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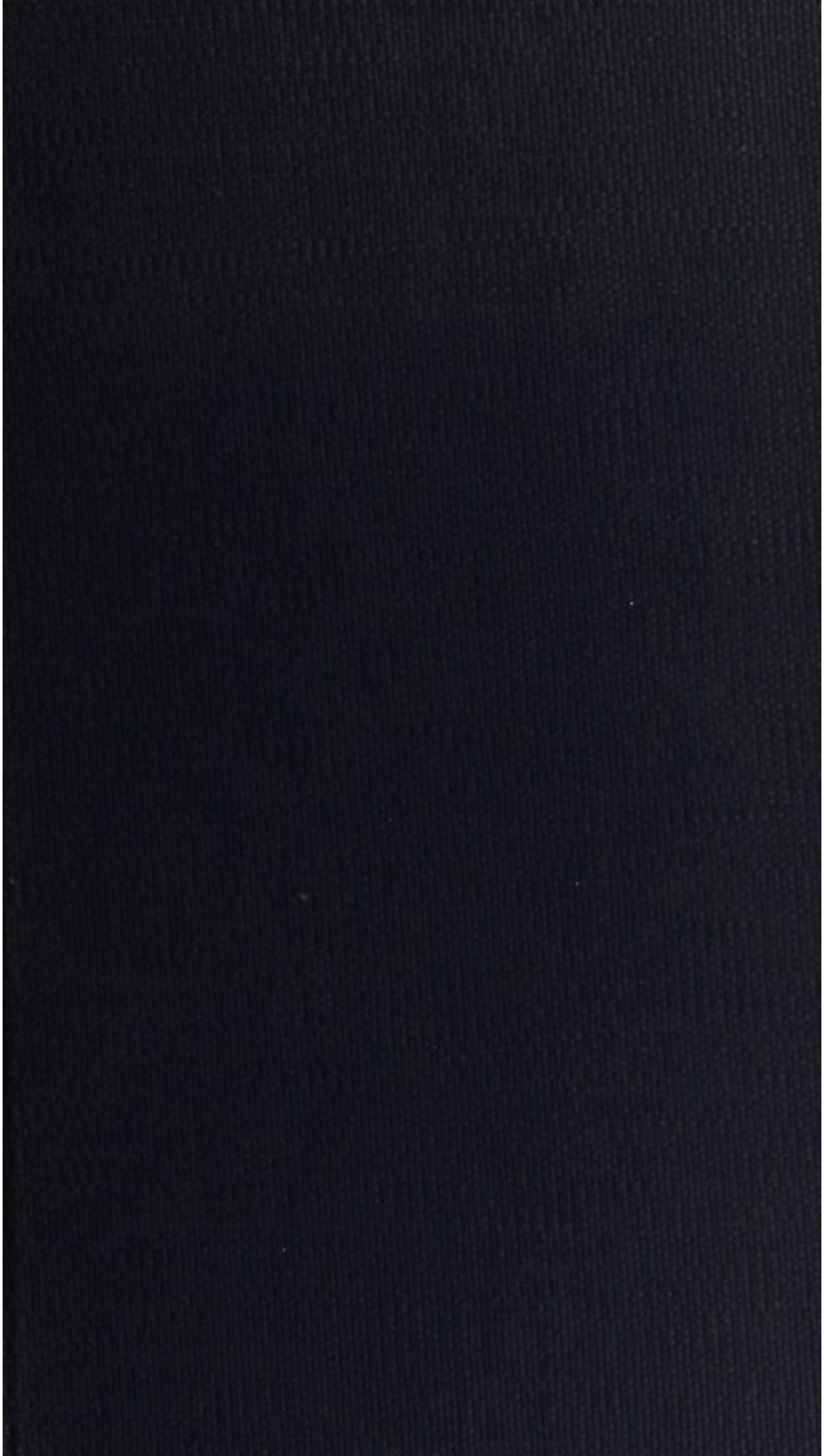
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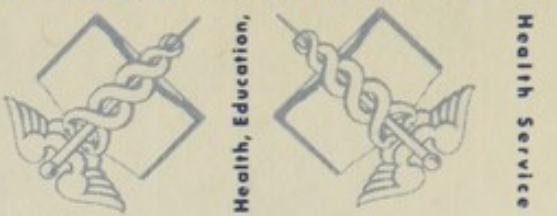
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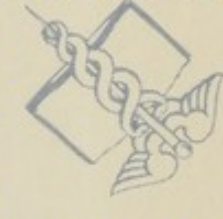
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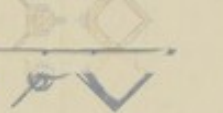
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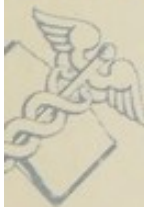
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CHEMISTRY,

FOR SCHOOLS, FAMILIES, AND PRIVATE STUDENTS.

BY A. H. LINCOLN PHELPS.

PRINCIPAL OF THE PATAPSCO FEMALE INSTITUTE, MARYLAND.

AUTHOR OF THE FIRESIDE FRIEND &c. WITH A SERIES OF WORKS ON BOTANY, NATURAL PHILOSOPHY AND CHEMISTRY, DESIGNED FOR BEGINNERS AND MORE ADVANCED STUDENTS.

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PREFACE.

CHEMISTRY is a most comprehensive science ;—while it instructs the philosopher in the constitution of matter, it teaches man how to perform the most common operations in the business of life, such as the preparation of food, the warming and ventilation of apartments, soap making, washing, &c. The arts of dyeing, glass making, engraving, and of preparing medicines, have their foundation in chemical science.

From the intimate connection which subsists between the different branches of Physical Science, the Author of this work has been naturally led from the study of one, to that of others ; and the pleasures and advantages she has derived from these pursuits, have induced the desire that they might be more generally appreciated and enjoyed, especially by her own sex. Her series of works on Botany, Natural Philosophy, Chemistry, and Geology, she is happy to believe, have been studied by many who would not have felt the courage to encounter more erudite works. Teachers, diffident of their own acquirements, have been taken by the hand, and guided, along with their pupils, in paths which the Author had labored to free from difficulties. It is pleasant, to reflect that we are companions of the young, in their search after knowledge, and that *our* thoughts thus become incorporated with *their* thoughts, when the mind, yet free from prejudice, is open to the reception of truth ;—it is a still higher satisfaction to believe that while imparting to the young mind scientific truths, we may be instrumental in implanting the seeds of piety, to be developed with the mental germination, so that the blossoms of the intellect, may be accompanied by the fruits of the soul.

CHEMISTRY.

CHAPTER I.

INTRODUCTORY.

GENERAL VIEWS OF PHYSICAL SCIENCE.—APPLICATIONS OF CHEMISTRY.

1. THE Physical Sciences are so intimately connected that the study of one throws light upon the others. Natural Philosophy, Natural History and Chemistry are sister sciences possessing many characteristics in common, but each distinguished by peculiar traits.

2. The object of all the Physical Sciences is the investigation of the material world. No object is too vast for the grasp of science, none too small for its observation. The celestial orbs, the lowly flowret and minute insect, are, alike, objects of scientific research ; and all, in their own peculiar way, proclaim,

“ The hand that made us is divine.”

3. Let us imagine the three *sister sciences* surrounded by the objects of their several researches ;—We see *Philosophy* turning from the contemplation of the *heavenly bodies*, to cast an approving look upon the *steam-engine*, and *mechanical powers*, or to examine with her *optical glasses* the structure of a mite, or some object in the far distant regions of space. *Natural History*, the priestess of nature, crowned with the *flowers* of all climates, calls around her *all animated things*, whether of the earth, the air or sea. She also claims as hers the *rocky foundation of the earth*, its *metallic treasures*, the *diamond of the mine*, and the *ocean's pearl*.

4. And what of all that is above, upon, or under the surface of the earth, belongs to Chemistry since her sister sciences have appropriated to themselves the works of nature and of art ? Chemistry claims the *elements*, of which *all material substances*

-
1. Connection of the Physical Sciences.
 2. Their object and scope.
 3. The sister sciences.
 4. Province of Chemistry.

are composed ; she, under the direction of their great Creator, presides over their combination, and, at the appointed time, effects their dissolution, carefully garnering up her atoms, so that not one shall be lost. Chemistry, then, may be imagined as veiled from observation, and carrying on those secret processes of composition and decomposition which are intimately connected with the operation and suspension of the vital powers in plants and animals. In obedience to her laws, inorganized matter assumes various forms of beauty and regularity, as in crystals and diamonds, and, at her command, the hardest rocks crumble into dust.

5. The question is often asked, “ does the study of the sciences tend to establish the mind in the truths of religion, and promote christian humility ; or, rather, does not science put nature in the place of God, and heighten the pride of man, by filling him with lofty notions of his own powers, which can thus penetrate the mysteries of creation ? ” We answer that such effects may arise from a superficial study of the sciences—he, who looks not beyond nature, to nature’s God, who seeing a *little*, believes that he sees *all* of the mysteries of creation, cannot truly be called a philosopher. The discoveries of science demonstrate the existence of physical laws which must have originated in one Omniscient and Omnipotent mind ;—they exhibit nature as the mere creation of Almighty power, subservient to his will, and governed by his laws. Man, by the light of science, beholds himself as an atom in creation ; even his discoveries humble him ; for the more he learns of the wonders of nature, the more extensive seem the fields yet unexplored, and the more humble his own attainments.

6. It is the office of science to explain *appearances*, and to teach man to distinguish them from reality. Thus, we learn from Astronomy that the *apparent* motion of the heavenly bodies is not real, but caused by the motion of the earth ; we learn from Optics, that we do not see the *real object* before us, but its *image* depicted on the back part of the eye, and, there, contemplated by the mind. Chemistry proves, that what *appears* to be the destruction of matter is not such ; but, that when a body *seems* to undergo a process of dissolution, its particles are only set free to enter into new combinations, and that no atom, which has been created, is suffered to be lost.

5. Effects of the study of the sciences upon the human mind. Religious influence of science.

6. Science teaches to distinguish the apparent from the real. That matter is indestructible. Combustion not the destruction of atoms, but of combinations.

7. Inquiries into the nature of compounds, and the various changes of which matter is susceptible, must be deeply interesting to every intelligent mind. But it is not alone for the *pleasure* of science that its pursuits are recommended; nor can we assent to the definition of a writer on Political Economy,* viz; "that a philosopher is a person whose *trade* it is to *do nothing*, and *speculate* on every thing." Chemistry is not merely a grave pastime for philosophers; it bears an important relation to the useful arts; and most of the inventions of modern days owe their origin to this science, or depend on principles which Chemistry alone can explain.

8. *Art* and *science* are mutually dependent on each other; the former *works*, the latter *thinks*. It would be as absurd to contend which is the more useful to society, the *working* man or the *thinking* man, as whether the hands or the brain are the more necessary in effecting mechanical operations. Thinking and working should go together; the more the working man thinks, or in other words, the more he combines science with mechanical skill, the more likely will he be to excel, and to improve on what others have done. The man of science who is skillful in manual operations, possesses a great advantage in being able to adapt to their proper use, his instruments of observation and experiment, to supply their deficiencies, or to invent new instruments.

9. Mechanical operations are a series of philosophical experiments. The soap *boiler*, in combining oil and water through the medium of an alkali, illustrates on a large scale the doctrine of Chemical Affinity. The glass maker exhibits chemical phenomena, in melting together, and combining alkaline, saline, metallic and earthy materials; in the effect of coloring matter upon the compounds thus formed; and in cutting, grinding and polishing glass. The *tanner*, by a chemical process, converts the soft spongy skins of animals into leather, which is hard, tough, and impervious to water. The *farmer* in manuring his grounds, and in mixing soils of different kinds, is working on principles which he can only understand by a knowledge of the effects of chemical combinations. The physical *sciences* and the *arts* of life, must go, hand in hand, in the work of improvement. Every advance in science gives a new advantage to the arts, and every improvement in the arts offers to science a fresh field

* Smith, See Wealth of Nations, Book 1, Chap. 1, p. 15.

7. Relation of Chemistry to the useful arts.

8. Mutual dependence of art and science.

9. Common operations effected on scientific principles. Soap boiling—Glass making—tanning, &c.

of research, and new facilities for discovery. Thus, the philosopher and the artisan are mutually dependent on each other.

