetable substances which, in combination with *sugary* bodies, produce the spontaneous process of fermentation (see Chap. VII — spontaneous decomposition of vegetables). They occur generally in seeds and fruits, more seldom in stalks and leaves of plants. They are neither soluble in water nor alcohol; but readily dissolved in diluted potash, and in sulphuric or muriatic acid. When exposed to moisture they emit a highly disagreeable smell, similar to putrefying meat; proving thereby that *nitrogen* enters into their composition. They may be divided into *lees (dregs), vegetable albumen*, and *gluten.*

a. Lees (dregs).

§ 341. Lees or dregs are the sediment deposited by all fermentous liquors. They form a yellowish-grey, smeary mass, which, when washed with water has a peculiar smell and bitter taste. When perfectly dry, it forms a yellowish-brown, brittle body, which is but sparingly soluble in *hot* water and boiling alcohol.

b. Vegetable Albumen.

§ 342. This is a substance more or less contained in all vegetable juices, from which it may be extracted by means of cold water, in a manner similar to starch (see § 309). It contains a considerable quantity of nitrogen. When boiled it expands in a sort of foam, like the white of an egg (hence the name); and when dry forms a grey, brittle mass, which becomes slightly decomposed when boiled with alcohol.

c. Gluten.

§ 343. This substance is principally obtained from wheat flour, which by the gradual addition of water is formed into a soft, ductile paste. This is afterwards washed with water, while the paste is worked between the fingers, until the water flows off in a clear stream. By this process the starch and vegetable albumen (see last section) are carried off, and the pure gluten remains in the hands. It is of a grey color, possessing almost as much elasticity as elastic gum, and may be drawn out and will contract again like this substance. It is insoluble in water, adheres to all solid substances, and appears, when dry, as a hard, brittle, greyish-brown body. When moist it undergoes putrefaction, and emits a very offensive smell. When, in a state of moisture, it is boiled in alcohol, it becomes decomposed into three distinct parts, viz: a yellowish, glutinous mass which remains dissolved in the alcohol — a sort of mucilage which is precipitated — and a third substance which remains undissolved.

The precise proportions of the elements of gluten are not yet ascertained; but whatever its chemical composition may be, it belongs certainly to the most important vegetable substances, and affords the principal nutriment contained in plants.

RECAPITULATION.

Questions for Reviewing the most important Principles contained in Chapter V.

A. QUESTIONS ON THE GENERAL REMARKS ON THE DIFFERENCE BETWEEN ORGANIC AND INORGANIC BODIES.

[§ 297.] Do the bodies in animated nature obey the same laws to which they are subjected in dead matter? As what may every living body be considered? *Through what two periods must all bodies pass, which are endowed with life?*

[§ 298.] In what consists principally the difference between organized and unorganized matter?

Are the *in*organic elements of plants and animals also perishable? What then is it that is destroyed by the death of the animal or plant? In what is the life of the plant or animal seated? What must this directing agent be superior to?

[§ 299.] What are we in *in*organic chemistry generally able to do? Is this also possible with regard to plants or animals? What do organic bodies even need for their support?

Give examples.

[§ 300.] In what do the chemical processes of plants and animals take place? What are these vessels called?

Do we know anything as regards the manner in which these processes are carried on? Do we know for certain whether the different elements which we have discovered in plants and animals are actually chemically combined with one another, or whether they exist only in a state of mixture?

[§ 301.] Where are the products of vegetables which are used in domestic economy or in the arts seated? What processes are required for the collection of those products which are diffused throughout the whole plant?

[§ 302.] What are the immediate ingredients of plants, which are obtained by chemical analysis?

[§ 303.] By what means may the liquid and solid parts of plants be again decomposed? What are the elements resulting from their decomposition?

Give examples.

[§ 304.] How many different elements result from the decomposition of the more remote ingredients of plants into their ultimate principles? Which elements are the ultimate principles of plants?

[§ 305.] Into what four classes may all vegetable matter be divided?

QUESTIONS ON THE UNSALIFIABLE VEGETABLE SUBSTANCES.

[§ 306.] Into what two classes may all unsalifiable vegetable substances be again divided? What vegetable substances are called neutral? What substances are called watery?

[§ 307.] Which are the most remarkable neutral unsalifiable substances from the vegetable kingdom?

[§ 308.] How is *woody fibre* obtained? What are its properties?

[§ 309.] How is starch obtained? What are its properties?

[§ 310.] Where does mucilage or gum occur? When is it termed mucilage? When, gum? What are the properties of these substances? What are the peculiar properties of gum? Into what does it become converted by the action of nitric acid? What does it yield when distilled in a retort?

[§ 311.] From what plants is sugar obtained? By what process is the raw sugar of commerce obtained from the sugar-cane? What is the remaining liquid called after the sugar shoots in regular crystals? By what means is the raw sugar refined, and made loaf sugar? How is candied sugar obtained? Into what does sugar become converted when distilled with nitric acid?

[§ 312.] Where do watery unsalifiable substances occur? What watery, unsalifiable vegetable substances occur in nature? Which are products of art? What property do they all possess in a high degree?

[§ 313.] By what properties are the volatile or essential oils distinguished? From what vegetable organs are they obtained? What properties do they generally possess? For what purposes are they used?

To what class of oils does camphor belong? Into what does it become converted by nitric acid? What does it form in combination with the alkalies and oxides?

[§ 314.] By what means are the fats or fixed oils obtained? What are their properties? What do they form when combined with the alkalies? For what purposes are they especially calculated?

What may take place when the fixed oils are mixed with lamp-black, charcoal, cotton, flax, or wool? What ought this to teach us?

[§ 315.] To what substances has the name of resins been applied? What substances belong to this class of bodies?

What is the color and property of most resins? For what purposes are they used?

How is India rubber or gum elastic obtained? What substance is it supposed to contain in considerable quantity? What invaluable property does it possess? For what purposes is it, on this account, used?

[§ 316.] From what substances is wax obtained? What are its properties? Of what elements is it composed? How many per cent of carbon and hydrogen does it contain? What does this account for?

[§ 317.] What sort of product is alcohol? Where is it contained?

What are the properties of pure alcohol? How does it act upon animal and vegetable substances? By what means may it be decomposed? What does it yield when decomposed?

What is the difference in the chemical composition between woody fibre, starch, sugar, and alcohol? What, therefore, must be founded in their different proportions?

[§ 318.] Into what does alcohol become converted when distilled with the different acids? What is the yellowish liquid called which remains? What does oil of wine form when again combined with the acids? What properties do both products possess? How are the different kinds of ether distinguished from one another? *Give examples.* What kind of ether is extensively used in medicine? By what means is it obtained?

QUESTIONS ON THE SALIFIABLE VEGETABLE BASES.

[§ 319.] How many different bodies belong to this class? What are their properties? What do they form with the acids? What are their ultimate principles? How are the salts denominated which these substances form with the various acids?

QUESTIONS ON THE VEGETABLE ACIDS.

[§ 320.] By what means are the vegetable acids distinguished from the neutral or unsalifiable vegetable substances? In what state do they occur?

A. Fixed Vegetable Acids.

[§ 321.] By what properties are the fixed vegetable acids generally distinguished? What are the most remarkable vegetable acids?

[§ 322.] In what plants does tartaric acid occur in its simple form? From what other substance may it yet be obtained? In what way? What sort of salt does tartaric acid form when united with the alkalies? How is this salt obtained?

What sort of substance is bi-tartrate of potash, or tartar?

[§ 323.] Where does citric acid occur? How may it be produced by art? In what way is it commonly obtained? Into what substance does citric acid become converted when slowly heated with alcohol? What are the salts called which citric acid forms in combination with the different salifiable bases?

[§ 324.] In what vegetable substances does malic acid occur? From what kind of berries is it commonly extracted? What are its properties? What are the salts called which it forms in combination with the salifiable bases?

[§ 325.] What are the properties of oxalic acid? What class of salts does it form with the different salifiable bases? What are the most remarkable salts belonging to that class?

[§ 326.] In what substances is gallic acid contained? In what way is it chiefly obtained?

What are the principal properties of gallic acid? What sort of precipitate is obtained from a saturation of gallic acid with carbonate of potash, or muriate of tin? Of what is gallic acid a principal ingredient?

[§ 327.] How is vegetable jelly obtained? How may it be purified? What shape does it exhibit, when dry? What kind of taste has it in a state of moisture? With what substances does it combine?

[§ 328.] From what substances is bitumous acid produced? What properties does this acid possess, when perfectly dry? Into what substances does it become decomposed by dry distillation?

During what other process is bitumous acid produced?

[§ 329.] Which are the most important acids belonging to the class of vegetable acids, capable of sublimation? Where are these acids found? How may they be obtained?

[§ 330.] Where does benzoic acid occur? In what way is it generally obtained? What are its properties? What class of salts does it form in combination with the mineral alkalies and oxides?

[§ 331.] Where does succinic acid occur? By what means may it be produced? What are its properties? What class of salts does it form with the mineral and volatile alkalies?

[§ 332.] From what substance is boletic acid obtained? What are its properties?

[§ 333.] What acids belong to the liquid vegetable acids? Where do Prussic and cyanic acid occur? What do these two acids seem to be? Of what elements are they compounded?

[§ 334.] Where does acetic acid occur? By what other processes is it formed? Of what substance does acetic acid form the principal ingredient? What is the composition of vinegar?

How is vinegar prepared? What sort of residue is obtained when vinegar is distilled to thickness? By what means may vinegar be rectified (made stronger)?

What are the principal properties of acetic acid? What class of salts does it form with the mineral oxides? Which are the most remarkable of these salts?

With what other *organic* substances does acetic acid yet combine? In what consists the difference between the chemical composition of vinegar and alcohol?

[§ 335.] From what substances may Prussic acid be obtained? What does Prussic acid yield when treated with blood, alum, and vitriol of iron?

QUESTIONS ON VEGETABLE SUBSTANCES OF AN INDETERMINED NATURE.

[§ 336.] Into how many classes may all vegetable substances of an indetermined nature be divided? What are the three classes?