10. The process of bleaching linen and cotton was long and laborious, requiring weeks and even months for its completion, until by the discovery of *chlorine*, the manufacturer was presented with a liquid, which, by immersing the cloth in it for a few hours, produced the necessary effect. The same chemical agent, chlorine, is most usefully employed as a purifier of infected atmospheres, thus preventing the contagion of dangerous diseases.

11. The discovery of *iodine* may be traced to the observation of a soap boiler. In the refuse of soap ley, he discovered certain corrosive properties for which he could not account. He applied to a Chemist, who, on subjecting the substance to analysis, discovered a new and important chemical element which he named *iodine*.

12. A striking instance of the benefits of science, in alleviating human suffering, is to be met with in the needle manufactories of England. The workmen are obliged to breathe an atmosphere filled with minute particles of steel, which fly from the grindstones, used in pointing the needles. The irritation produced by this dust on the lungs caused consumption. Various expedients were resorted to; but no gauzes or screens could exclude this fine and penetrating dust. At length the magnetic influence was resorted to, and masks of *magnetized* steel wire gauze were constructed; the floating atoms of steel being thus arrested, the workman now breathes freely, in the assurance that he is not inhaling a fatal atmosphere.

13. The *safety lamp*, the *lightning rod*, the *life boat*, are gifts presented to man by science. Chemical science, is not only deeply interesting, as unfolding the laws and secret operations, of nature; but eminently useful, considered in its relation to the diseases and wants of man and the progress of human improvement.

14. *Scientific pursuits exercise on the mind itself*, a healthful and invigorating influence, by bringing into action and disciplining the intellectual powers. In considering the *variety of the works of creation*, the grand and the minute so harmoniously combined, and the system by which the whole universe is connected in an infinite series of relations; in observing the readi-

10. Practical applications of chlorine.

11. Discovery made by a soap boiler.

12. Application of the magnetic power.

13. Other applications of scientific discoveries.

14. The mind of man adapted to the study of nature.

ness with which the human mind seizes upon facts which unfold these dependencies and relations, and the elevation and enlargement which such studies give to the soul, we are led to believe, that, as the earthly parent surrounds his child with the instruments and means of knowledge, so our Almighty Father made, beautified and enriched the material world, that He might thus, give lessons of wisdom to His children, and afford scope for the intellectual energies with which he had endowed them.

15. Chemistry begins where the other physical sciences end. For example, Natural Philosophy considers the *mechanical properties* of matter; Natural History examines the *external organs or form* of objects, with a view to their classification; while Chemistry, penetrating to their internal particles, examines their *constitution*.

16. Chemistry teaches the *elements* of which matter is composed, the *properties of these elements*, and their *laws of combination*; it also shows what are the *component parts and properties of compound substances*.

17. The foundations of chemical science are *observation, experiment and analogy*. By *observation*, facts are noted and impressed on the mind; by *experiment*, new facts are brought to light; by *analogy*, we infer what is unknown from what is known. Thus, suppose a person to notice that when a certain vegetable substance, which is common in brooks and ponds and grows under water, is exposed to the sun, globules of *air* appear on its filaments, while no such globules of air are seen upon the weeds which are in shade. This is an *observation*. The observer, by inverting over it a wine glass filled with water, sees this air rising up through the water until it fills the glass. Having now secured a portion of the air, he is ready to try an *experiment upon its nature*. On introducing a burning taper into it, he finds that the taper burns with greater brilliancy and fierceness than in common air. He has now ascertained that this air differs from the common air. He is then led by *analogy* to inquire, whether other green vegetables will not, in similar circumstances, give off air of the same kind. In this way we may suppose *oxygen* gas, might have been observed, experimented upon, and finally found to exist in a great variety of substances.

18. All the knowledge we possess of external objects is founded upon *experience*; this furnishes facts, and the *comparison of these facts* establishes relations. Such inductions, connected

15. Distinction between the physical sciences.

16. Definition of Chemistry.

17. Foundations of chemical sciences. Definition of certain terms.

18. Process in the discovery of general laws.

with the intuitive belief that the *same causes* will produce the same effects, lead to the knowledge of *general laws*, and these laws constitute a science. Thus has Chemistry, beginning with scattered and isolated facts, advanced to its present distinguished rank among the sciences.

19. The properties of matter are either *Physical* or *Chemical*; the former are considered in Natural Philosophy, the latter in Chemistry.

20. The attraction of gravity or of large masses, has no influence in chemical action; but, chemistry exhibits another species of attraction, called *affinity*, which operates only between the minute particles of matter.

21. Heat, Light and Electricity have important influences upon chemical combinations; as they have not been proved to be ponderous or to have weight, they are called *imponderable agents*, the consideration of these agents, together with the laws of affinity, will constitute the First Part of the following works;—Part Second will treat of the *chemical elements* of ponderable matter; or *Inorganic Chemistry*; Part Third will explain the chemical constitution of *vegetable* and *animal* substances, the study of which, constitutes *Organic Chemistry*.

19. Properties of matter.

20. Difference between the attraction of gravity and that of affinity.

21. Division of subjects.

PART I.

HEAT, OR CALORIC.

CHAPTER II.

GENERAL REMARKS ON THE IMPONDERABLES.—HEAT.—EXPANSION
BY HEAT.—THERMOMETERS.

22. The *imponderable* agents have a very important influence over all terrestrial matter. These agents are *Heat*, *Light* and *Electricity*, which last includes *Galvanism*.

23. It is not known whether these agents are strictly material substances, or only motions or affections of matter. We cannot confine and exhibit them as we can other *material* bodies, nor do the most delicate balances show that they *possess weight*. It is thought by some, that since we cannot prove these agents to possess the common properties of matter, they ought not to be regarded as *material* existences. Some philosophers are of opinion, that they are merely the effects of vibratory and rotatory motions among the particles of matter; and that their *intensity* depends on the *velocity* of *their motions*.

But whether they be material existences, or only properties of matter, they are found to be subjected to physical laws. We shall therefore, consider them as *invisible fluids*, pervading nature, and requiring only the intervention of other kinds of matter to render them evident.

HEAT, OR CALORIC.

24. *Heat*, in common language, is used to signify both cause and effect. By *caloric*,* chemists understand the *cause* of which *heat* is the *effect*; it is the agent which produces in our minds, by means of external organs, the sensation of heat. The term *igneous fluid*, *matter of heat*, &c., mean the same as caloric.

25. Caloric is a subtle, invisible fluid, universally diffused, and highly elastic, that is, composed of particles that strongly repel each other, but possess an attraction or affinity for all other substances.

26. There are six sources of caloric, viz. 1. *the Sun* : 2. *Com-*

* From *calor*, a Latin word signifying heat.

22. Imponderable agents.

23. *Different opinions with respect to the imponderable agents.*

24. Definition of caloric.

25. Nature of caloric.

26. Sources of caloric. *Mechanical means of producing heat.*

bustion : 3. *Electricity* : 4. *The bodies of living animals* : 5. *Chemical action* : 6. *Mechanical action*. The mechanical means of producing heat are *friction* and *percussion*.

The rubbing together of two pieces of wood is an example of friction, and the hammering a piece of metal, of percussion. By these means, wood and other combustibles may be set on fire : and many serious accidents have occurred in consequence, as the burning of factories, explosion of powder mills, and the like.

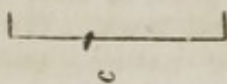
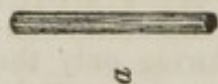
27. Caloric is capable of two modes of existence ; in the one, it is manifested to the senses, and its degrees of intensity may be measured by means of certain instruments. When in this state, it is called *free caloric*, *sensible heat*, *caloric of temperature*, &c. In the second case, the caloric is concealed from the senses, and is said to be *latent* or *hidden*.

Expansion.

28. One of the most important and universal effects of caloric is, to *expand* all bodies into which it enters ; and that such is the effect of caloric is proved by the fact, that a body so expanded returns to its original bulk on cooling.

Experiment. Let a small bar or cylinder of iron, *a*, be fitted to pass through the aperture at *b* and let its length be such that it will fit into the notch *c*. On being heated, it will be found too large to pass through the aperture at *b*, and too

Fig. 1.



long for the space *c* ; when cooled it will contract to its original dimensions.

29. A very useful application of this principle is familiar to wheel wrights. It is highly important that the parts of a carriage wheel should be united in the firmest possible manner. For this purpose, when the wooden portions have been nicely joined, the iron band is constructed so small, that it cannot be forced on when cold. The band now being made red hot, it expands, so as readily, to encompass the wheel ; and in cooling, it contracts, compressing and binding the parts and joints together with an immense force.

30. It is supposed that caloric causes expansion, by insinuating itself between the particles of a substance, and driving them by its elastic force, to a greater distance from each other. Thus, a body when heated occupies greater space, and is of a less specific gravity, than when cold.

27. Free and latent heat.

28. Caloric expands bodies. *Experiment to show the expansion of a solid body by caloric.*

29. *Application of this principle in the manufacture of carriage wheels.*

30. Manner in which caloric causes the expansion of bodies.

31. It might be inferred *a priori*,* that the expansive effect of caloric would be opposed by the cohesive attraction of the particles ; and accordingly we find cohesion and caloric, universally acting as antagonists to each other.

Bodies exist in the solid, liquid or gaseous state, according to the prevalence of the cohesive or repulsive forces. In solids, the power of cohesion, is greater than that of repulsion, and the particles are held closely together. In liquids, the cohesion is so far overcome, that the particles can move freely among themselves ; and in æriform bodies, though cohesion undoubtedly exists, it is not apparent, on account of the predominance of the repulsive power. We should hence expect, that with the same addition of caloric, liquids would expand more than solids and gases more than either, and this is practically true.

32. It is demonstrable, that some bodies expand much more than others ; and that when any solid is heated gradually, through any range of temperature, the hotter it becomes, the more it expands by the same acquisition of heat. For instance, if a metallic rod of known dimensions, be heated from 60° to 100° it will expand to a certain degree. If now another 40° of heat be applied to it, the increase of its dimensions will be greater than in the former case. And this is easily explained ; for the cohesion being partially overcome by the first addition of heat, the second portion will have less opposition to encounter and will produce a proportionally greater effect.

33. By the application of various degrees of heat, solid bodies may all, or nearly all be converted into liquids, as in the melting of ice, the fusion of wax, metals, &c. Liquids, by the further addition of caloric, may be converted into gases.

34. An instrument called the *pyrometer*,† has been invented to show the degrees of intense heat, above those which we are able to estimate by the mercurial thermometer. Mercury boils and becomes vapor, at 660° ; above that point, therefore, it is incapable of measuring heat. The pyrometer depends for its operation, on the expansion of metals, and shows the different degrees of expansibility of different kinds of metals.

The figure shows a rod of metal, *A A*, resting horizontally upon supporters. One end of the rod is fixed, the other end touches the wheel work, *B B*, which is so connected with the index *C* that a slight motion of the wheels, causes a considerable movement in the index. The rod of metal,

* By *a priori* is meant, beforehand, or prior to any reasoning or experimenting, on the subject.

† From the Greek *pur*, fire, and *metron*, measure, signifies *fire measurer*.

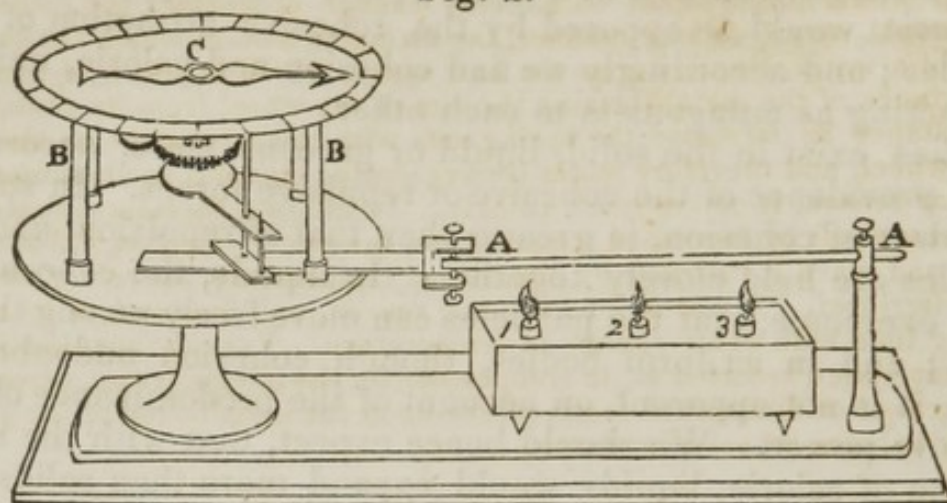
31. Expansion opposed by cohesive attraction. Why liquids expand more than solids, and gases more than either.

32. Expansion greater at certain stages of heat, with an equal increase of caloric, than at other stages.

33. Effects of heat in changing the state of bodies.

34. Pyrometer. Its use and construction. Describe the figure.

Fig. 2.



on being heated by the lamps 1, 2, 3, expands and presses against the wheel, which communicates motion to the index. The more expansible is the metal, the farther the index will move on the plate.

35. The pendulum of a clock, in order to vibrate seconds, must always be of a given length; but as metals expand with heat, the pendulum is liable to shorten in winter and lengthen in summer:—it follows that the clock will go faster in winter than in summer. By lengthening or shortening the pendulum, this evil may be remedied. About thirty-nine inches is found to be the length necessary for a pendulum to vibrate seconds. It may be readily understood why a short pendulum should

Fig. 3.



vibrate faster than a long one, when it is considered that the pendulum is the *radius* of a circle, which circle is larger or smaller, according to the length of the radius. Thus suppose A and B to be two pendulums, of which B is the longer. B must describe the arc, *c, d*, of a circle, while A only describes the arc from *e* to *f*.

36. Various circumstances have rendered it most convenient to construct pendulums of metal, though their liability to expansion and contraction by change of temperature, is an imperfection. If the temperature of the pendulum be raised, its dilatation will evidently remove its mass farther from the point of suspension, and will cause its rate of vibration to be slower; while the diminution of temperature will be attended with the contrary effect.

35. Why will a clock go faster in winter than in summer? How may this evil be remedied? Why does a short pendulum vibrate faster than a long one?

36. Effect of expansion and contraction upon the balance-wheel of a watch.

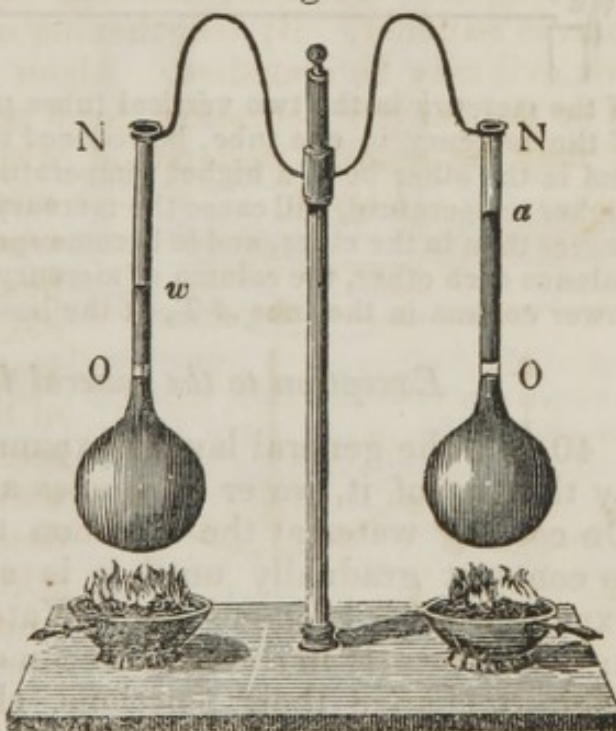
Thus it would follow, that with every change of weather the rate of the clock would vary. In like manner, the swinging motion which the balance wheel of a watch receives from the hair spring which impels it, depends on the distance of the metal forming the rim of the wheel from its center. If this distance be *increased* the spring acts with less advantage on the mass of the wheel, and therefore *moves it more slowly*; and if it be diminished, for a similar reason, it moves more quickly. It follows, therefore, that when a wheel *expands* by increased temperature, the *rate of vibration will be diminished*; and when it *contracts* by diminished temperature, the *rate of vibration will be increased*. A watch for the same reason, will fluctuate in its rate of keeping time with every change of temperature. Various ingenious inventions have been resorted to, to compensate for the irregularities, occasioned by increased or diminished temperature upon the metallic rod of the pendulum, or balance wheel of a watch.

Expansion of Liquids.

37. Liquids, like solids, differ greatly in their several expansibilities by heat. In general, the less the heat requisite to boil a liquid, the more it will expand by a given increase of temperature. And further, liquids like solids are subject to an increasing rate of expansion, as the heat is raised higher.

Experiment. Fill to *o*, *o*, two small matrasses, the one with alcohol, the other with water; place under each, a pan of burning charcoal, or immerse the bulbs in boiling water. The alcohol will rise to *a*, while the water is at *w*.

Fig. 4.



On cooling, the liquids will gradually return to their original bulk. As a general rule, those liquids expand the most uniformly through a steady rise of temperature, which require the strongest heat to make them boil. Alcohol boils with a lower degree of heat than water; it is, therefore, exceedingly expansive; and the nearer it approaches the boiling point, the more rapidly its volume increases.

38. Since expansion by change of temperature changes the weight of a given bulk of a liquid, and this change of weight is in the inverse proportion to the expansion, it follows, that all the

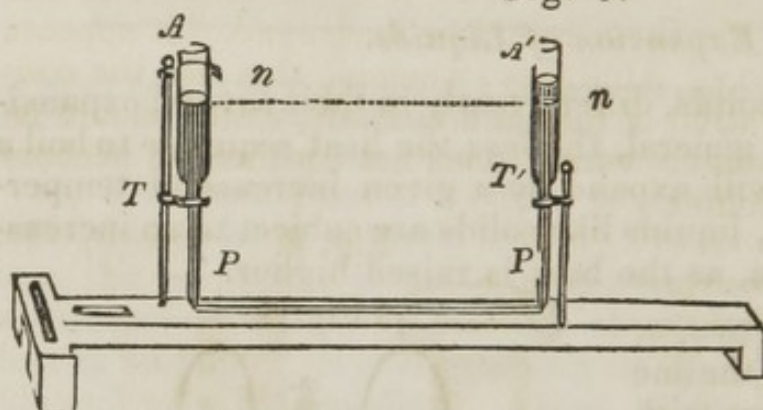
37. Liquids vary in their capacities of expansion by heat. Experiment to show the different effects of heat in the expansion of alcohol and water. General rule with respect to the expansion of liquids.

38. Manner of determining the degrees of the expansion of liquids.

ordinary methods for determining the specific gravities of liquids may likewise be applied to determine their degree of expansion. The specific gravity of the same liquid at different temperatures is different, and always in an inverse proportion to the expansion: the less the specific gravity, the greater, in the same proportion, will be the expansion.

39. The French Chemists have determined the absolute expansion of mercury by means of an apparatus here represented, and which may be applied in the same manner in the case of other liquids. It depends on the hydrostatical principle, that two vertical columns of liquid communicating by a horizontal tube, will have heights in the inverse proportion of their densities.

Fig. 5.



AT and *A'T'* represent two vertical tubes of glass, which communicate with a horizontal tube *PP*. They are filled with mercury to the height *nn*. So long as the temperature is the same in every part, the surfaces

of the mercury in the two vertical tubes must stand at the same level: but if the mercury in one tube, be reduced to the temperature of melting ice, and in the other be of a higher temperature, the expansion produced by the higher temperature, will cause the mercury in one tube to dilate in a greater degree than in the other, and to become specifically lighter; still the columns balance each other, the column of mercury in the tube *A'T'* will balance the lower column in the tube *AT*, at the lesser temperature.

Exception to the general law of Expansion.

40. To the general law of expansion by heat, and contraction by the loss of it, water furnishes a most remarkable exception. On cooling water at the common temperature, it will be found to contract gradually until it is about 40° when it begins to expand until it becomes ice. Water, in becoming ice, increases in bulk $\frac{1}{9}$; water in freezing becomes crystallized; the particles begin to change their positions, shooting out into needles and crossing each other at various angles, as may be seen when water is freezing in a shallow vessel. It is supposed that this new arrangement of particles is the cause of its increasing in bulk, and the supposition is supported by the facts, that solutions of

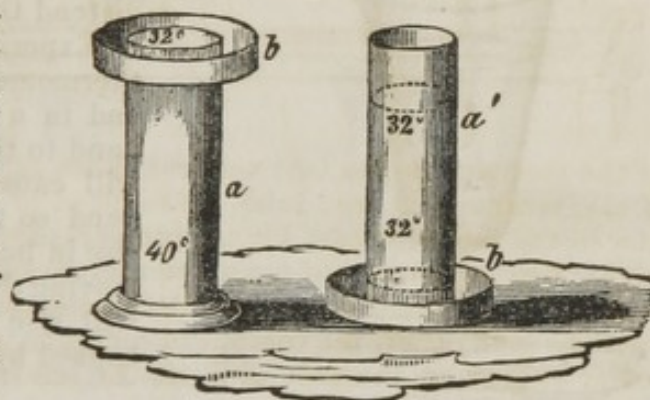
39. Describe the apparatus for determining the absolute expansion of mercury or other liquids.

40. Effect of cooling water below 40° . Change which takes place at this temperature, and probable cause of this change.

salts, in crystalizing are enlarged in bulk, and that several of the metals on solidifying after fusion, also expand, taking, at the same time, a crystalline structure. This property renders antimony so useful for casting types, and cast-iron for various utensils, as the metal on cooling, perfectly fills the mould; whereas, if they followed the general law of condensing by the loss of heat, they would shrink, and receive an imperfect impression.

41. In the economy of a wise and good Providence, this property of water has very important consequences; for if ice were heavier than water, the lakes, rivers, and even the ocean itself, in cold countries would become solid ice, and all animal life which now exists within them would be destroyed. It appears a wonderful provision of Almighty wisdom, that, for the convenience and preservation of man and animals, water should be almost the only substance which does not continue to become heavier as it grows colder.

Fig. 6.



42. Let $a a'$ represent two vessels filled with water at the temperature of about 66° ; $b b'$ are tin trays surrounding the upper part of one vessel, and the under part of the other, and filled with a freezing mixture, viz., ice and salt. The first effect of the cold is to reduce the temperature of the whole mass of water to 40° , at which point water is at its greatest density. After this,

the cooling process in the vessel a , will be limited to the surface, where the temperature will gradually fall to 32° , at which point the water will freeze; for the freezing water, being lighter than the water below, will remain on the surface. This is what takes place in lakes and large bodies of water.

In the vessel a' , where the cold is applied at the bottom, the effect is very different; for the water when cooled below 40° becomes lighter and rises, the warmer or heavier portions descend, in their turn become cooled, and again rise; other, successive portions follow the same course, until the whole, being reduced to 32° , or the freezing point, hardens into one solid body of ice. The process described in the vessel a , or where the cold is at the surface, is that which goes on in nature; that in the vessel a' , is what would take place, did not water, unlike all other known substances, become lighter before it freezes, so that a stratum of ice-cold water at 32° , lies over a mass of warmer water at 40° .

43. The force with which water expands in freezing is immense, bursting not only earthen and glass vessels, but even

41. What would be the effect of cold on lakes and rivers if water became heavier as it changed to ice? 42. *Exp.*

43. Expansive force of freezing water.

cannon and strong metallic vessels, and causing chasms in rocks. By this expansion water pipes are also burst, and pavements thrown up.

Expansion of Aeriform Bodies.

44. In their expansion by heat, aeriform bodies differ from liquids and solids in three important points, viz;—

Fig. 7.



1st. Aeriform bodies expand more than liquids and solids with *the same increase of temperature*; the cohesion of their particles being already more than counterbalanced.

2nd. They expand *equally*.

3d. They *expand uniformly through all temperatures*.

45. Experiment 1st. Hold, near the fire, a bladder *partially* inflated. The air within, being expanded by the heat, will soon distend the bladder.

Experiment 2nd. Place an empty thermometer tube (Fig. 7.) with its open end in a glass of water, and apply the hand to the bulb *a*; the heat of the hand will cause the air within the bulb to expand so that a portion will rush out and rise in bubbles through the water; on removing the hand from the ball, the water will rise in the tube to fill the vacuum caused by the condensation of the air.

Thermometers.