[§ 337.] Which are the most remarkable coloring matters found in plants?

What are those dyeing stuffs called which are soluble in water, or dilute spirits of wine? What colors are only entirely dissolved in alcohol? How are they all acted upon by chlorine and muriatic acid? What do all of them leave after combustion?

What becomes of some of the salts when mixed with different solutions of coloring matter? Which salts are most liable to this decomposition?

[§ 338.] In what state is indigo obtained from vegetables? What are the elements of the different kinds of indigo?

[§ 339.] How were the different vegetable extracts formerly divided? What substances are properly called vegetable extracts? How do most of them taste?

By what properties are they all more or less distinguished? Has any of them as yet been obtained in its simple form?

[§ 340.] What vegetable substances are called fermentous principles? Where do they occur? What are their properties? Into how many different substances may they be divided?

[§ 341.] What are lees or dregs? What sort of mass do they form? What are the properties of this mass?

[§ 342.] What sort of substance is vegetable albumen? In what way may it be obtained? What does it form when heated or boiled? What properties does it possess when perfectly dry?

[§ 343.] How is gluten obtained? What are its properties? Into what three distinct substances does it become decomposed, when, in a state of moisture, it is boiled in alcohol?

Why does gluten belong to the most important vegetable substances?

CHAPTER VI.

ANIMAL CHEMISTRY.*

§ 344. *Ingredients of the Animal Body.* The animal body consists, like the plant, of immediate, more remote, and ultimate chemical ingredients. The immediate ingredients, which are discovered by the chemical investigation of animal substances, are

1. *Gaseous;* viz: *Carbureted hydrogen gas, Carbonic acid gas, Nitrogen, Oxygen,* &c.
2. *Liquid;* like the *Gastric juice* of the stomach, *Saliva, mucilage, bile, chyle, blood, milk,* &c.
3. *Soft, and easily melting.* To these belong the *greasy substance in the joints,* the *marrow,* the *fat,* the *humors of the ear* and *eyes,* &c.
4. *Soft and Elastic;* like the *muscles,* the *flesh, ligaments, tendons,* the *membranes, cartilage, hair, scales, feathers, wool,* &c.
5. *Hard;* the *bones, horns,* and *hoofs* of animals, the *claws,* and *nails,* and the *coverings of insects.*

§ 345. These ingredients of the animal body, may,

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* We shall not dwell, here, upon the principal difference between plants and animals, which undoubtedly consists in sensation and locomotion of the latter. This is a more proper subject for Natural History and Physiology. Chemistry treats only of the combination and analysis of substances, as far as the elements of matter are concerned, and with regard to these, the remarks made on the composition of vegetables, (§ 297 — 301), apply equally to that of animals.

like those of the plants, be divided into *combustible* and *incombustible* substances. The combustible ones are again,

1. *Neutral;* in which the hydrogen is to oxygen in the same proportion as in water, (as 1 to 8), like the sugar of milk.

2. *Watery;* in which the hydrogen is to the oxygen in a larger proportion than in water, (in a larger proportion than 1 to 8), like the oils and fats.

3. *Acetous;* in which the hydrogen is to the oxygen in a less proportion than is necessary to form water, (in a less proportion than 1 to 8). To this class belong the animal acids.

4. *Undetermined;* like fibrin, glutin, cheese, &c.

The incombustible animal substances, which remain as ashes at the combustion of those we have just enumerated, are either *oxides* or *salts.* The principal oxides obtained by the combustion of animal matters, are *soda, silicous earth, oxide of iron,* and of *manganese.* The salts produced in the same manner are *carbonate of lime, and potash, muriate of soda,* (chloride of potassium), *sulphate of lime,* and *phosphate of lime* and *magnesia.*

§ 346. The *ultimate* principles or elements of the animal body are the same as those of the plants; viz; *hydrogen, oxygen, carbon,* and *nitrogen;* to which may be added a small proportion of sulphur, phosphorus, magnesium, and iron; but the proportion, in which these elements are combined, are essentially different from those in which they are compounded in vegetables. That nitrogen enters much more into the composition of animal substances than it does in that of vegetables, is sufficiently evident from the highly offensive smell which accompanies their spontaneous decomposition, owing to the ammonia, (a compound of nitrogen), and sulphureted hydrogen, which are then given off in great quantities.

Among the various parts of which the animal body is composed, those enumerated in § 344 and § 345 are by far the most interesting; we shall proceed now to describe those among them, a knowledge of which is indispensable to a proper understanding of our own physical organization.

1. *Animal Jelly, (Glue).*

§ 347. *Animal Jelly,* or glue, (or at least, a substance which by boiling with water becomes changed into jelly),* composes the cellular membranes, the skin, ligaments, and tendons, as well as the cartilage, and the cartilaginous parts of the bones of most animals. It is obtained chiefly by boiling these substances, (more especially the skins and bones) for a considerable time, after having previously washed them with cold water. It possesses generally a pale yellowish color, and is semi-transparent and elastic ; but when dry, it is solid, brittle, and of a lamellar texture. It is specifically heavier than water, without taste or smell, and does in no way effect vegetable colors. A solution of animal glue, or the gelatinous substance it forms with water, soon undergoes spontaneous decomposition, accompanied by a fetid smell, produced by the ammonia which is given off during this process.

The connecting power of glue is weakened by boiling ; but its solubility is thereby increased. When submitted to dry distillation, it is decomposed into a highly inflammable gas, carbonate of ammonia, a brown watery liquid, *(spiritus* cornu cervi), a brown sort of tar, and a quantity of animal charcoal, which, however, is less combustible than vegetable charcoal, on account of the nitrogen which it contains.

Gelatine (animal glue mixed with water) is also soluble in the acids, and in solutions of pure alkalies. It combines with muriatic and several other dilute acids, and with a variety of mineral bases and salts.

2. *Albumen.*

§ 348. This substance occurs in the eggs of birds, lizards, fishes, and insects ; in the chyle, the blood, and in several secretions of the animal body. Of its occurrency in the vegetable kingdom we have already spoken n the preceding chapter, (§ 342). The *white* of eggs contains much pure albumen, mixed, however, with a con-

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* Many distinguished philosophers deny the existence of *already formed* jelly in the animal body ; but consider it as a product of a gluey substance boiled with water.

siderable portion of water. By evaporating this, albumen is obtained in a solid state.

Properties. When albumen is exposed to a temperature of about 174° Fahrenheit, it becomes converted into a white, solid, somewhat elastic mass; which when perfectly dry, changes into yellow, becomes hard and brittle, is insoluble in water, and resists putrefaction for a considerable length of time; whereas, in a coagulated state, it speedily undergoes spontaneous decomposition. A solution of albumen in water *coagulates* at a boiling heat, and so much is this a characteristic of albumen, that even a solution of one single part of it in one thousand parts of water, becomes opaque at a temperature of 212° Fahrenheit. When burned in an open fire, it emits a smell like burnt feathers, and leaves charcoal. From a solution in water, it may be precipitated by *nitric*, *sulphuric*, and *muriatic* acid. It combines with the mineral bases and salts, and with lime forms a perfectly solid mass. By dry distillation it is decomposed into its elements, *hydrogen*, *carbonic acid gas*, *prussic acid*, *water*, *carbonate of ammonia*, *nitrogen*, *and carbon.*

3. *Blood.*

§ 349. This liquid, into which all nutriment is converted, and which by its circulation renews constantly the whole organization of the body, consists principally of three parts, viz: 1, a certain fibrous substance termed *fibrin;* 2d, of albumen, (which is the cause of its coagulation by heat and the acids); 3d, of a small variable proportion of mineral salts, (chloride of sodium, potassium, phosphate of lime, &c.). These substances have for each other but little affinity; for in a very short time after blood has been drawn from the vein, it coagulates, that is, becomes separated into two very distinct parts, viz. into a yellowish-green liquid, which exudes from below the surface, the *serum*, and a remaining solid substance, called the *cruor*.

The *cerum* consists of a solution of albumen, gelatine, and salt of sodium, potassium, and magnesia. The *cruor* can, by washing with water, again be separated into *fibrin* and *coloring matter*. The latter ingredient consists of nearly the same elements as albumen, (see the preceding section), with an almost imperceptible addition of oxide of iron.*

Chemical Changes in the Nature of Blood, occasioned by Respiration.

§ 350. The process of respiration consists, as is generally known, in two distinct operations. By the first, which is termed *inspiration,* a certain portion of atmospheric air is taken into the lungs, which after coming in contact with the blood, and suffering certain chemical changes, is by the second again expelled. The *changes* which atmospheric air undergoes by the process of respiration, are the following:

1. The whole volume of air is considerably diminished.
2. The quantity of oxygen is reduced.
3. It receives an addition of vapors of water, and, in men, also of nitrogen, together with a considerable portion of carbonic acid gas.

The changes produced in the *blood* by the same cause, consists principally,

1. In an *absorption of oxygen.*†
2. In a *diminution of carbonic acid and water*, and
3. In a *subsequently lighter color*, owing to the diminution of carbon.

An account of the absorption of oxygen gas (1) the process of respiration is generally called the *oxidation of the blood.* Some philosophers, however, call it the *decarbonization* of the blood, because a great quantity of *carbon* is expelled. How far the process of respiration is necessary to animal life, and what important end in the constitution of man and animals is thereby answered, is a subject for Physiology.

4. *Of the Milk.*

§ 351. This well known white liquid, which exists in

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* See Gmehlin's Chemistry, Heidelberg, 1830.

† Some Philosophers pretend also of nitrogen.

the breast of female quadrupeds, and in all other animals which bring forth living young ones, is composed of the following ingredients:

1. Water, (by far in the greatest proportion).
2. A small portion of pure acetic acid.
3. A fat substance, called *butter*.
4. Animal albumen.
5. Mucilage.
6. Sugar of milk; and
7. A small proportion of salts of potash, lime, and magnesia.

These substances appear to be partly in a state of solution, and partly only suspended in the liquid. When milk is boiled, a portion of its animal albumen collects at its surface in form of a pellicle, (small skin), which as soon as it is removed, is replaced by another. If it falls to the bottom, it becomes burnt, and imparts to the milk a peculiar, disagreeable taste. It is probable that heated milk would entirely coagulate, like albumen, if this latter substance were not diffused through a great portion of water.

5. *Butter.*

§ 352. If milk is suffered to stand, even excluded from the atmosphere, a spontaneous decomposition takes place — an oily unctuous substance rises to the top, which is called *cream*. This is by agitation (churning) again separated into a substance called *butter*, and a thin fluid resembling milk deprived of its cream. Butter is a valuable article of domestic economy; possesses generally a yellow color, a peculiar agreeable taste, and is of a soft consistency. When melted, which may be effected at a temperature of 98° Fahrenheit, it becomes transparent; but its taste is rendered less agreeable. In this state, or salted, it may be kept much longer without becoming rancid, and is capable of transportation by sea.

6. *Cheese.*

§ 353. When milk is allowed to stand until, by a sort of acetous fermentation (see Chap. VII.) it becomes sour, it coagulates, and forms two distinct parts; viz. the *curd*, which is a solid substance, and a liquid called *whey*. The curd of milk, pressed, salted, and dried, composes *cheese*. The *whey*, a thin, transparent fluid, contains still a portion of curd and butter, and is used in Switzerland for the preparation of certain kinds of cheese.

7. *Sugar of Milk.*

§ 354. The whey of milk, when separated from butter and curd, and evaporated at a gentle heat, yields a substance called *sugar of milk*. This is a solid mass, which is readily dissolved in water, and may be clarified with the white of eggs, and again evaporated. Upon cooling, it forms regular crystals of a sweetish taste, which are insoluble in alcohol.

Remark. There is considerable difference between the milk of different animals. Human milk is sweeter than that of cows, but yields no butter. *Goats'* milk is thick and fat, and abounds in curd. Its butter is less consistent than that of cows' milk; but it contains more sugar of milk. The milk of sheep resembles that of cows, and yields the greatest quantity of butter. Mare's milk yields hardly any butter, or cream. *Asses'* milk is the most watery of all, and contains the least quantity of curd and butter.

8. *Animal Mucus.*

§ 355. This substance is obtained by washing mucus secretions with cold water, and drying the parts which remain undissolved. It is transparent and brittle, and consists principally of *carbonate of ammonia*, and *animal oil.* Together with water, it forms the principal ingredient of the mucus of the nose, tears, wind-pipe, saliva, and bile, and the intestines.

9. *Animal Oils and Fats.*

§ 356. To this class of animal substances we reckon chiefly *butter*, *tallow*, *lard*, *wax*, and *spermaceti*.

Butter and wax have already been described, (in § 352,

§ 316). Fat is extracted from muscular and membranous substances, by exposition to a gentle heat. Fat thus purified is called *lard* when soft, and *tallow* when of a hard consistency. It has an insipid taste, and when perfectly pure is destitute of smell. It is insoluble in water, or alcohol, but united with potash or soda, forms *soap*, (see Chap. III, § 150). By long keeping it becomes rancid, which is probably owing to its combination with oxygen. The *fat of whales* is obtained in a liquid state as an *oil*. From its great value in artificial illumination, it is an extensive article of commerce.

Spermaceti (sperm-oil) is chiefly obtained from the fat of the white whale. It crystalizes from a solution in hot alcohol in white shining leaves, or in a radiant mass. It melts at 112° Fahrenheit, is inodorous, and has no action on vegetable colors. It is extensively used for the manufacture of candles.

10. *Animal Acids.*

§ 357. The human and animal body contains or yields a number of acids, which occur in the mineral and vegetable kingdoms. To these belong the *phosphoric*, *muriatic*, *sulphuric*, *carbonic*, *acetic*, *benzoic*, and *malic acids*, all of which have already been described in the preceding sections; but besides these, a number of others, which are more or less peculiar to animal formation. The most important of these are the *olific*, *lactic*, *mucous*, and *formic acid.*

a. Olific Acid.

§ 358. This acid is formed in the bile of men, bullocks, swine, and bears; also in old tallow and cheese. It crystalizes in white needles, a little before the freezing point of water, to a colorless or yellowish oil, (hence its name), and evaporates under the recipient of an air pump, without decomposition. It is soluble in water, has a faint rancid taste and smell, and combines with the mineral acids and bases.

*b. Lactic Acid.**

§ 359. Lactic acid is found in its simple form, or united with ammonia, potash and soda, in almost all animal parts and liquids; in the blood, in the milk, muscles, &c, (see Chap. VII). It is also produced by the acetous fermentation of a variety of vegetable substances; or may be obtained from sour milk, by evaporating it to about ⅛ of its volume, and filtering the residue.

Properties. It is a yellowish-brown syrup, incapable of crystalization, which has a very sour taste, and deliquesces at the atmosphere. With the different mineral alkalies it forms a kind of salt, called *lactates.* These salts are soluble in water, (some of them also in alcohol), and deliquesce in contact with air.

d. Mucous Acid. (Saccho-lactic Acid.)

§ 360. *Mucous acid* is the product of nitric acid distilled with *sugar of milk*, or *vegetable gum.* It is a white, sandy powder, which has little smell or taste, and reddens litmus paper. It is soluble in cold, but much better in warm water. When heated, it melts with a brown color, and becomes partly decomposed into carbureted hydrogen gas, carbonic acid, acetic acid, and a sort of charcoal of a metallic lustre. In a red-hot crucible it burns like oil. With the mineral bases it combines to a kind of salts, which are called *saccho-lactates.*

e. Formic Acid.

§ 361. The acidity of *ants* is taken advantage of, by distilling them with water, by which means a peculiar acid is obtained, which has received the name of *formic* acid, (from a peculiar kind of ants called *formica rufa).*

Properties. Concentrated formic acid does not congeal at any degree of artificial cold, although it is specifically *heavier* than water. It has a peculiar pricking, sour

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* The two celebrated chemists, Fourcroi and Vauquelin, first discovered this acid in the amnios of cows; hence its name.

taste, may be mixed with water in all proportions, and combines with the mineral alkalies to a kind of salts, called *formiates.*

11. *Of the Different Liquids employed in the Process of Digestion.*

§ 362. The principal liquids and secretions which are subservient to the process of digestion, are the *saliva*, the *gastric juice*, and the *bile*.

a. Saliva.

§ 363. This is a liquid secreted by certain glands, and brought into the mouth to be mixed with the food during mastication. It is transparent, gradually deposing its mucous, inodorous, and nearly of the same specific gravity as water. The saliva of men produces generally a weak, alkaline effect on vegetable colors, (reddens litmus paper). During some diseases the saliva is sour, and forms with nitric acid a transparent pellicle. It is principally composed of water, mucous, albumen, chloride of potassium, and phosphate of lime, soda, and ammonia.

b. Gastric Juice.

§ 364. This liquid issues from the inner coats of the stomach, and serves in the process of digestion, as a most powerful solvent. It contains, besides several animal substances, such as mucous, albumen, saliva, &c, muriatic and acetic acid, together with chloride of potassium, and sodium. The gastric juice, thrown up by vomiting, is very much similar to saliva; and it is therefore the opinion of some celebrated physiologists, that the true gastric juice is only a secretion in the stomach, through the irritation produced by the food. Its *solvent* power is so great, that after death the stomach itself is corroded by it.

c. Bile.

§ 365. The bile of a healthy man has generally a greenish-brown color, a bitter, nauseous taste, and is seldom very clear or transparent, because a yellow, insoluble, mucous substance is suspended in it. It is decomposed by all the acids, whereby a large proportion of albumen and resin is deposited.

Human bile consists principally,

1. Of a very *bitter resin*, which is the yellow substance suspended in it, to which we have just alluded.
2. Of *albumen*.
3. Of *soda*, through whose agency the yellow resin is kept in a liquid state.
4. Of mineral salts, phosphate and sulphate of soda, chloride of sodium, and oxide of iron; and
5. Of a large proportion (about 91 per cent) of water.

In sick persons the resinous substance suffers considerable diminution, which gives the bile nearly the same appearance as albumen.

The bile of oxen, calves, sheep, dogs and cats consists of resin, a sweet, sugary substance; a peculiar yellow body, composed of mucous and brown coloring matter, pure soda, phosphate and sulphate of soda, chloride of sodium, phosphate of lime, and even *traces* of phosphate of iron.

12. *Of the Chyle.*

§ 366. By the digestion of food in the stomach, a white juice is formed, which is afterwards yielded, and converted into blood, through which the whole body receives its nutriment. The chyle of amimals, 4 or 5 hours after taking food, possesses a perfectly white color, is, on account of its fat, more or less opaque, and has a saltish, sometimes sweetish taste. It is specifically heavier than water; but lighter than blood. (If a person be bled 4 or 5 hours after taking food, a small portion of chyle will float on top of the coagulated blood). It produces a weak alkaline effect on the color of violets, which is changed into green (see Intro. page 38). In about ten minutes after being taken from the *Thoracic duct*, it becomes of the consistency of jelly, and in course of 24 hours separates into two parts, viz: into a solid coagulum, and a serous, colorless liquid, similar to that obtained by the spontaneous decomposition of blood (§ 349). The coagulum has a strong resemblance to cheese, while the serous part, dissolved in water, has a sweet taste, somewhat like milk, to which the whole substance of the chyle is more or less analogous.

Dry chyle, when burnt, yields 32 per cent of ashes, consisting of carbonate of soda, chloride of potassium, a little potash, and phosphate of lime.

13. *Substance of the Brain and Nerves.*

§ 367. The brain of men and quadrupeds consists of a soft, medullary substance, which undergoes spontaneous decomposition when exposed to the air, and gives off a peculiar acid before it undergoes putrefaction. It consists,

1st. Of a brownish-red, liquid fat, which, by its combustion, yields phosphoric acid.

2d. Of a more solid lamellar fat (wax), peculiar to the brain.

3d. Of phosphorus contained in these fats.

4th. Of an animal extract called *osmazome.*

5th. Of animal albumen.