46. The senses being very fallible means of measuring heat, the wants of science demanded the invention of some instrument for that purpose. About the middle of the seventeenth century, the Florentine Academicians made an attempt towards such an invention; their imperfect thermometer consisted of a glass tube, with a bulb at one extremity, filled to a certain mark with alcohol, and closed at the open end;—the expansion of this liquid, or its rise *above* the mark, indicated *heat*; and its contraction, or fall *below* the mark, indicated *cold*. This instrument, called the *Florentine glass*, was introduced into England by Boyle. At

44. Particulars in which aeriform bodies differ from liquids and solids in their expansion by heat. 45. *Exp.*

46. Why was the invention of the thermometer important? First attempt towards the construction of the thermometer.

first, the supposition that a liquid could contract and expand in a tube closed at both ends, was ridiculed as absurd, and it was not until the philosophers of the day were convinced by the experiments of Boyle, that this fact was admitted.

47. The invention of the first thermometer,* is usually ascribed to Sanctorius, an Italian; this instrument depended for its effects on the expansion of air by means of heat.

If a matrass be held in both hands by its bulb, the warmth communicated will expand the air within, and expel a portion of it. Now immerse the mouth of the instrument in a vessel containing a colored liquid, (see Fig. 8.) and remove the hands; the air will gradually cool and contract, while the liquid will rise into the tube, to supply the place of the air which was forced out. The apparatus in this condition, constitutes the Air Thermometer of Sanctorius. On the approach of a heated body to the bulb, the expansion of the enclosed air drives down the liquid in the tube; thus, the lower the column of liquid, the greater is the degree of heat indicated; this is the reverse of what takes place in the common mercurial thermometer, where the greater the height of the column of mercury, the greater is the degree of heat signified.

Fig. 8.



The superior advantages of the air thermometer, consist in the *great expansive property of air* by which *minute* changes of temperature are rendered obvious. But this advantage is outweighed by the objections, that so great an expansion of air with a slight degree of heat would require an unmanageable length of tube for observing any considerable increase of heat; and that the variable pressure of the atmosphere influences air, independently of temperature, so that the air thermometer can only be depended on when the barometer stands at a fixed point.

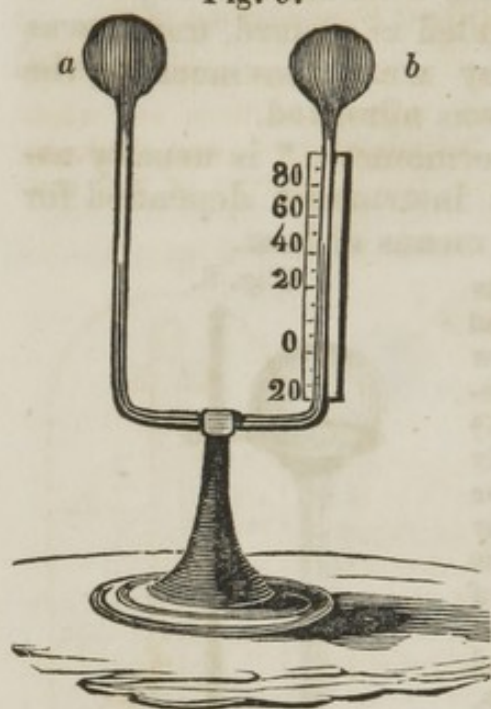
48. A modification of the air thermometer, invented 160 years ago, by Sturm, and revived by Prof. Leslie, in 1804, is extremely useful in some experiments. It consists of a glass tube, (Fig. 9.) bent like the letter U, and having a bulb, *a* and *b*, at each extremity. It contains a colored liquid, commonly sulphuric acid, tinged with cochineal. If heat be applied to one of the bulbs, as at *a*, it will expand the air within, causing the descent of the liquid in one branch, and its ascent in the other towards *b*. The distance the liquid moves, is measured by a scale attached to one of the branches, and divided into *equal* parts, called *degrees*. It is obvious that, with this instrument, we can only learn the *difference* of the temperature of the two bulbs. On this account, it is called the *Differential Thermometer*.

* From the Greek *therme* heat, and *metron* measure, meaning an instrument to measure the degrees of heat.

47. Thermometer of Sanctorius. What causes the liquid to descend in the tube on the approach of a heated body while in the mercurial thermometer, the column of mercury rises under the same circumstances?

48. Leslie's Differential thermometer.

Fig. 9.



49. *Howard's differential Thermometer* is very delicate. In form and principle, it resembles that of Leslie; but the fluid it contains, is sulphuric ether, an extremely volatile substance. One of the bulbs is left with a minute opening, and a sufficient quantity of the colored ether being introduced, it is then boiled. The vapor of ether now rises and fills the tube, expelling the air through the aperture. While the ebullition is going on, and the tube is full of vapor, the opening is suddenly closed by fusing the glass.* The ethereal vapor now indicates the changes of temperature, as the air does in the thermometer of Leslie, but as the vapor expands in one branch, it causes a pressure on that in the other, and the latter *becomes liquid*; thus relieving the countervailing pressure which would impede the motion of the ether, if the second bulb contained an incondensable gas or vapor.

50. As air is not extensively applicable for the purpose of a thermometer, and as the small expansibility of solids renders them almost useless for this purpose, Chemists have sought among liquids for one, combining the most advantages, with the fewest objections. It is evident that perfect fluidity and freedom of motion are essential; oils and viscid liquids, therefore, are unfit, though a thermometer of the former was recommended by Newton. To be of extensive application, also, the liquid should be one which boils with great difficulty; for its indication can be taken only while it retains the liquid state; and, for the same reason, it should be able to support a great degree of cold without freezing. Its expansion, also, should be as nearly as possible uniform, through a great range of temperature. *Mercury* or quicksilver, though far from perfect, possesses the necessary requisites in a higher degree than any other known liquid, and is, therefore, in general use as a thermometer.

51. The principle scales in use, are 1st. The centigrade, or that of Celsius, used principally in France and Sweden, and generally known over Europe. Of this scale the freezing point is marked 0° , and the boiling point 100° . 2nd. The scale of Reaumur, used in France before the revolution, and still retained in Spain, on which the freezing point is at 0° , and the boiling point at 80° . 3d. That of De Lisle, the use of which is confined to Russia; this is a descending scale, the boiling point being 0° and the freezing point 150° . 4th. The scale of Fahrenheit which is used in this country, Great Britain, and Holland. On this the freezing point is marked 32° , and the boiling point 212° , the intermediate spaces containing 180 equal parts or degrees.

* Glass tubes thus closed, are said to be *hermetically sealed*.

49. Howard's Differential thermometer.

50. Objections to air and solids for extensive use as thermometers. Why oil is unfit. Requisites in a liquid to be used for this purpose. What liquid is then generally used for the thermometer?

51. Different thermometer scales in use.

52. A temperature expressed in degrees of one of the above scales is easily convertible to those of another, by applying the following rules.

1st. To reduce any number of degrees of the centigrade scale to terms of Fahrenheit, multiply the number by 9, divide by 5, and to the quotient add 32. The converse process is as follows; subtract 32 from any number of Fahrenheit's degrees, multiply the remainder by 5, and divide by 9; the quotient will express the same temperature in degrees of the centigrade.

Examples.

Centigrade.	Fahrenheit.
$100^{\circ} \times 9 = 900 \div 5 = 180$	add $32 = 212^{\circ}$.

Fahrenheit.	Centigrade.
$212^{\circ} - 32 = 180 \times 5 = 900 \div 9 = 100^{\circ}$	

2d. The degree of Fahrenheit being in length to that of Reaumur in the ratio of 4 to 9; to reduce an expression of Reaumur's scale to one of Fahrenheit, we must multiply by 9, divide by 4 and add 32; and, on the contrary, to obtain an expression by Reaumur's scale equivalent to a given one by Fahrenheit's, we subtract 32, multiply by 4 and divide by 9.

Example.

Reaumur.	Fahrenheit.
$16 \times 9 = 144 \div 4 = 36^{\circ}$	add $32^{\circ} = 68^{\circ}$.
$80^{\circ} \times 9 = 720 \div 4 = 180^{\circ}$	add $32^{\circ} = 212^{\circ}$.

Fahrenheit.	Reaumur.
$212^{\circ} - 32 = 180 \times 4 = 720 \div 9 = 80^{\circ}$	
$68^{\circ} - 32 = 36 \times 4 = 144 \div 9 = 16^{\circ}$	

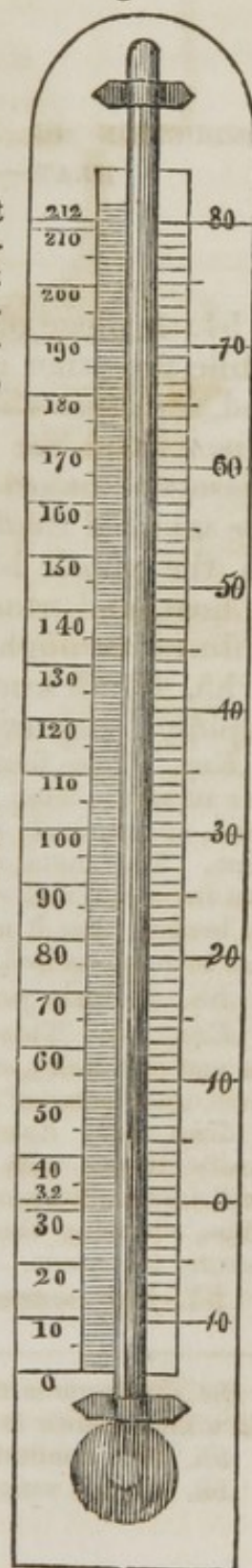
Thermometers are sometimes constructed with different scales affixed to the same tube, so that the correspondence of the degrees of different thermometers may be at once perceived. The figure represents a thermometer, with Fahrenheit's and Reaumur's scales.

53. The mercurial thermometer is accurate in its indications of temperature, as high as 212° ; for though mercury, like other liquids, expands proportionally more at high than at low temperatures, the irregularity is exactly compensated by the expansion of the glass tubes. But above 212° , the glass expands more rapidly than the mercury, and the indications are less

52. Rule for reducing degrees of the centigrade thermometer to those of Fahrenheit, and for converting degrees of Fahrenheit to those of the Centigrade. Examples. Rule for reducing degrees of Reaumur's thermometer to Fahrenheit's, and for converting degrees of Fahrenheit to those Reaumur. Examples.

53. Irregularities of the mercurial thermometer.

Fig. 10.



accurate. This instrument may, however, be used for common purposes, to compare degrees of heat as high as 500° , and quite accurate as low as 39° below zero, when it freezes. When it is desirable to measure temperatures lower than 39° , alcohol must be employed.

CHAPTER III.

CONDUCTION OF HEAT.—RADIATION AND REFLECTION.—LATENT HEAT.—LIQUEFACTION.—FRIGORIFIC MIXTURES.

Conduction of Caloric, or Heat.

54. A piece of wood may be held in the hand, by one end, while the other is burning; but if a bar of iron be heated at one end, the other will soon be too hot for the hand. This difference arises from the unequal facility with which bodies allow the passage of caloric through their masses; or, in other words, from the unequal *conducting powers* of bodies. When a solid is heated, the caloric is received by the particles nearest the source of heat, and transmitted to those next them, and so on, till it is diffused through the whole mass.

55. Of all known bodies, metals transmit caloric the most rapidly; they are, therefore, called the best *conductors*.

Exp. Take four small rods; one of metal, one of glass, one of wood, and one of whale-bone, and cement one end of each to a lump of sealing-wax; then, successively expose each rod at the opposite end to the heat of a blow-pipe. The metal soon becomes so hot as to melt the sealing-wax from it; but the wood and whale-bone, may be destroyed by the heat, and the glass so heated, that it may be bent, while the sealing-wax at the opposite end has not become melted.

56. Metals possess different conducting powers.

Exp. 1st. Thus, if equal sized rods of several metals be coated with wax, at one extremity, and be equally exposed to heat at the other, the wax will melt upon some of the rods much sooner than upon others.

Exp. 2nd. Let cones of different kinds of metals (see Fig. 11.) be severally tipped with wax, and placed upon a heated metallic plate, the wax will first melt upon the one which is the best conductor of heat, and so on; thus, showing the relative conducting powers of the different metals composing the cones.