6th. Of water, and

7th. Of a number of mineral salts, chloride of sodium, phosphate of potash, of lime, of magnesia.

Nerves. The nerves of men contain less liquid, than the brain, but more lamellar fat (wax of the brain), together with a much larger portion of albumen.

The brain of a *calf*, or of an *ox* is of a greyish color ; its fat is more greasy than crystaline, and it contains, besides the substances enumerated in the human brain, a considerable quantity of *phosphate of ammonia* with traces of iron.*

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* The analysis of a peculiar substance found in the brain of an idiot yielded 6 per cent white *tallow*, half coagulated albumen, and a peculiar cartilaginous matter, which was insoluble in water. See Gmehlen's Chemistry, Vol. III.

14. *Fibrin (Animal Gluten).*

§ 368. This substance forms the principal ingredient of the muscular and fleshy parts of animals. It may be procured in its simple form in two different ways.

1st. By washing meat or flesh cut up into small pieces with cold, and afterwards with warm water; and

2d. By frequent ablutions of the *coagulum* of blood on a linen strainer, until nothing but a white, fibrous matter remains.

Properties. In a state of moisture it is a semi-transparent, elastic substance; but when dry it is a brown, transparent, brittle mass, which is insoluble in cold water; but gives to *boiling* water a milky color. It is specifically heavier than water, and possesses neither taste nor smell. It consists principally of *carbon, oxygen, nitrogen,* and only a small proportion of *hydrogen* gas.

15. *Of the Bones, Teeth, and Cartilage.*

§ 369. The bones and teeth of animals are composed partly of earthy salts, which give them solidity and hardness, and partly of animal matter, which serves for the purpose of cement, and keeps the earthy ingredients in a state of union.*

All bones contain a portion of cartilaginous gelatine; but the harder they are the less they possess of this substance. When bones are boiled for a considerable time in water, the cartilaginous matter is extracted from them in form of animal glue. Cold muriatic acid dissolves even their salts, and leaves them in a state of soft transparency, preserving still their natural shape and figure.

This state seems to be the first stage of organized bones, and it is well known that the bones of infants and children partake more or less of this nature, until by the growth of the individual they become gradually harder, and finally obtain that firmness which they have in adults.

Bones are entirely dissolved in hot muriatic acid; from which, by adding ammonia, a precipitate may be formed,

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* Henry's Chemistry, Vol. II, page 366.

consisting of a great proportion of animal glue, and phosphate of lime. By dry distillation they yield the same product as animal jelly ; but leave a peculiar kind of charcoal *(bony charcoal)* consisting of a mixture of animal coal, and salts of magnesia and lime.

§ 370. The *teeth* and the *enamel* with which they are covered agree, in the main point, with the construction of the bones ; but they contain, besides, as a basis, a peculiar animal substance, of which the enamel seems to be destitute.

According to the experiments made by the celebrated Dr Antenrieth of the university of Tubingen, the bones of children contain about 2 per cent of benzoic acid (see § 339). Upon growing, this acid is expelled ; but occurs again (about 1 per cent), in old men, and is sometimes the cause of obstinate diseases.

Cartilage, when boiled for some time in water, becomes entirely dissolved, the product being animal glue or jelly.

16. *On the Marrow.*

§ 371. This substance is lodged in the hollow parts of the long bones ; and consists chiefly of membranes, fat, and red serum. The oily substance contained in most hard and solid parts of the bones (Dipple's oil), consists merely of fat and serum. It was formerly used in medicine.

17. *Of the Muscles, Membranes, Ligaments and Tendons.*

§ 372. It is highly probable that muscular flesh consists merely of fibrin, mixed, however with *fat*, *blood*, *mucous*, and *nerves*. When washed with cold water it yields *albumen*, *saliva*, *osmazom* and *salts*. When boiled in water, it yields glue or fat, the residue being nearly all fibrin, which, when burnt, leaves phosphate of lime as ashes.

§ 373. *Membranes.* These are thin transparent substances, destined to line the different cavities of the body, or in form of bags to contain liquids. They are generally soluble in water, and dissolve into animal glue, which proves that they are principally composed of *Gelatine.*

§ 374. The *tendons,* or *sinews* are the cords which connect the muscles with the bones. Their composition differs from that of muscular flesh, only by the absence of fibrin.

§ 375. The *ligaments* are the strong bands by which the bones themselves are tied together. They are less soluble in water, and when dried are darker and less transparent than the sinews. The rest of their chemical composition is similar to that of the tendons.

18. *Covering of Animals.*

To these belong the *skin, nails, claws, horns, hair, bristles,* &c ; *feathers* and *wool.*

a. Of the skin.

§ 376. The *skin* is composed of two parts — an external white coat, which is nearly insensible, and is called the *cuticle* or *epidermis ;* and an internal one, which is endowed with great sensibility, called the *cutis vera* (true skin). Between these two there is a soft, mucous substance, called the *rete mucosum.* The external skin (the cuticle) is insoluble in water and the acids, and consists chiefly of the same substance as horn (supposed to be a composition of coagulated albumen and animal glue or gluten). The external skin (cutis vera), on the contrary, contains a number of blood-vessels and nerves, is highly elastic, and may by boiling water, be converted into animal glue ; a proof that its principal ingredient is gelatine.

This is the reason why the skins of animals yield glue, and why, by the process of tanning, they are capable of being converted into leather; because tan, when poured upon animal glue, renders it elastic and impenetrable to water.

b. Nails, Claws, Horns, Hoofs, Scales, &c.

§ 377. These substances, with the exception of the *scales of fishes,* (which are formed of layers of membranes and phosphate of lime), are very nearly allied together with regard to their chemical composition. Their principal ingredient is the same horny substance of which the exterior skin is composed.

Horns of oxen contain besides, 1 per cent of fat and a peculiar animal substance which may be precipitated by tan.

The hoofs of horses contain a greater proportion of salts, and yield, by calcination, 4 per cent of phosphate of lime.

The horns of stags are in their composition similar to bones, but they contain more cartilage.

c. *Hair, Bristles, Feathers, Wool and Silk.*

§ 378. The hair of man consists of thin tubes, of a brown, horny substance, filled with a fat oil, and surrounded on the outside with a sort of tallow, which, according to its color, gives the hair a black, brown, light, and even red appearance. Black hair, when dissolved in hot potash, leaves a blackish-green residue of oil, iron, and sulphur; red hair leaves red oil, sulphur, and only traces of iron. The ashes of human hair consist of common salt (chloride of sodium), silicious earth and oxide of manganese. The hair of horses leaves, upon calcination, 12 per cent of phosphate of lime.

§ 379. *Bristles* consist principally of the same substance as horn. *Feathers* are supposed to resemble hair in their *chemical* composition. The *quills* consist of pure coagulated albumen. *Wool* consists likewise of the same substances as hair or bristles; but it is surrounded by a greasy sweat, composing about 40 per cent of its whole weight. (This sweat is the reason why wool forms *soap* with the pure alkalies). We are almost entirely ignorant as to the chemical composition of silk. It consists of a peculiar gluey substance, of wax, and a small quantity of essential oil. Yellow raw silk contains, in addition to these ingredients, a peculiar resinous substance.

The use of wool and silk, in the manufactory of cloth and silks, is as well known as the application of the other coverings of animals in domestic economy and the arts.

RECAPITULATION.

Questions for Reviewing the most important Principles contained in Chapter VI.

[§ 344.] What are the immediate ingredients which are discovered by the chemical investigation of animal substances?

[§ 345.] How may these ingredients be again divided? Into what four classes may the combustible animal substances be again divided?

What are the incombustible animal substances which remain as ashes, at the combustion of those which you have just mentioned?

[§ 346.] What are the ultimate principles of the animal body? How do we know that nitrogen enters largely into the composition of animal substances? To what is the offensive smell owing, which accompanies the spontaneous decomposition of animal substances?

[§ 347.] What sort of substance is animal jelly (or glue)? How is it obtained? What properties does it possess? What does a solution of animal glue or jelly in water, soon undergo?

What changes does glue undergo by boiling? Into what substances does it become decomposed by dry distillation? What sort of animal substance is *Gelatine*? With what substances does it combine?

[§ 348.] Where does animal albumen occur? What does the white of eggs contain? How may pure albumen be obtained from the white of eggs? What are the most remarkable properties of albumen? What changes does a solution of albumen in water undergo at a boiling heat? What sort of smell does it emit when burnt at an open fire? By what acids may it be precipitated from a solution in water? Into what elements does it become decomposed by dry distillation?

[§ 349. Of how many different parts does *blood* consist? Have these substances much affinity for each other? How is this ascertained?

What are the ingredients of the *cerum?* Into what two substances may the *cruor* be again separated by washing it with water? What are the ingredients of the coloring matter of blood similar to?

[§ 350.] Of how many distinct operations consists the process of respiration? In what consist the two processes? What are the changes which atmospheric air undergoes by the process of respiration?

What are the changes which the blood itself undergoes?

What is the process of respiration also called, on account of the absorption of oxygen gas? Why do some philosophers call it the *decarbonization* of the blood?

[§ 351.] What are the principal ingredients of milk? What becomes of the portion of albumen contained in milk when the latter is boiled? What sort of taste does it impart to the milk, when it falls to the bottom and becomes burnt? What change would milk undergo by the process of boiling, if it did not contain a large quantity of water?

[§ 352.] What becomes of milk when it is suffered to stand still, even when excluded from atmospheric air? What is the oily, unctuous substance called, which rises to the top? Into what two substances is cream separated by agitation or churning? What are the principal properties of butter? How may butter be preserved, or be made capable of transportation by sea?

[§ 253.] Into what two substances does milk become decomposed, when suffered to stand until it becomes sour? What substance does the curd of milk form when pressed, salted and dried? For what purpose is the whey used in Switzerland?

[§ 354.] What substance does the whey of milk yield when separated from butter and curd, and evaporated at a gentle heat? What properties does sugar of milk possess?

What difference is there between goats' milk, and the milk of cows? What sort of milk is that of sheep? What sort of milk is the most watery of all, and contains the least quantity of curd, or butter?

[§ 355.] How is animal mucus obtained? What are its properties? What is its principal ingredient in combination with water?

[§ 356.] What animal substances belong to the animal oils and fats? From what substance is *fat* extracted? When is fat called *lard*? When, *tallow*? What does fat form when united with potash or soda? What becomes of it by long keeping? In what state is *the fat of whales* obtained?

How is spermaceti obtained? What are its properties? For what purposes is it used?

[§ 357.] What acids are contained in the animal body that occur also in the mineral and vegetable kingdoms? What other acids does it contain, which are peculiar to the animal kingdom?

[§ 358.] Where is olific acid formed? What are its properties? With what substances does it combine?

[§ 359.] Where does lactic acid occur? By what process is it procured? What kind of salts does it form with the mineral alkalies? What property do these salts possess?

[§ 360.] What sort of production is mucous acid? What are its properties? To what kind of salts does it combine with the mineral bases?

[§ 361.] What sort of acid is obtained by distilling ants with water? What are the properties of concentrated formic acid? What sort of salts does it form with the mineral alkalies?

[§ 362.] What are the principal liquids employed in the process of digestion?

[§ 363.] What sort of liquid is saliva? What are its properties? What effect does the saliva of men produce on vegetable colors? What changes does saliva undergo in certain diseases? What are its principal ingredients?

[§ 364.] Whence proceeds the gastric juice, and in what particular process does it act as a solvent? Of what substances is it composed? To what is the gastric juice which is thrown up by vomiting similar? What is the opinion of some physiologists respecting the nature of gastric juice? How does gastric juice operate upon the stomach after death?

[§ 365.] What are the properties of human bile, in a state of perfect health? How is bile affected by the acids?

What are the principal ingredients of *human* bile? Which of these ingredients is particularly affected by sickness?

What are the ingredients of the bile of oxen, calves, sheep, dogs and cats?

[§ 366.] What sort of juice is formed by the digestion of food in the stomach? What properties does the chyle of animals possess, 4 or 5 hours after taking food? How do we know that chyle is specifically lighter than blood? How does chyle affect the color of violets? What changes does it undergo when taken from the thoracic duct? What are the properties of the coagulum, and what those of the serous part into which chyle separates?

What are the ingredients of the ashes, produced by burning dry chyle?

[§ 367.] What kind of substance is the brain of men and quadrupeds? Of what ingredients does it principally consist?

In what respect do the nerves of men differ from the brain?

What difference is there between the chemical composition of the brains of calves or oxen, and that of men?

[§ 368.] What kind of substance is fibrin or animal gluten? In what ways may it be produced in its simple form? What are its properties? Of what elements does it consist?

[§ 369.] Of what substances are the bones and teeth of animals composed? What do all bones contain? By what means may the cartilaginous matter be extracted from them? How are bones affected by cold muriatic acid?

What changes do the bones of children gradually undergo, until they grow to be adults?

How are bones acted upon by hot muriatic acid? What substances do they yield by dry distillation?

[§ 370.] What is the chemical composition of the teeth and the enamel similar to?

What remarkable discovery did Dr Autenrieth, of Tubigen, make with regard to the bones of children and old men?

Into what does cartilage become changed by boiling it for some time in water?

[§ 371.] Where is the marrow seated? Of what does it principally consist?

[§ 372.] What does muscular flesh probably consist of? What does it yield when mixed with cold water? What does it yield when mixed with warm water?

[§ 373.] What kind of substance are the membranes? What property do they generally possess?

[§ 374.] What office have the tendons or sinews? In what respect does their composition differ from muscular flesh?

[§ 375.] What sort of substance are the ligaments? In what respect does their chemical composition differ from that of the sinews? What is the rest of their composition similar to?

[§ 376.] Of how many different parts does the skin consist? What is the name of the external white coat which is nearly insensible? What, that of the internal one, which is endowed with great sensibility? What kind of substance is situated between these two? What is the composition of the epidermis? What that of the cutis vera?

What is the reason that the skins of animals yield glue, or are capable of being converted into leather?

[§ 377.] What is the principal ingredient of the nails, claws, horns, hoofs and scales?

What do the horns of oxen contain, besides the substance contained in the nails?

What, the hoofs of horses?

What substance are the horns of stags similar to?

[§ 378.] What does the hair of man consist of? What residue does black hair leave, when dissolved in hot potash? What, red hair? What are the ashes of human hair composed of? What do the hair of horses leave upon calcination?

[§ 379.] What are bristles composed of? What is the composition of feathers similar to? What do the quills consist of? Of what substances does wool consist? What is the chemical composition of silk? What does yellow raw silk consist of?

CHAPTER VII.

OF THE CHEMICAL PROCESS ACCOMPANYING THE DEVELOPMENT, LIFE, AND DEATH OF ORGANIZED BODIES.

A. GERMINATION OF SEEDS.

§ 380. From the experiments which have been made with the seeds of different plants, we are able to lay down the following principles:

1. *No seed can germinate without moisture.* Water alone, however, is insufficient for this purpose. Seeds thrown into water die, and become putrid.

2. *Atmospheric air, or oxygen gas, must have an uninterrupted access to it.*

No germination takes place in pure carbonic acid, hydrogen, or nitrogen gas, or very rarified air. But these gases do not *destroy* the seed; they merely prevent its development into a plant.

3. *It is necessary that the temperature should be at least above the freezing point of water.*

Different seeds require different degrees of temperature; but none germinate at a temperature as low as 32° Fahrenheit.

B. PROCESS OF NUTRITION NECESSARY TO LIFE.

§ 381. Both plants and animals have certain external organs, which enable them to take up a greater or less quantity of gases, liquids, and even solids, destined to serve them as nutriment. They decompose these substances into their chemical ingredients, appropriate to themselves a certain portion of them, and rid themselves of the rest. By this continued process of absorption and expulsion, the whole vegetable and animal life is constantly renovated, and those animal products produced, which we have described in the preceding chapters.

The effect of atmospheric air on the organization of plants is similar to that produced by the respiration of animals, (see § 350). They absorb a certain portion of oxygen, and yield in its state an equal volume of carbonic acid gas.

C. OF THE SPONTANEOUS DECOMPOSITION OF ORGANIC SUBSTANCES.

§ 382. Every organized body, immediately after its death suffers a spontaneous decomposition of its chemical ingredients, which soon or late become dissolved into their elements. With regard to *vegetables*, this spontaneous process has received the name of *fermentation.*

§ 383. The immediate products of the spontaneous decomposition of vegetables differing from each other essentially in nature and quality, naturally lead us to suppose that there are *different kinds* of fermentation; but we distinguish more especially between the *vinous* and *acetous.* Both kinds require,

1. The presence and joint action of water.
2. An uninterrupted access of air, (to yield a sufficient quantity of oxygen).
3. A proper degree of temperature. (A very high temperature disturbs, and a very low temperature retards the process of fermentation.)

1. *Vinous Fermentation.*

§ 384. The product of this fermentation is a vinous, or at least a spirituous liquid, (wine, beer, cider, &c) hence its name. *Sugar*, or *sugary substances*, *are the only vegetable matters capable of vinous fermentation. But for this purpose they need the assistance of the fermentous principles of lees, albumen, and gluten.*

In order that the fermentous principle shall act upon the sugar, it is necessary that it should be in close contact with the latter. This is the reason why no fermentation takes place in the grape itself, where both substances are in a state of *separation.* It explains also, why the presence of *water* is indispensable; because by dissolving both the sugary and the fermentous principle, it brings both substances in immediate contact. The vinous fermentation of sugar may therefore be considered *as the result of its decomposition by the fermentous principle.*

Phenomena accompanying Vinous Fermentation.

§ 385. The phenomena which accompany the vinous fermentation of vegetables, are the following:

1. As soon as it commences, a motion is perceived in the interior of the liquid, its temperature rises by several degrees, and it becomes *turbid.*

2. The *volume* of the liquid is increased; a thick scum is forming on its surface, and a very considerable quantity of carbonic acid is produced, which is impregnated with alcohol. (Hence we infer that the sugar is decomposed into *carbonic acid* and *alcohol.*)*

3. When these phenomena have continued for some time, the volume of the liquid contracts again, the temperature is diminished, the scum disappears, no more carbonic acid is produced, and a precipitate is formed, which renders the liquid clear and transparent.

4. Instead of the *sweet* taste which the liquid had before the fermentation, it has now a *pungent* taste, an *aromatic* flavor, its specific gravity is diminished, and it

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* This agrees perfectly with the analysis of sugar, alcohol, and carbonic acid:

Sugar consists of $\begin{cases}\text{3 equivalents of } \textit{carbon}, \\ \text{6 do of } \textit{oxygen}.\end{cases}$

Carbonic acid consists of 1 equiv. of carbon and 4 of oxygen.
Alcohol do 2 do of carbon and 2 of oxygen.

Amounting together to 3 equiv. of carbon and 6 of oxygen.

possesses intoxicating qualities, in a word — it has become transformed into *wine*.

§ 386. *Wine*, the product of vinous fermentation, must be considered as a peculiar substance, the various kinds of which agree in the following characterizing properties:

1. All kinds of wine are specifically lighter than water, and have more or less color.
2. All of them have a peculiar, pungent taste, and an aromatic flavor.
3. They are all intoxicating (in a greater or less degree).
4. They yield alcohol by distillation.

Most of the properties of wine are probably owing to the last mentioned circumstance, for which reason many distinguished chemists consider alcohol as the product of vinous fermentation.

The difference in taste, color and intoxicating effects of the various kinds of wine is owing,

1st. To the greater or less quantity of water which they contain.

2d. To the vegetable acids which enter into their chemical composition — (*citric*, *malic*, *tartaric* and *acetic* acid; which were contained in the liquid either before or during fermentation).

3d. To the peculiar nature and properties of the coloring matter.

4th. To the quantity of sugar; and

5th. To the proportion of mucilage, gluten, and vegetable extract.