57. By some recent experiments, the conducting power

54. Difference in the power of wood and iron to conduct heat. Manner in which caloric is transmitted in solid bodies.

55. Best conductors of caloric.

56. Metals vary in their conducting powers. *Exp. 1st. Exp. 2nd.*

of several metals has been found to decrease in the following order, viz., gold, silver, copper, platinum, iron, zink, tin and lead; the latter being the poorest conductor of caloric of all the metals. Among *bad conductors* of heat are stones, dry wood, charcoal, dry air, feathers, and other light animal and vegetable substances, particularly the usual materials for clothing. It is on account of the small conducting power of wool, cotton, &c., that they are chosen for their particular use; for in summer, when the solar heat would scorch the skin, they impede its progress *to the* body, and in winter they retard the passage of heat *from* the body to the cold air. Wool is not so good a conductor as linen; in a hot summer's sun, therefore, a white woollen dress is preferable to linen. Owing to the difference of their conducting powers, the different articles in a room, though really at the same temperature, will seem different to the touch. A marble slab will feel colder than a woollen carpet, because it absorbs heat more readily from the hand. For the same reason good conductors, when heated, transfer their caloric rapidly to the hand, and will therefore *burn* it, though a bad conductor, at the same temperature will scarcely feel warm. Thus coffee pots and other metallic vessels, intended to hold hot liquids have wooden handles. The conducting power of metallic vessels gives them an advantage over glass or earthen ware for heating liquids rapidly.

Fig. 11.



58. The low conducting power of charcoal has given rise to a useful application of it in the *Refrigerator*.* There are different kinds of this article; a simple and useful one may be made as follows;—procure a box of wood, divided by partitions of tin and iron, into three compartments. Inclose this box in one larger, by about an inch in each of its internal dimensions. The space between the boxes is to be filled with powdered charcoal. If meat, butter, wine, or other articles, be put into the two extreme compartments, and ice into the middle one, they may be preserved cool and fresh in the hottest weather; for the charcoal scarcely permits the passage of caloric from without, while it is readily transferred through the metallic partitions from the meat &c. to the ice. A great saving is also effected in this way in the consumption of ice. In constructing ice houses, straw, which is an imperfect conductor of heat, is usually placed around the walls, roof and floor. A building made with double walls, having a space between them filled with air furnishes an excellent ice house; for air where no source of radiation is present, is nearly impenetrable by heat.

* Derived from the Latin, and signifies a *cooler*.

57. Arrangement of metals according to their conducting powers. Why wool, cotton &c., are used for clothing. Why articles in the same room appear of unequal temperature. Why wooden handles are used for metallic coffee pots. Why metallic vessels are better than earthen for heating liquids.

58. The refrigerator. Ice houses.

Conducting Power of Liquids.

59. Liquids possess the power of conducting heat in a very small degree. Heat applied to one proportion of a liquid is distributed through the mass, not by conduction, as in the case of solids, but by the motion of the particles. When heat is applied to the bottom of a vessel containing a liquid, the particles nearest the source of heat become warm, expand, and being then lighter than the rest, rise to the upper surface; the next

Fig. 12.

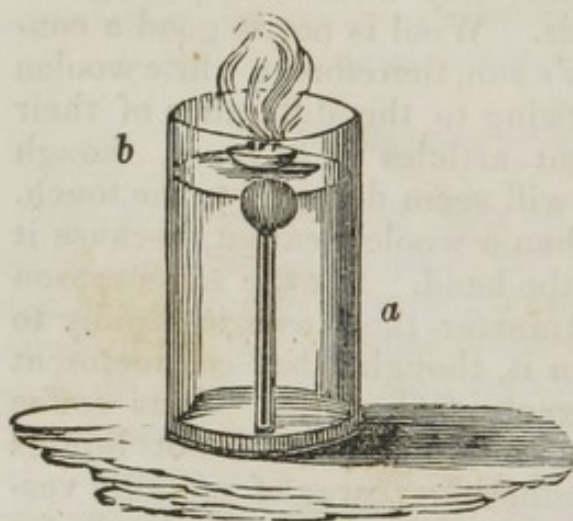
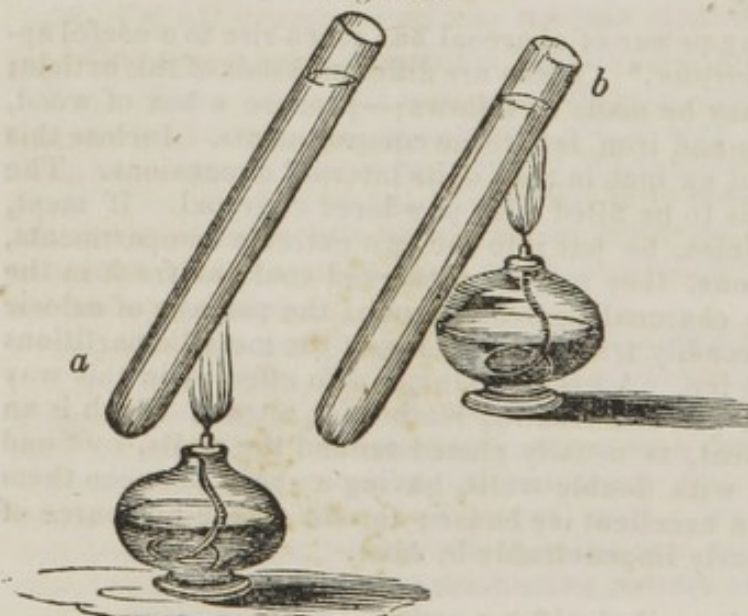


Fig. 13.



stratum does the same, and so on till the whole is heated. But if the heat be applied at the top, the caloric will penetrate but a small distance downward.

60. *Exp. 1st.* Let *a* be a glass vessel (Fig. 12.) nearly filled with water, and including an inverted air thermometer; *b* a small dish containing burning charcoal, and separated from the thermometer bulb by a thin stratum of water. While the surface of the water is heated to the boiling point, the thermometer below will indicate very little increase of temperature.

61. *Exp. 2nd.* Let *a* and *b* (Fig. 13.) represent two thin glass tubes filled with water. If the heat of a lamp be applied to the bottom of the tube *a*, the whole mass of water within the tube will soon become equally heated, and begin to boil. But let the heat be applied near the top of the tube *b*, and the surface may be made to boil while the water at the bottom remains cold. The hot water being lighter than cold, it will remain at the surface; while, if the par-

59. Mode in which heat is distributed through liquids. Why liquids do not become heated when caloric is applied to the upper surface.

60. *Exp. 1st.*

61. *Exp. 2nd.*

62. *Exp. 3d.* Fill a glass vessel with water, and throw into it a few particles of amber, then apply heat to the bottom of the vessel; and a rising current will immediately begin in the center of the vessel, while descending currents appear at its sides, as represented by the direction of the arrows. (see Fig. 14.) It is by successive changes in the weight of the different particles of water, that the whole mass becomes heated.

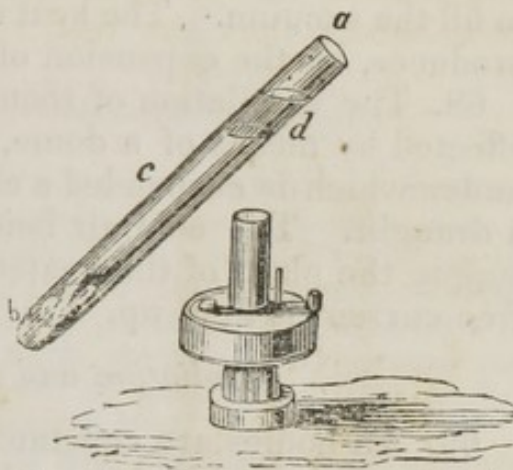


63. *Oil is a bad conductor of heat.*

Exp. 4th. Let *a b* (Fig. 15,) represent a thin glass tube, two feet in length, closed at one end, and open at the other; pour into it two inches of powdered ice or snow, then upon this mass pour eight inches of oil, *c*; and over this two or three inches of alcohol, *d*. The alcohol may be boiled, and even evaporated by the flame of a lamp, while the oil will not be sensibly heated, nor the frozen mass melted.

As liquids are heated by internal motion, they must become cool in the same manner: and hence we see why soft solids and semifluids, like warm bread, puddings, &c. cool very slowly; the internal motion of the particles being impeded, and the conducting power feeble.

Fig. 15.



Effect of Caloric on Aeriform Bodies.

64. Aeriform bodies possess the power of conducting heat, if at all, in a very slight degree. Like liquids they are heated by internal movements among their particles.

65. *When air is heated, currents are produced.* In a heated room, the warmer air ascends, parts with caloric, and becoming heavier descends; thus, there is an ascending and descending current continually in motion. If the door of a warm room be opened, warm air rushes out at the upper space, while cold air enters below. This may be proved, by holding the flame of a lamp at an open door: at the upper part of the door the flame will be blown outwardly, at the lower part inwardly, while midway, it will remain perpendicular.

66. *Argand lamps*, or lamps which have a circular hollow wick surrounded with a glass cylinder, are supplied with a current of fresh air to support combustion by the same principle as the draft of a fire place. The heat of the flame expands the air above it, and this being thus rendered lighter than the atmosphere around, rises and leaves a vacuum towards which the sur-

62. *Exp. 3d.*

63. *Exp. 4th.* Why soft solids cool more slowly than liquids.

64. Aeriform bodies in respect to their conducting power.

65. What produces currents of air.

66. Argand lamps.

rounding portions of air now press. The glass chimney becoming heated, serves still more to rarefy the enclosed air, and by thus rendering the upward current more lively, promotes combustion; for with new portions of air, to supply the place of that which has ascended, fresh quantities of oxygen are added, and the flame is increased.

67. When a fire is made in the open air, winds from all quarters are rushing towards it, even in the calmest day. This is because the air near the fire, being made lighter by heat, rises into higher regions of the atmosphere, and colder air rushes in to fill the vacuum. The heat of the sun over the tropical regions produces, by the expansion of air, the trade winds.

68. The ventilation of rooms designed for large assemblies is effected by means of a dome, having an aperture at its vertex, under which is suspended a chandelier to heat the air and cause a draught. The cold air being constantly admitted below, to supply the place of the heated and vitiated air which ascends, a free current is kept up.

Radiation and reflection of Caloric.

69. All bodies are constantly giving out caloric; and the temperature of a body rises, when it receives more than it gives out; or falls, when it gives out more than it receives. The caloric thus given out, is called *radiant caloric*, and following the same law as light, emanates *equally from all sides* of the heated body, and proceeds in *straight lines*, moving with great velocity. By suspending a heated ball, and holding the hand at a short distance on any side, the heat will be immediately perceived, and, in the same degree in all directions. In this case, caloric is radiated, as it is from the Sun.

70. Radiant caloric is *reflected* by various bodies; and the laws which govern this reflection are the same as those which govern the reflection of light.

71. When a ray of heat falls *obliquely* upon a surface whether plane or curved, its direction is altered; and the divergence is such, that, if we draw a perpendicular to the surface through the point where the ray strikes it, the angle between this perpendicular and the incident ray, is precisely equal to that between the same perpendicular and the reflected ray: in other words, the *angle of incidence* is equal to the *angle of reflection*.

72. *Exp. 1st.* Resting one edge of a sheet of tin upon the hearth, incline

67. Why wind blows towards a fire made in the open air. Cause of trade winds.

68. Ventilation of public rooms.

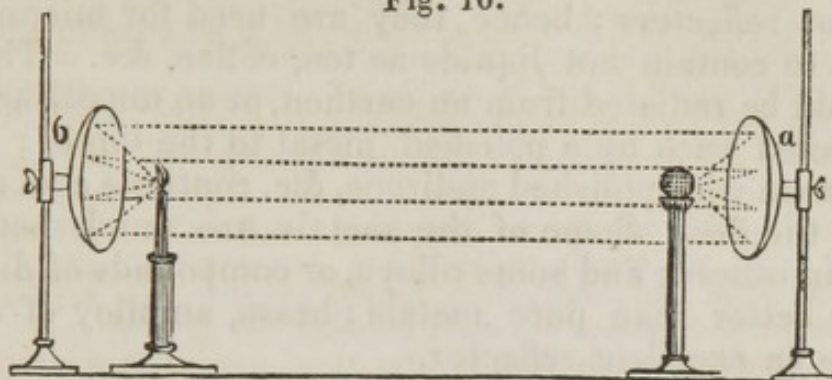
69. Radiant caloric.