Upon this last mentioned circumstance depends the main difference between beer, cider, and the wine of *grapes*.

2. *Acetous Fermentation.*

§ 387. By this name we distinguish that kind of fermentation of vegetable matter, the product of which is *vinegar*. A great number of vegetable substances, particularly the different kinds of gum and vegetable extracts, are capable of acetous fermentation; but they need for this purpose in addition to the *fermentous principles* also *a free access of air, to absorb a sufficient quantity of* *oxygen*, and *a temperature of from* 74 *to* 84 *degrees Fahrenheit.*

A limited portion of alcohol seems to be favorable to the process, and increases the quantity of vinegar; but the presence of sugar is believed to be a considerable obstacle.

§ 388. The phenomena attending the *acetous fermentation* are similar to those which accompany the *vinous* decomposition of vegetable substances (see the last section). They consist in an internal movement, increase of temperature, development of carbonic acid, formation of fibrous matter, which renders the liquid turbid, &c; but the liquid acquires gradually an *acid* taste and smell, until it becomes changed into what is properly called *vinegar.* This product is found upon distillation to be nothing else but very dilute *acetic acid* (see § 334), mixed, however, with different vegetable substances, such as *gluten*, *gum*, *vegetable extract*, &c, upon which depend principally the quality and kind of vinegar.

It has already been mentioned, that acetic acid, the principal ingredient of vinegar, is also obtained by dry distillation of wood, and other vegetable and animal matter.

3. *Of the Process of Putrefaction.*

§ 389. One of the principal characteristics of animal substances is their spontaneous decomposition after death, which is called *putrefaction.* This is a process analogous to the fermentation of vegetable matter, and leads to the same results — that is, to a complete destruction of all chemical combinations, as they existed in the animal during its life-time; although the products of putrefaction and the phenomena which are dependent on it, are essentially different from those which are produced by the fermentation of vegetable substances.

There are a few vegetables capable of exhibiting the phenomena of putrefaction. These are in their nature and chemical composition very much similar to animal matter, and contain (like cabbage) a considerable portion of nitrogen. It is on this account some philosophers speak of the *putrid fermentation of vegetables.*

§ 390. The conditions under which putrefaction takes place are the same as those which are indispensable to the fermentation of vegetables — viz : *presence and coöperation of water, free access of air, and a proper degree of temperature.*

It is highly probable that there are different degrees and kinds of putrefaction, according to the different classes and kinds of animals ; but the whole process has, as yet, been too little investigated to describe more than the general phenomena which accompany it.

Putrefaction with free access of Air.

§ 391. The putrefying substance (commonly muscular flesh and meat) assumes first a peculiar musty appearance and smell, which soon afterwards becomes sour, pungent, and fetid. Its taste becomes exceedingly nauseous ; the cohesion of its particles is considerably diminished, the *organic* texture entirely destroyed, and the whole changed into a soft, pappy brown (sometimes greenish) mass. Carbonic acid gas is now given off in great profusion ; but the quantity of inflammable (hydrogen) gas is visibly diminished. By degrees the fetid smell ceases ; the mass obtains again a certain degree of solidity, and becomes converted into an earthy substance of a blackish color. This is the end of the whole process.

If the process of putrefaction is carried on with a *small* quantity of water, a great portion of inflammable gas (carbureted hydrogen) is given off. If *much* water be added, then, very little gas is developed ; but the water assumes an *insufferable* fetid smell.*

Put refaction with little or no access of Air.

§ 392. The phenomena accompanying this sort of spontaneous decomposition of animal substances are entirely different from those we have just mentioned ; particularly if the animal body be also secluded from day-light,

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* The cause of this excessively offensive odor is not yet sufficiently ascertained. The formation of carbureted, phosphureted, and sulphureted hydrogen alone cannot account for this phenomenon.

and submitted to a moderate degree of temperature. Putrefaction advances, then, but very slowly; the odor which it emits is *musty*, but not *fetid;* and the whole is changed into a blackish, powdery substance, bearing great resemblance to *animal charcoal.* At the same time a considerable quantity of nitric acid is formed.

The process of putrefaction may be retarded for a long time by the assistance of *alcohol*, the *acids*, some of the *salts*, the *volatile or essential oils*, and by the *exclusion of atmospheric air.* The *mummies* of the Egyptians, and the anatomical preparations which are kept in spirits of wine, and which, in this state, resist putrefaction even for centuries, are sufficient proofs of this assertion.

§ 393. All combustible substances contained in the animal body are thus subjected to destruction by water, air, and the joint operation of the elements. But the products of their spontaneous decomposition are not entirely lost; they serve to enliven and nourish the vegetation of plants, which, in their turn, afford nutriment to animals; and so does this change from life to death and decomposition, and from decomposition again to life and death, continue to set the springs of human industry in motion, and affords, by a wise distribution of Providence, the means of our nutriment and comfort.

RECAPITULATION.

Containing Questions for Reviewing Chapter VII.

[§ 380.] What principles are we enabled to lay down from experiment respecting the germination of seeds?

[§ 381.] What are all animals and plants provided with, for the purpose of nutrition? What do they do with he substances they take up by these organs? What end is attained by this continued process of absorption and expulsion?

What is the effect of atmospheric air on the organization of plants, similar to? Why?

[§ 382.] What change does every organized body suffer, immediately after death? What is this process called with regard to vegetables?

[§ 383.] What are the principal kinds of fermentation? What do both kinds of fermentation require?

[§ 384.] What sort of product is produced by *vinous* fermentation? What vegetable substances are alone capable of vinous fermentation? What assistance do they need for this purpose?

What is necessary in order that the fermentous principle should act upon the sugar? What is this the reason of? Why is the presence of water necessary for this kind of fermentation? As what, therefore, may the vinous fermentation of sugar be considered.

[§ 385.] What phenomena accompany the vinous fermentation of vegetables?

[§ 386.] What characterizing properties have all kinds of wine?

To what peculiar ingredient of wine are most of its intoxicating qualities owing?

What are the causes of the difference in taste, color, and intoxicating effects of the various kinds of wine?

On what depends the principal difference between beer, cider, and the wine of grapes?

[§ 387.] What do you understand by the *acetous fermentation* of vegetable substances? What vegetable substances are capable of this kind of fermentation? What do they need for this purpose, in addition to the fermentous principle?

Is the presence of alcohol favorable or a hindrance to acetous fermentation? Is this also the case with sugar?

[§ 388.] What are the changes produced by acetous fermentation? What is this product, upon distillation, found to be composed of?

[§ 389.] What is the spontaneous decomposition after death of all animal substances, called? What is this process analogous to? To what results does it lead?

What vegetable substances are capable of exhibiting the phenomena of putrefaction? What is this sort of putrefaction of vegetables, by some philosophers called?

[§ 390.] What are the conditions under which putrefaction takes place?

[§ 391.] What phenomena accompany the putrefaction of animal substances with free access of air.

What kind of gas is given off, when the process of putrefaction is carried on with a small quantity of water? What takes place when a large quantity of water is added?

[§ 392.] What phenomena accompany the putrefaction of animal substances with little or no access of air?

By what means may the process of putrefaction be retarded for a considerable length of time?

APPENDIX.

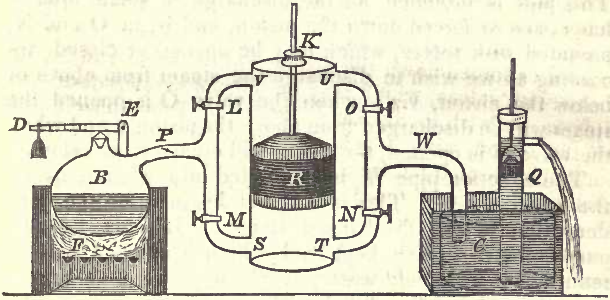
ON THE STEAM ENGINE.

[IT is not to be expected that a complete treatise on so complicated a machine should be annexed to an elementary treatise on Chemistry; but an acquaintance with its principal parts being absolutely indispensable to a correct understanding of a great number of valuable improvements in mechanics and the arts, we have endeavored to give to the learner a brief sketch of its most important elements.]

§ 394. We have already had occasion to allude to the elasticity of steam, and gave, in § 35, Fig. XCIV, an example of its power to raise a piston that shall work airtight in a cylinder. Now it is easily conceived that if the piston rod is attached to some lever or wheel, it may communicate to them a certain force or motion, which by a proper arrangement may be transferred to any particular part of the machine where we wish it to operate. A machine constructed for this purpose, and in which the elasticity of steam is employed for the moving force, is called a *steam engine.*

§ 395. In the experiment represented in Fig. XCIV, page 84, the piston is only forced up by the expansive power of the steam; but when the steam is condensed and a vacuum created under the piston, it is the pressure of the atmosphere which forced the piston down again. Engines constructed upon this principle are called *atmospheric* engines. They require the cylinder to be cooled down after each stroke of the piston, in order to produce the necessary condensation of the steam, and the subsequent creation of a vacuum for the moving down of the piston. This is naturally the cause of a great loss of fuel, because each new stroke of the piston must be produced by the forming of a fresh quantity of steam, and a subsequent condensation of it, by cooling down the cylinder. Besides this inconvenience, the motion of an atmospheric machine cannot be regulated like that of the engine we are about to describe.

Fig. CXXXVI.



§ 396. Fig. CXXXVI represents the most essential part of what is called a *double working engine.* B represents a section of the boiler, provided with a safety-valve, in order to admit of the passing of the steam in case its elastic force should endanger the safety of the machine. The pressure upon this valve may be regulated by the movable weight D, suspended from the end of the lever DE. V U S T represents the barrel or cylinder, to which the piston R is fitted in such a way as to admit of its moving up and down, without allowing the least quantity o water or steam to escape between it and the barrel. To the piston is attached the piston-rod R K, which is also made cylindrical, and is kept air and steam tight by the *stuffing-box* K, made of leather and stuffed with wool, tow, or some other elastic substance, to enable the rod to work freely up and down, without permitting the escape of steam

The pipe P, which is called the steam-pipe, communicates with the boiler, and is destined to convey the steam to the barrel V U S T. It is divided into two branches, each of which may be closed or opened by means of cocks or valves placed in L and M, so as to admit the steam either *below* or *above* the piston, according as the piston is to rise or to descend in the barrel.

On the opposite side of the cylinder there is a similar tube W, called the *eduction*-pipe, likewise divided into two branches, and communicating with the barrel in U and T. This pipe is intended for the discharge of steam after it has raised or forced down the piston, and is, in O and N, provided with valves, which may be opened or closed, according as we wish to discharge the steam from above or below the piston, viz: when the valve O is opened the steam will be discharged from above the piston; and when the valve N is opened, the steam will escape from below it.

The eduction pipe W, is conducted into what is called the *condenser* C. This is a vessel destined for the condensation of the discharged steam. It must for this purpose be constantly kept cool, which is effected by surrounding it with cold water, or placing it in a cistern — the *cold water well* — filled with water. To promote the rapid condensation of the steam a stream of cold water is constantly discharged into the condenser.

The *pump* Q, which in its construction is similar to a common pump (see Natural Philosophy, Chapter V), is a very essential part of the low-pressure steam engine. By a mechanical contrivance it is connected with, and worked by the rising and descending of the piston rod, and serves for the important purpose of creating a constant vacuum by freeing the condenser from air and water as fast as the steam is discharged into it. Without this pump the condenser would soon be filled with air and water, and the discharge of the steam be rendered impossible, which would arrest the operation of the whole machine. This mode of creating a vacuum, is one of the chief improvements of the steam engine, for which we are indebted to James Watt, a celebrated English engineer, whose merits in this branch of the arts have entitled him to the gratitude of the age.

§ 397. When the machine is to be set in operation, the water in the boiler is heated by the furnace, and by that means converted into steam. The four valves, L, M, N, O, are then all opened, so as to admit the steam from the boiler, above and below the piston, and at the same time to allow its escape into the condenser, and from thence through the valve of the pump Q, into the open air. The object of this is to expel the air from every part of the machine, in order to create a vacuum by the subsequent condensation of steam. This process is called *blowing through*. When this is done, the valves M and O are closed, in order to admit the steam only above the piston, through the valve L, and to allow the escape of it from below the piston, through N and the eduction pipe U, into the condenser. This forces the piston down to the bottom of the barrel, and imparts the first motion to the engine. The valves L and N are now closed, and O and M opened. By this means the steam from the boiler is, through M and S, admitted below the piston, while the steam above the piston is permitted to escape through the valve O, into the condenser. The effect of this operation is the forcing up of the piston to the top of the barrel. The valves M and O, being again closed in their turn, and L and N opened, a fresh portion of steam from the boiler forces the piston down again to the bottom of the barrel; and so does the alternate opening and closing of the valves M, O, and N, L, respectively, admit the steam below or above the piston, and produces the moving up and down of the piston rod, by which means the whole machinery is set in motion.

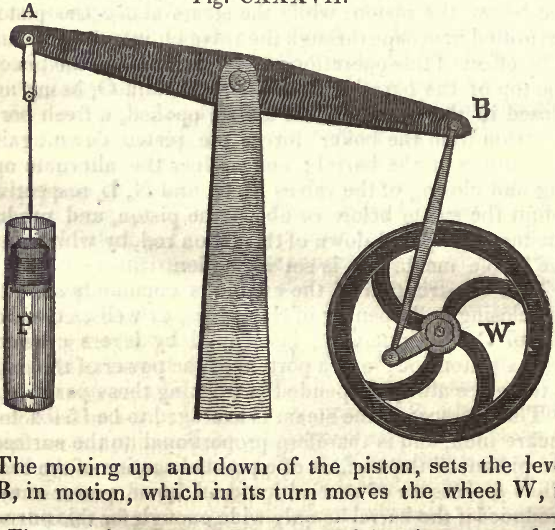
The construction of the engine is commonly such that the closing and opening of the valves, as well as the working of the air pump Q, is effected by levers connected with a piston-rod; and a portion of the power of the engine is therefore always expended in working these parts.

The pressure of the steam is averaged to be 15 lbs. to the square inch, and is therefore proportional to the surface of the piston, or the surface of a parallel section of the barrel. Thus a pressure of several hundred horse power may be produced if the barrel be only wide enough for this purpose.

Example. If the horizontal diameter of the barrel were 3 feet, the area of a sector would, according to the rules of geometry,* be 1017.8784 square inches, and the pressure of the steam 15,268 lbs! If the horizontal diameter of the cylinder were 6 feet, then the pressure would amount to 61,072 lbs.! and so on. We see from this that we can at pleasure increase or decrease the power of the engine by widening or contracting the barrel and piston, provided the materials are strong enough to resist the force of the steam. For in proportion to the pressure of the steam, the piston will be moved up and down with a greater or less force; which, therefore, ought to be regulated according to the purpose for which the engine is constructed.

§ 398. If the motion to be produced by the machine is *rotary*, as is, for instance, the case in the construction of steam-boats, then it is only necessary to connect the piston-rod with one end of a lever, and the wheel which is to be turned, with the other, as is represented in the adjoining figure.

Fig. CXXXVII.



The moving up and down of the piston, sets the lever A B, in motion, which in its turn moves the wheel W, in

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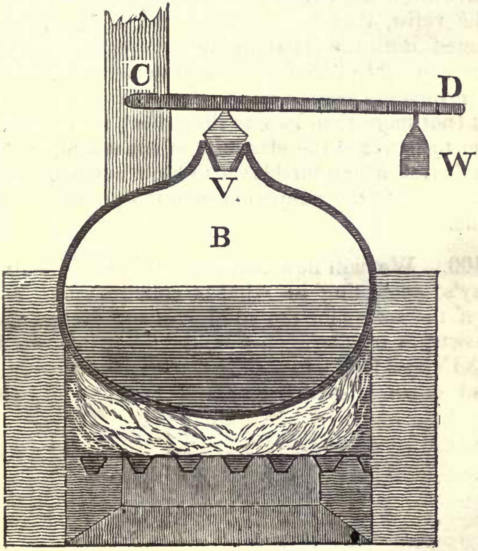
* The area of a circle is found by multiplying the squares of the radius by the number 31.1416. (See Grund's Geometry, Part I).

the same manner as a grindstone is turned by a crank moved by the motion of the foot. If the motion to be communicated is to act perpendicular or horizontal, then this is effected by a system of levers constructed in various ways, and the operation of which is easily understood by the inspection of the machine.

From what we have thus far explained, the learner will be able to understand how the elastic force of steam is capable of setting a complicated machine in motion, and that this force may be increased to an almost infinite extent, transcending by far the effects produced by any other agent in nature. We will now proceed to explain separately the construction and use of the safety-valve, and the manner in which the valves L M, N O, are alternately opened and closed by the operation of the machine itself; after which we shall give a short description of Watt's low-pressure engine, now commonly used for propelling steam-boats.

Fig. CXXXVIII.



§ 399. Fig. CXXXVIII represents separately the boiler and safety-valve of a steam engine. The valve V, as may be seen from the figure, is shaped conically, and connected with a lever C D, which, in D, is charged with a small weight W, to keep the valve down. This weight may be moved further from, or nearer to the valve, according as we wish the steam in the boiler to attain a greater or less degree of elasticity. When it is moved nearer the fulcrum C, it will, according to the law of the lever, require less force to lift it (to open the valve) than when it is removed further from it.

Now, the elasticity of the steam in the low-pressure engine being equal to about 15 lbs. to the square inch, we can easily compute the pressure which it will exercise upon the lower surface of the valve; to counteract which it will only be necessary to depress the valve with a power equal to the same weight. But for this purpose we need not attach any weight to the lever C D; because the atmosphere itself has that power (Natural Philosophy, Chap. V); the valve, therefore, without the weight, could not be opened until the elasticity and consequent pressure of the steam should exceed 15 pounds to the square inch. It is, nevertheless, necessary to attach a small additional weight (not more than two or three lbs.) to the lever C D, in order to increase the elasticity of the steam in the boiler to a degree which enables it to blow out with sufficient force to prevent the admission of atmospheric air into the machine.

§ 400. We will now mention an improvement of Mr Murray's, consisting in what is called a *single slide*, instead of the valves for the admission and escape of steam. It consists, as may be seen from the following two figures, CXXXIX and CXL, in a slide S, capable of being moved up and down in the direction from L to M, which is

Fig. CXXXIX.

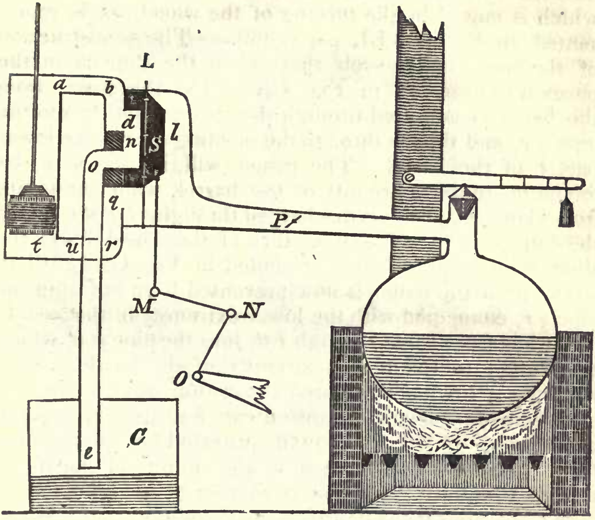
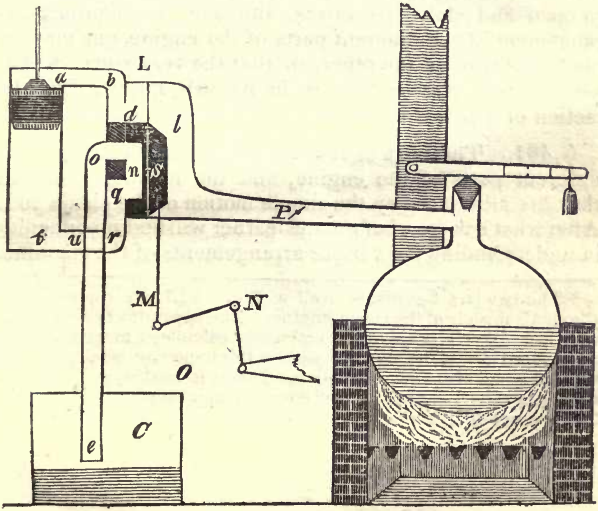