70. Reflection of radiant caloric.

71. Law which governs the reflection of heat.

it backward, till, on holding your face vertically over it, the image of the fire can be seen in the tin; the warmth will be felt upon the face, though it be screened from the direct heat of the fire.

Fig. 16.

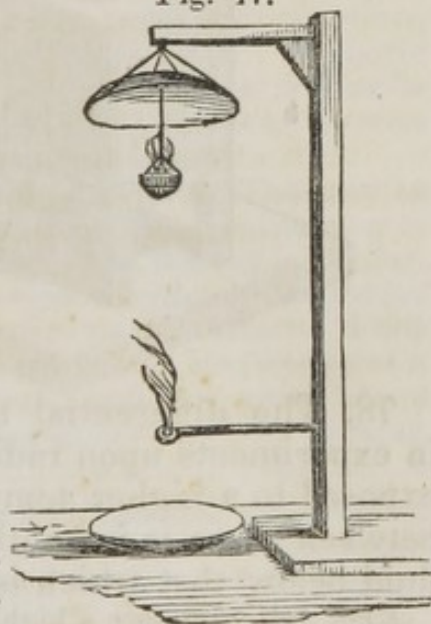


73. *Exp. 2nd.* Place a heated iron ball in the focus of a concave metallic mirror, (Fig. 16,) opposite to this, and at any convenient distance, place a second concave mirror, in the focus of which put a candle, having on its wick a bit of phosphorus. The *diverging* rays of radiant caloric proceeding from the ball to the mirror *a*, are reflected by the latter in parallel lines to the mirror *b* which *converges* them at its focus, igniting the phosphorus and thus lighting the candle. If a thermometer be substituted for the candle, the mercury in it will be raised by the radiated heat.

74. *Exp. 3d.* Remove the heated ball from the focus of the mirror *a* (Fig. 16,) and replace it by a piece of ice; a thermometer in the focus of the mirror *b*, now radiates more caloric than it receives, and the mercury will instantly fall. This experiment has given rise to a supposition that a *fluid of cold* existed, and was radiated by the ice; but cold is a mere negation, implying only the absence of heat.

75. *Exp. 4th.* Sir Humphrey Davy contrived the following mode of showing the radiation of caloric. He placed two mirrors vertically, (Fig. 17,) with a wire-basket of burning charcoal in the focus of the upper one, and a little dish of phosphorus in the focus of the lower. The phosphorus was set on fire by the reflected heat from the lower mirror. Now all the heat that reaches this mirror, and is concentrated in its focus, must be radiant and reflected, as the current of heated air passes upwards.

76. Bodies vary in their powers of *radiating*, and of *reflecting* caloric; and these two properties are in an *inverse proportion* to each other; that is, those substances which are the *best radiators*, are, generally, the *worst reflectors*: or, as the radiating power increases, the reflecting power diminishes.



72. *Exp. 1st.*

73. *Exp. 2nd.*

74. *Exp. 3d.*

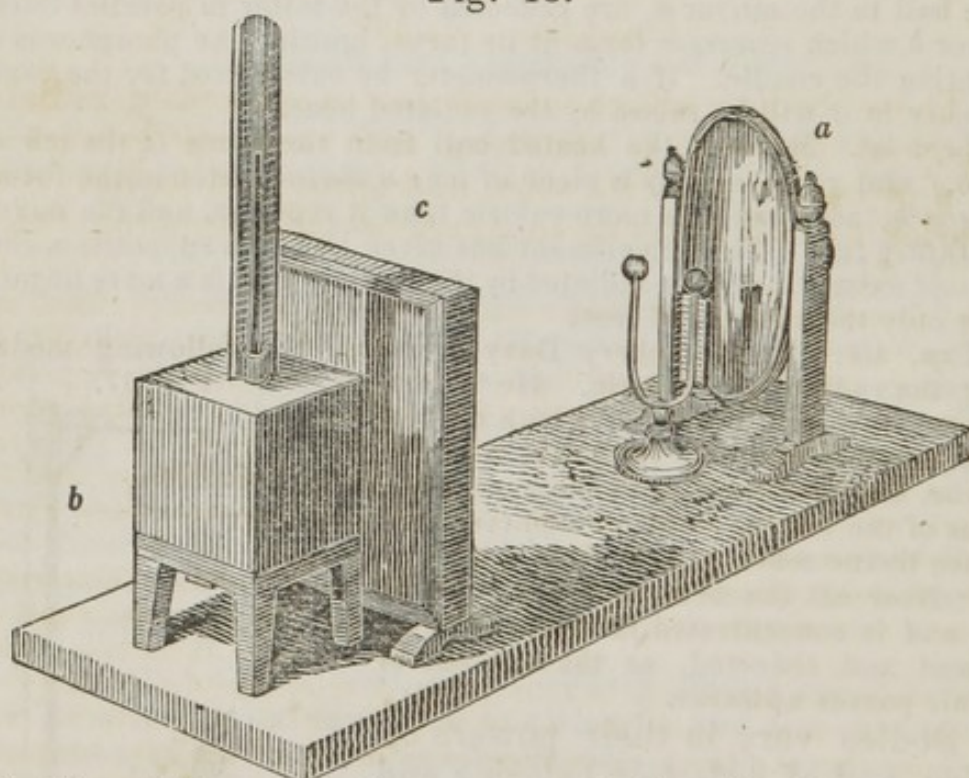
75. *Exp. 4th.*

76. Reflection and radiation opposite qualities. Examples: the metals.

Polished surfaces reflect caloric better than rough ones ; and the reflecting power of the same surface is directly in proportion to its degree of polish. Of all bodies, the metals when polished, are the best reflectors ; hence, they are used for mirrors, and for vessels to contain hot liquids as tea, coffee, &c. The heat which would be radiated from an earthen, or an unpolished vessel, is reflected back by a polished metal to the liquid ; hence, also the reason why polished andirons, &c. continue cool though exposed to the fire. Some of the metals are much better reflectors than others ; and some alloys, or compounds of different metals, are better than pure metals : brass, an alloy of copper and zinc, is an excellent reflector.

77. It is obvious, that the *reflection* of caloric must be directly opposed to *absorption* ; and, since it is equally obvious that the more caloric a body absorbs, the more it will radiate, the reason is manifest, why the best reflectors are the worst radiators.

Fig. 18.



78. The differential thermometer is found to be very useful in experiments upon radiant heat ; as, when one of the bulbs is exposed to a higher temperature than the other, the difference between them is instantly shown, by the falling of the colored fluid below that which is most heated.

Exp. 1st. Suppose a highly polished metallic mirror (Fig. 18,) *a*, placed a few feet from a cubical tin vessel *b*, filled with boiling water ; let a differential thermometer be placed so that one of the bulbs shall be in the focus of the mirror, and an instantaneous rise of the temperature will be in-

77. Why are the best reflectors, the worst radiators.

dicated by the instrument. If a glass mirror be substituted for the metallic one, the thermometer will be much less affected, by which it appears that glass is not so good a reflector of heat as polished metal. If the surface of the reflector be coated with lamp-black, all reflection is destroyed, and of course the thermometer is not affected. If a screen *c*, be interposed between the tin vessel of hot water and thermometer, the latter will immediately indicate the absence of a portion of heat it before received, though the source of the heat is as near the bulb as before; this shows that the thermometer was not affected merely by contiguity to the heated body, but by radiated heat.

79. *Exp. 2nd.* If a cubical tin vessel, having one of its sides coated with lamp-black, another papered, and another glazed, be filled with boiling water, and the thermometer placed in the focus of a metallic reflector, it will be found, that as the different sides are respectively presented to the reflector, the thermometer will exhibit different degrees of temperature, showing that the different sides of the vessel possess the power of radiating heat in different degrees.

The radiating power of lamp-black is found to be 100°.

paper,	98°
glass,	90°
bright tin.	12°

80. Those bodies which *absorb heat most readily*, radiate it most powerfully, that is *absorbing* and *radiating* powers are equal; a piece of iron heats soon, and parts with its heat readily; a brick neither heats as soon, nor so quickly parts with caloric.

It was formerly supposed that such substances as *received* heat most readily, must *retain* it longest; philosophers, therefore, thought that housekeepers should make their tea in earthen or porcelain tea-pots, rather than in metallic ones; but tea-makers insisted that they found by *experience*, that tea would "*draw best*" in bright silver or pewter tea-pots. The latter opinion is now proved by philosophy to be correct, since water retains its heat much longer in the polished metallic vessel, and, by this means, extracts more fully the peculiar virtues of the tea.

81. Some *colors absorb* caloric more readily than others. This may be shown by a very simple experiment. Take a piece of black and another of white woolen cloth, and lay them upon the snow, when the sun is shining. In a few hours the black will be found to have sunk considerably below the surface of the snow, while the white will remain on the surface. From this we infer that the black cloth *absorbed* caloric from the sun, and gave it off in sufficient quantity to melt the snow beneath, while the white did not absorb, and consequently did not give off caloric; with respect to light,

78. Use of the differential thermometer in experiments upon radiant heat. Suppose a glass mirror be substituted for the metallic one, or the thermometer coated with lamp-black. How is it proved that the thermometer was not affected by contiguity to the heated body?

79. *Exp. 2nd.* Illustrating by means of the differential thermometer the radiating powers of lamp-black, paper, glass and tin.

80. Absorption, and radiation equal. Why metallic tea-pots are better than earthen.

81. Different powers of colors to absorb caloric.

black bodies absorb all the rays and reflect none; while, in the case of caloric, black bodies not only absorb, but reflect in an equal proportion. Thus a white beaver hat is cooler for the head, in summer, than a black one, and light colored garments are more agreeable than dark colored.

82. It is by contact with the earth, that the atmosphere becomes hot; for *radiant caloric*, either from the sun, or other sources, passes through aeriform bodies, without heating them. We, therefore, find the upper regions of the air, though nearer the source of heat, considerably colder than those next the earth.

The *formation of dew*, is connected with this subject. In perfectly clear weather, the earth, which is, at all times radiating caloric, cools rapidly as soon as the sun sets, for it then radiates more than it receives. The atmosphere contains watery vapor, which losing caloric by contiguity to the cool surface of the earth, becomes condensed and appears in drops, or minute particles of moisture, upon the leaves, flowers, and grass.

Insensible Heat.

83. If we immerse two thermometers in two portions of water just taken from the same reservoir, the temperature of each will be the same, however unequal their quantities; yet it is evident that a quart of water must contain twice as much caloric as a pint of the same temperature. It is clear then, that the thermometer cannot indicate the absolute quantities of caloric contained in bodies; and that every substance contains some heat, (the quantity being peculiar to itself,) which is not perceptible by the senses, and does not affect the thermometer. This is called by the name of *combined, insensible, or latent caloric*.

84. If equal portions of water, at different temperatures, be mixed, the temperature of the mixture will be found an exact arithmetical mean between the two original temperatures; but if equal weights of *water*, and *any other liquid* be mingled, under the same circumstances, the resulting temperature will differ from the mean.

Exp. Mix a pound of water at 40° , with a pound of mercury at 185° , the thermometer will stand at only 45° in the mixture; or if the water be at 185° , and the mercury at 40° the mixture will raise the thermometer to 180° . Here, in the first case, the 140° of caloric lost by the mercury, only increased the temperature of the water by 5° , and in the second case the water by losing 5° of heat, raised the mercury by 140° .

85. The power that a body has of retaining more or less caloric in a latent state, is called in relation to another body its

82. Heat of the atmosphere, how produced. Formation of dew.

83. The thermometer does not indicate the absolute quantity of caloric in bodies. Name given to the portion of caloric that does not affect the thermometer.

84. Effect of mixing water of different temperatures, or of mixing water and any other liquid.

relative capacity for caloric; and the relative quantity of heat so retained, is called its *specific caloric*. Dr. Black, to whom the discovery of this difference of bodies in their relations to heat is due, supposes that the insensible caloric is in a state of chemical combination, by which its properties are neutralized.

The specific heat of bodies is estimated by comparing them with some particular body, of which, the specific heat has been taken as unity; that of *water* is the standard which has been generally chosen.

The experiment may be made by mixing them separately, with equal weights of water of a different temperature, and ascertaining the resulting temperature; or by observing the time necessary to bring each to a given temperature by the same source of heat; for those having the greatest specific heat, (or capacity for caloric,) will require the longest time; or, by observing their relative times of cooling under the same circumstances; for those which are longest in heating, are also longest in cooling; or by observing the quantity of ice which will be melted by each after having been heated to a given temperature; for those having the greatest specific caloric, will melt the most ice. The last method is the foundation of Lavoisier's *Calorimeter*.*

86. In speaking of the specific heat of a particular body, we refer to that body in one state only; for in passing from one state to another, it acquires a new specific caloric; thus, ice has a certain specific heat, water another, and steam another. Liquids have more specific heat than solids, and gases more than liquids; the individuals of each class differing, also, among themselves. It is by absorbing and rendering *latent*, a quantity of caloric, that bodies pass from the solid to the liquid, and from the liquid to the gaseous state; and when vapors are reconverted to liquids, and liquids to solids, the latent caloric becomes *sensible*.

87. *Laws of specific heat.* 1st. Every substance has its particular specific caloric, which changes, when the body changes its form, or composition.

2nd. Gaseous bodies, in becoming denser, lose, and in rarefying, acquire capacity for caloric; hence,

3d. A change of density always occasions a change of temperature.

The coldness of the upper regions of air, with the consequent presence of snow and ice on high mountain tops, is supposed to be caused by the rarity of the air at that height, by means of which it has a great capacity for heat, absorbs, and renders latent the free caloric from surrounding bodies, and, thus, remains, always, at a low temperature.

* *Calorimeter* is from *calor*, heat, and *metron*, measure, a measurer of heat.

85. Meaning of the terms capacities for caloric, specific heat &c. Opinion of Dr. Black. Mode of estimating the specific heat of bodies. Exp. for ascertaining the specific heat of different bodies.

86. Specific heat varies with change of state.

87. Laws of specific heat. Cause of the coldness of the upper regions of the air.

Liquefaction.

88. Liquefaction is an effect of insensible caloric. If ice be moderately exposed to heat, it will gradually liquefy, and the temperature will be at 32° , during the whole process of melting; but the last portion of ice being dissolved, the water will gradually grow warm, till it attains the temperature of the surrounding atmosphere. Here the ice has been receiving caloric which has had no sensible effect in raising its temperature, but has been occupied in bringing it to the liquid state. This *latent* heat in the water, is called the *caloric of fluidity*. The same process takes place, whenever any solid becomes liquid, as in the dissolving of saline bodies, the fusion of metals, &c. When a metal is heated to a certain degree, called its *fusing* point, a portion of it begins to melt; all the heat received after this, goes to carry on the process of liquefaction; the temperature remaining stationary, till all the metal is in a state of fusion; after which, if the heat be continued the temperature will increase.

89. The *heat* which has been appropriated in these instances, is always *given out again*, when the liquid becomes solid; for example; if water be kept entirely motionless, it may be cooled by artificial means, several degrees below the freezing point, (32° ;) but on agitating it, a portion freezes, and in solidifying, gives out sufficient caloric to raise the whole to 32° . Sulphur and phosphorus, after having been fused, may sometimes be cooled to common temperatures without resuming their solidity; but if in this state, they are touched with a glass rod or other substance, they instantly solidify, giving out their caloric of fluidity.

The principle deduced from the fact that caloric disappears during the liquefaction of a solid, is usefully applied to the obtaining very low temperatures, artificially, by means of freezing mixtures.

90. *Frigorific*,* or *freezing Mixtures*, consist, of certain soluble salts, and snow, or pounded ice. The effect depends on the tendency of the salt to dissolve in water; this induces the liquefaction of the ice, by which, heat is absorbed; and the salt dissolving in the water thus formed, removes a further portion of heat. It is obvious that the more rapid the liquefaction, the more intense the cold produced, and therefore the most effective; the

* From *frigus* cold, and *facio* to make.

88. Caloric of fluidity.

89. What becomes of the caloric of fluidity, when the liquid is reconverted to a solid.

90. Of what freezing mixtures consist, and how prepared. Greatest cold produced.

pulverizing of the materials assists the operation, by hastening the process of solution. By the use of equal weights of crystalized muriate of lime and snow, quicksilver has been frozen. The greatest cold produced by freezing mixtures, is said to be about 100° below the zero of Fahrenheit; by evaporation, a mere intense cold may be produced, but no known process can deprive a body of all its caloric.

91. In employing these mixtures, care must be taken that they are thoroughly mingled together. The best vessels for using them, are of metallic ores of different sizes, having double sides at a distance of half an inch from each other. The article to be frozen, is to be put into the smaller vessel, which may then be placed in a larger one, and surrounded with the mixture. A double cover is now to be put on, to prevent the caloric of the atmosphere from defeating the experiment.

In making ice cream, the vessel (Fig. 19.) used for containing the mixture to be frozen, is usually of tin, and of the form represented in the figure; *a* is the body of the vessel, and *b* the handle affixed to the cover, which is made to fit very close to exclude the caloric of the atmosphere. The cream, now being prepared with sugar, &c., is put into the tin vessel, which is then immersed in pounded ice and salt, or other freezing mixture, contained in a larger vessel. To facilitate the freezing process, the vessel containing the cream must be occasionally shaken by the handle. When the cream is found to be frozen around the side of the vessel, which is in contact with the freezing mixture, a knife or spoon should be introduced to remove the frozen parts, so that other portions may take its place.



Freezing Mixtures.

Mixtures.	pts. by wt.	Thermometer sinks.	Degree of cold produced.
Sea salt	1	to -5°	
Snow	2		
Sea salt	2	to -12°	
Muriate of ammonia	1		
Snow	5	to -25°	
Sea salt	5		
Nitrate of ammonia	5	from $+32^{\circ}$ to -23°	55°
Snow	12		
Dilute Sulphuric acid	2	$+32^{\circ}$ to -27°	59°
Snow	3		
Concentrated Muriatic acid	5	$+32^{\circ}$ to -30°	62°
Snow	8		
Concentrated Nitrous acid	4	$+32^{\circ}$ to -40°	72°
Snow	7		
Chloride of Calcium	5	$+32^{\circ}$ to -51°	83°
Snow	4		
Fused potassa	4		
Snow	3		

91. Manner of using these mixtures. Ice cream apparatus.

Freezing is also effected by the rapid solution of Salts.

Mixtures.	pts. by wt.	Thermometer falls.	
Muriate of ammonia	5	from + 50° to + 10°	40°
Nitrate of potassa	5		
Water	16		
Nitrate of ammonia	1	+ 50° to + 4°	46°
Water	1		
Nitrate of ammonia	1	+ 50° to — 7°	57°
Carbonate of Soda	1		
Water	1	+ 50° to — 3°	53°
Sulphate of Soda	3		
Diluted Nitrous acid	2	+ 50° to — 14°	64°
Sulphate of Soda	6		
Nitrate of ammonia	5	+ 50° to — 12°	62°
Diluted Nitrous acid	4		
Phosphate of Soda	9	+ 50° to — 21°	71°
Diluted Nitrous acid	4		
Phosphate of Soda	9	+ 50° to — 0°	50°
Nitrate of ammonia	6		
Diluted Nitrous acid	4	+ 50° to + 3°	47°
Sulphate of Soda	8		
Muriatic acid	5		
Sulphate of Soda	5		
Diluted Sulphuric acid	4		

To produce the greatest effect, the substances should be cooled in a freezing mixture before they are united.

CHAPTER IV.

VAPORIZATION.—EBULLITION.—STEAM DISTILLATION.—GASES AND VAPORS.

Vaporization.

92. Vaporization is the conversion of liquid and solid substances into vapor, which may be effected in two ways; viz; by evaporation and ebullition; the former takes place without any visible motion among the particles, while the latter is manifested by external agitation.

93. Such bodies as have never been converted into vapor by heat, are said to be *fixed*; substances known to be vaporizable, are called *volatile*. Solids usually become liquids before they vaporize; some, however, as arsenic and iodine, pass at once from the solid, to the æriform state.

92. Vaporization. How produced.

93. Fixed and volatile bodies.

94. *Evaporation* is the slow conversion of a body into vapor. It takes place whenever a liquid is exposed freely to air. In a very few cases, also, solids disappear, slowly, from the same cause.

A vapor differs from a gas in being more easily condensed into a liquid; the drying of wet clothes in the air, is an example; and sometimes the vapor may be seen rising and passing off. If such clothes are exposed to a fresh and keen wind, with the air some degrees above the freezing point, the current of air hastens the process of evaporation, and heat is so rapidly carried off, as to cause the freezing of the remaining water, and the cloth is hard and stiff, until further evaporation carries off all the water contained within its pores.

95. The rapidity of evaporation is influenced by the following circumstances.

1st. By the *form of the vessel*; the evaporation takes place only from the exposed surface. A liquid to be evaporated, should, therefore, be put into a shallow vessel.

2nd. By the *moisture or dryness of the air*. The atmosphere is capable of retaining only a certain quantity of vapor; the drier the air, therefore, the more rapid the evaporation.

3d. By the *motion or stillness of the air*. Evaporation takes place more rapidly when there are currents, by means of which, the saturated air is constantly removed and replaced by dry portions.

4th. By *pressure on the surface*. If any liquid be placed under the exhausted receiver of an air pump, the pressure of the atmosphere being now removed, the evaporation will take place with much greater rapidity.

96. Observe, that in a short time, the receiver would become filled with an atmosphere of vapor, which would exert a pressure as the atmosphere did before, and retard evaporation. But, if we place under the receiver some substance capable of absorbing the vapor as fast as it forms, the vacuum will be kept up, and the evaporation will continue as rapid as before. It is found that sulphuric acid has a powerful attraction for watery vapor. Professor Leslie has shown that by placing water in a flat dish over this acid, and removing the atmospheric pressure by an air pump, the rapid evaporation which takes place, renders latent so much of the caloric of the water, that a portion of it will freeze.

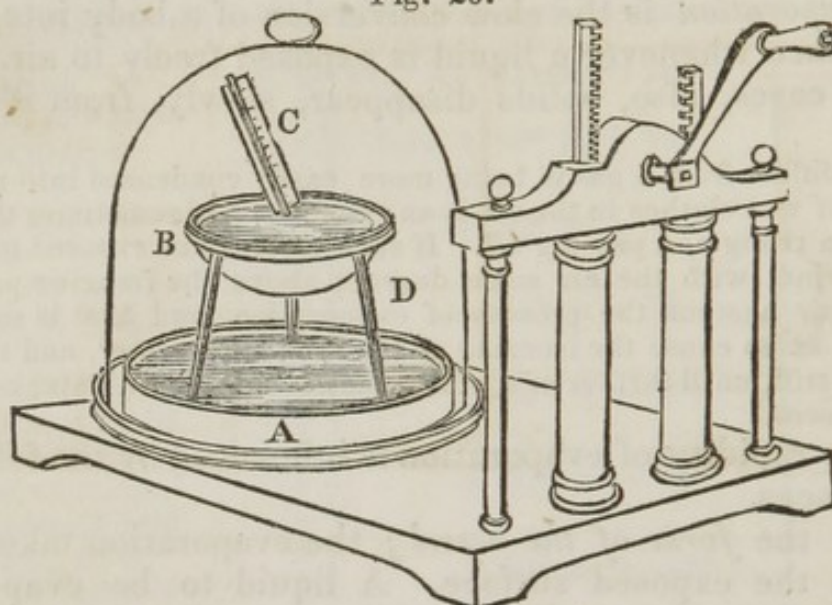
Exp. Upon the plate of an air pump, (Fig 20) place a flat, shallow, glass dish, A, about half filled with sulphuric acid, and a little above it, a tin or copper basin B, three parts filled with water, and a small thermometer C, immersed in the liquid.