Fig. CXL.



effected by means of the levers M N O, and an excentric, which is moved by the turning of the wheel, as is represented in Fig. CXLI, page 369. The construction of the machine is such that when the slide is in the position represented in Fig. CXXXIX, the steam from the boiler is admitted through the steam pipe P, into the pipe *q r*, and thence through the opening *u*, into the lower part *t*, of the barrel. The piston will, in this case, be forced up to the extremity of the barrel, while the steam from above the piston is discharged through *a b d n o e*, into the condenser C. The next turn of the wheel places the slide S, in the position represented in Fig. CXL. The steam from the boiler is now prevented from entering the pipe *q r*, connected with the lower extremity of the barrel; but it has free access through *l d*, into the pipe *a b*, which conducts it to the upper extremity of the barrel. This will have a tendency to force the piston down, provided the steam from below the piston can find its way into the condenser. But this is actually provided for by the pipe *t u r q*, which is now open in *n*, and admits of the steam passing through *o e*, into the condenser.*

We see from these figures how the motion of the piston rod itself, acting on the levers and the wheel, may serve to open and close the valves, and how, by a proper arrangement of the different parts of the engine, one may be made to act upon the other, so that the very power which sets the engine in motion, is in its turn, governed by the motion of which it is the cause.

§ 401. The next figure shows the construction of the different parts of the engine, and the manner in which they are all worked by the simple motion of the piston rod. After what has gone before, the learner will find no difficulty in understanding the various arrangements of the machine.

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* The two last figures, as well as Fig. CXLI, are copies of Mr Claxton's models of the steam engine. The apparatus itself appears to be remarkably simple, and eminently calculated to give a clear and distinct idea of the essential parts of this important machine. Mr Claxton is one of the most skilful mechanics in Boston, and has constructed a variety of physical and chemical apparatus, well answering the purposes of illustration in schools.

Fig. CXLI.

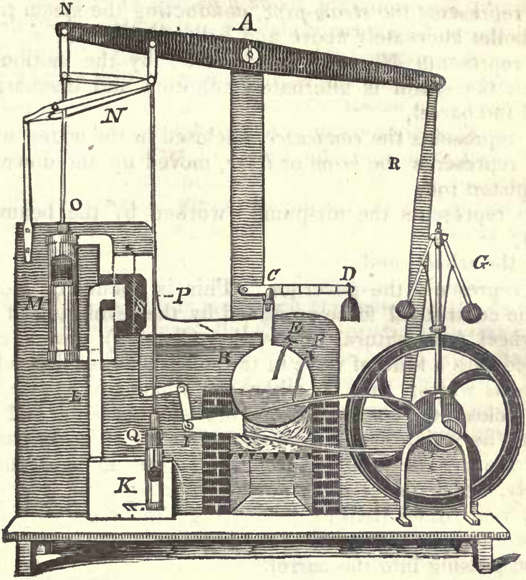

Fig. CXLI represents the connexion between the different parts of the engine we have just described.

B represents the *boiler.*

C represents the *safety valve.*

F, E are what mechanics call *steam* and *water gauges* respectively. They consist of hollow tubes provided with stop-cocks. The gauge F, as may be seen from the figure, has its lower end immersed in the water; but the gauge E, does not communicate with the surface of the liquid. When the stop-cock of the gauge E is opened, nothing but steam must rush forth, otherwise it is a sign that there is too much water in the boiler; but when the stop-cock of the gauge F is opened, no steam must pass, else it is a sign that the water is too high.

M represents the *cylinder* or *barrel.*

N O the *piston* and *piston-rod*,

P represents the *steam-pipe*, conducting the steam from the boiler alternately above and below the piston,

S represents *Murray's single slide*, by the motion of which the steam is alternately admitted and discharged from the barrel,

K represents the *condenser*, enclosed in the water well,

A represents the *beam* or *lever*, moved up and down by the piston rod,

Q represents the air-pump, worked by the beam or lever,

H the wheel, and

G represents the governor. This is opened or closed by the centrifugal force produced by the revolution of the fly wheel (see Natural Philosophy, Chap. I), and is connected with a kind of valve in the steam pipe, so that when it opens widest, that is, when the wheel turns fastest, it partly closes the communication between the boiler and the barrel, by which means a smaller quantity of steam passes into the cylinder, and causes the engine to work more slowly. The object of the governor, or regulator is, therefore, none other than to introduce greater regularity into the working of the machine by regulating the quantity of steam passing into the barrel.

Finally, R represents the crank rod, which gives motion to the wheel.

The remainder of the construction, as represented in the engraving, is sufficiently plain from inspection, and from the previous explanation of its parts.

§ 402. Before we conclude, it behooves us to say a few words on the difference between *low pressure* and *high pressure engines*.

The high pressure engine is one which has neither condenser nor air-pump, but in which the steam from above or below the piston is immediately discharged into the atmosphere. No vacuum, therefore, is created in the barrel, and the atmosphere having always access to that surface of the piston which is opposite to the steam, exercises on that side a pressure of 15 lbs. on the square inch. This pressure of atmospheric air must be overcome by the steam, *in addition* to the power which it needs for setting the machinery in motion; and it will, therefore, require a much greater elasticity of steam to set a high pressure engine in motion, than is needed for a low pressure engine. For while a steam pressure of 15 lbs. on the square inch is amply sufficient for all the operations of a low pressure engine (with condenser and air-pump), a pressure of steam, equal, at least, to 15 lbs. on the square inch is required in the high pressure engine, merely to counteract the pressure of the atmosphere; and the machine, therefore, can only work with the surplus of power which it has over the atmosphere. The principal advantage of a low pressure engine consists, therefore, in the complete *exclusion* of atmospheric air, which is effected by the condenser and the air-pump. But the high pressure engine occupies less space, and when its boiler and barrel are sufficiently strong, can exercise a powerful pressure with very little steam. Besides this, the water with which it is necessary to surround the condenser of the low pressure engine cannot always be readily procured; or the room in which the machine is to work does not admit of its presence. In all these cases high pressure engines are employed in preference to low pressure engines; and it is on this account, principally, that they are exclusively used in the construction of locomotives.

QUESTIONS ON THE STEAM ENGINE.

[§ 394.] What is a machine called in which the elasticity of steam is the moving force?

[§ 395.] By what power is the piston moved up, in the atmospheric engine? By what power is it forced down again, when a vacuum is created under the piston? What does this kind of engine require after each stroke of the piston?

[§ 396.] Explain Fig. CXXXVI. What is the use of the safety valve? What that of the *stuffing-box*? What is the use of the steam-pipe? What that of the valves represented in the figure? What office has the eduction pipe? In what consists the use of the condenser? How must the condenser constantly be kept for this purpose? What is the use of the cold water well? What is the use of the pump? What would soon take place if this pump ceased to work?

[§ 397.] What is the first step taken in order to set the engine to work? What is the process you have just described, called? What is the next step in order to move the piston down again? By what means is the piston afterwards raised again to the top of the barrel?

What is the average pressure of steam on the square inch in the low pressure engine? By what means may we, at pleasure, increase or diminish the power of this engine?

[§ 398.] By what means does the motion of the piston rod communicate motion to the other parts of the machine? Explain Fig. CXXXVII.

[§ 399.] Explain Fig. CXXXVIII. How must the safety valve be shaped? What is the pressure of the steam on the lower surface of the valve? What is the average pressure of the atmosphere on the exterior surface of the valve equal to? For what purpose is an additional weight attached to the lever?

[§ 400.] Explain Murray's *single slide*, represented in Figs. CXXXIX and CXL.

[§ 401.] Explain the different parts of the steam engine, as represented in Fig. CXLI?

What does B represent?
What, C D?
What is the use of the steam and water gauges?
Where is the barrel represented?
Where, the piston-rod?
Which is the steam pipe?
Where is the single slide?
Where is the condenser represented?
What is the object of the governor or regulator?

[§ 402.] In what respect does the construction of the *high* pressure engine differ from that of the low pressure engine ? Does the high pressure engine require more or less elasticity of steam, to be set in motion, than the low pressure engine ? Why ? In what, therefore, consists the principal advantage of the low pressure engine ? What, on the contrary, are the advantages of the high pressure engines ? What sort of engines are used for locomotives ?

TABLE II.

SCALE OF CHEMICAL EQUIVALENTS (OR ATOMIC WEIGHTS),

In which hydrogen gas is taken for unity, after Berzelius.

Oxygen,	8	Gold,	66
Hydrogen,	1	Platinum,	48
Chlorine,	35.4	Palladium,	56
Nitrogen,	14	Rhodium,	120
Carbon,	6	Iridium,	(?)
Sulphur,	16	Osmium,	(?)
Silenium,	40	Nickel,	29.5
Phosphorus,	16	Iron,	28
Boron,	16 (?)	Lead,	104
Iodine,	125	Tin,	59
Bromine,	(?)	Copper,	32
Silicon,	7.4	Zinc, (?)	32.2
Fluorine,	18.6	Bismuth,	71
Potassium,	39.2	Cobalt,	29.5
Sodium,	23.3	Antimony,	64.5
Lithium,	8	Arsenic,	37.6
Calcium,	20.5	Manganese,	28
Barium,	68.6	Tellurium,	32.2
Strontium,	44	Titanium,	31
Magnesium,	12	Cerium,	46
Glucinum,	18	Uranium,	217
Yttrium,	32	Columbium,	184
Allumium,	9	Tungsten,	96
Zirconium,	22.4	Cadmium,	56
Thorium,	(?)	Chromium,	28
Mercury,	101	Molybdenum,	48
Silver,	108	Vanadium,	(?)

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