This basin, is supported upon three glass legs, D, standing in the acid, and an air-pump receiver is placed over it. On proceeding to exhaust the air, the thermometer gradually sinks; the water, in consequence of the rapidity of its evaporation, appears to boil, and if the apparatus is in good order, it freezes in the course of five or ten minutes. The use of the surface of

94. Evaporation. Example.

95. Circumstances which influence the rapidity of evaporation.

Fig. 20.



sulphuric acid here, is to absorb the aqueous vapor, which it does very energetically, and consequently occasions a constant call upon the water for its formation. Now, *vapor cannot be produced without the absorption of heat*; and in the case before us, the heat requisite to convert one part of the water into *vapor*, is taken from the *other fluid portion*, which, thus losing the heat that constituted its fluidity, becomes solid, or freezes. There is another phenomenon often observable in this experiment, which is, that the temperature of the water falls several degrees below the freezing point, before congelation takes place; but the moment that the water freezes, it rises to 32° , in consequence of the escape of the residuary latent heat."

97. By the evaporation of ether, under an exhausted receiver, water may also be frozen.

Fig. 21.



Suppose a thin glass flask (Fig. 21) containing a portion of ether, is placed in a wine glass containing cold water to the level at *a*, and then covered with the receiver of an air-pump. On exhausting the air, the ether will pass into a state of vapor. In evaporating, the ether takes caloric from the surrounding bodies; the water in contact with it loses its *caloric of fluidity*, and becomes solid. A small animal, if exposed to a current of air, while wet with ether, would soon die from privation of vital heat.

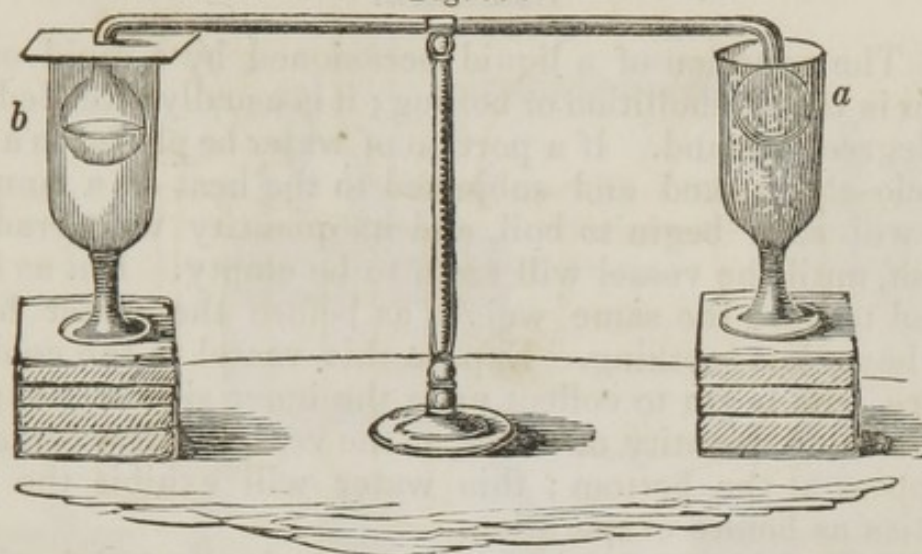
98. Dr. Wollaston's *Cryophorus*, (Fig. 22,) or *Frost-bearer* consists of a tube with a bulb, *a*, and *b*, at each end. One of the bulbs, *b*, is partly filled with water, and the remaining space contains watery vapor; the atmospheric air having been expelled by boiling the liquid, as in making a thermometer. If now the bulb, *a*, is immersed in a freezing mixture, the watery vapor will be condensed by

96. Use of sulphuric acid in evaporating water by the pressure of the atmosphere. Prof. Leslie's experiment.

97. Water frozen by the evaporation of ether.

98. Cryophorus.

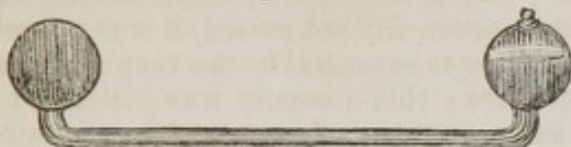
Fig. 22.



cold; a vacuum being formed, a new portion of vapor will rise from the water in the other bulb, and, in its turn, be condensed; in a few minutes, the water in the bulb at *b*, will be frozen quite solid.

The bulb may be secured against the admission of caloric, by a covered glass, as in the figure at *b*.

Fig. 23.



99. The *pulse glass* (Fig. 23.) is a small instrument resembling in its form the cryophorus. It contains a small portion of alcohol, and highly rarefied air. On grasping with the warm hand,

the bulb which contains the liquid, an ebullition takes place; the alcohol is converted into vapor, and passes over into the other bulb. The hand experiences a sensation of intense cold, on account of the heat which passes from it into the alcohol. The *sensible* heat of the hand has become *latent* heat in the newly formed vapor, which, if tested by the thermometer, would exhibit no increase of temperature above that of the liquid from which it had been formed.

100. Of all the causes which produce evaporation, temperature is the most effective.

101. The effect of heat in promoting evaporation, is extensively useful in chemical operations. It is often necessary to remove a portion, or the whole of a liquid, when it can be done in no other way than by evaporation; and this is usually effected by placing the liquid, contained in a flat dish, on a bed of sand, heated by a furnace below. This is called a *sand-bath*, and facilitates the *regulation* and equal *distribution* of heat. When evaporation is thus accelerated by heat, the vapor forms more or less rapidly, till the temperature is raised to a certain point, when the portions of the liquid in contact with the heated vessel, are converted into vapor, which forcing its way through the liquid, rises, in bubbles, to the surface, and escapes.

99. Pulse glass.

100. Effect of temperature on evaporation.

101. Utility of evaporation in chemical operations. Sand-bath. Effect of hastening evaporation by heat.

Ebullition.

102. The agitation of a liquid occasioned by a rapid escape of vapor is called ebullition or boiling; it is usually attended with some degree of sound. If a portion of water be placed in a glass flask, closely corked and subjected to the heat of a lamp, the water will soon begin to boil, and its quantity will gradually diminish, until the vessel will seem to be empty. But as it will be found to have the same weight as before the water boiled, it can have lost nothing. Expose this vessel to the cold air; moisture will begin to collect upon the inner side of the glass, until the same quantity of water, as the vessel at first contained, will appear at the bottom; this water will exhibit the same properties as before evaporation.

103. Dr. Black instituted some ingenious experiments, to determine the actual loss of heat during the conversion of water into steam. He heated water in a tin vessel up to the boiling point, and noted the time required for the purpose. The same heat was then continued, till the whole of the water was evaporated; and the time taken up by that process was also noted. Now since, on the one hand the accession of heat was constant, it was easily computed how high the temperature could have been, supposing the rise to have gone on above 212° , in the same ratio, as below it; and, on the other, as the temperature of the steam was not raised, it was inferred that all the accession of heat from 212° , was essential to the very state and constitution of steam at that temperature; this quantity was estimated at about 810° ; that is to say, that the same quantity of heat which is required totally to evaporate boiling water at 212° , would be sufficient to raise the water 810° , above the boiling point, or to 1022° if it had remained in the *liquid* state.

104. When steam is condensed into water, it gives out the latent heat which was essential to its state of vapor, and which, when set free, will raise the temperature of adjacent bodies, as much more than an equal weight of boiling water would do, as the latent heat of steam exceeds that of boiling water.

105. A small steam-boiler (Fig. 24,) *a* has been contrived for experiments on latent heat. The boiler is furnished with two stop cocks, *b* and *d*, to the latter of which is screwed the pipe *e*: when the latent heat of vapor is to be determined, water is put into the boiler, and made to boil by the application of an Argand lamp *f*: the end of the pipe *e*, being immersed in a given quantity of water in the vessel *g*, furnished with a thermometer *h*. After the water has boiled for some time, the increase of weight of the water in the vessel *g* may be ascertained, and then the indication of the thermometer will show how much heat has been imparted to the water by

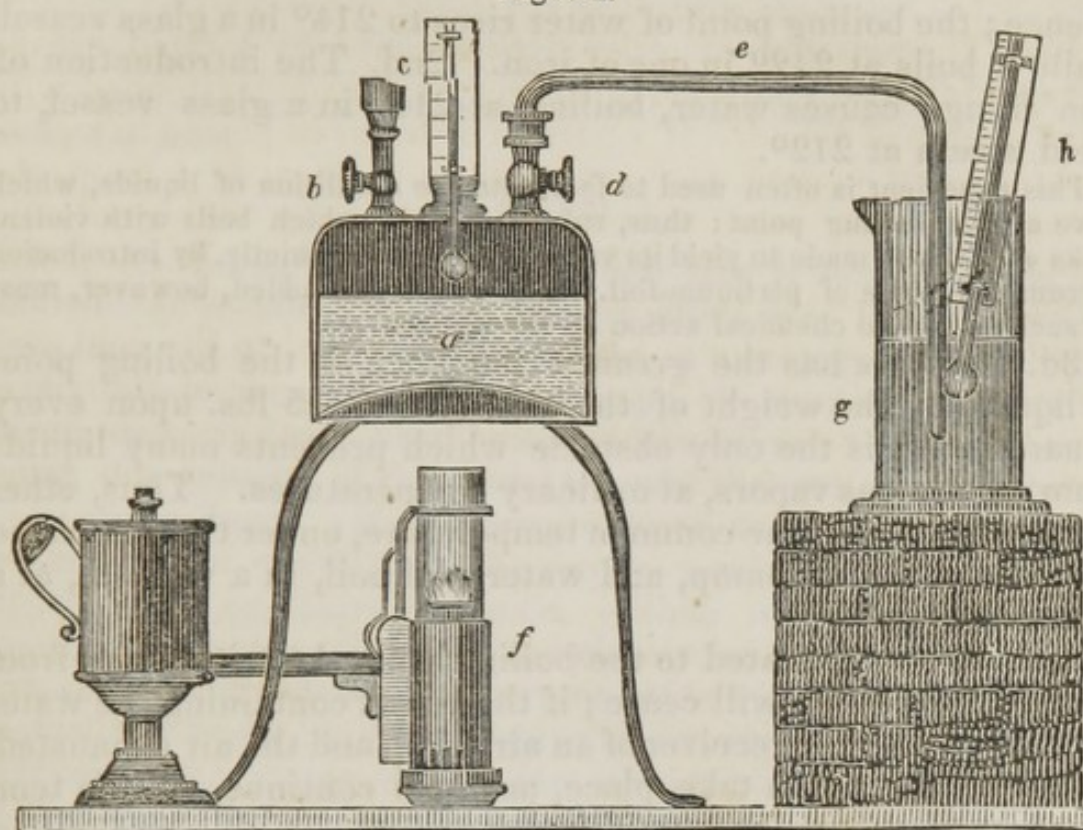
102. Cause of ebullition. Change which water undergoes in boiling. How is it proved that water loses nothing, and suffers no change in its constitution by boiling?

103. Inferences drawn from Dr. Black's experiments upon the heat required for converting water into steam.

104. Heat given out when steam is condensed into water.

105. Apparatus for experiments on latent heat, mode of using it, with inferences from the changes which are observed.

Fig. 24.



the condensation of a quantity of steam equal to the increase of weight. The effect thus produced may be compared with that which would result from the addition of an equal weight of boiling water; and it will be found that a given weight of steam at 212° , has the power of heating water many times more than an equal weight of water at the same temperature. The thermometer *c* passes through a collar into the boiler *a* for the purpose of ascertaining the heat of its contents.

106. It is probably, the greater affinity of heat for steam, more than for water, that makes the boiling point of water so perfectly stationary in open vessels over the strongest fires.

Every kind of liquid has its own particular temperature, at which it boils, called the *boiling point*. Beyond this point, no liquid can be heated in the open air; all the heat afterwards acquired, being consumed in converting the liquid into vapor; and every vapor, at the time of its being evolved, has the same temperature with the liquid which yielded it. Thus, water, as we have seen, cannot be heated under ordinary circumstances, and in open vessels, to a higher temperature than 212° , and the steam which rises is also at 212° . Alcohol boils at 173° , and ether at 96° .

107. The boiling point of water, may be made to vary with

106. Why the boiling point of water is stationary in open vessels, with different degrees of heat. Meaning of the expression, "boiling point." Boiling point of water, alcohol, and ether.

107. Circumstances which cause the boiling point of liquids to vary.

circumstances. 1st. The *nature of the vessel used* has some influence; the boiling point of water rises to 214° in a glass vessel, while it boils at 212° in one of iron. 2nd. The introduction of iron filings causes water, boiling at 214° in a glass vessel, to yield steam at 212° .

This expedient is often used to facilitate the ebullition of liquids, which have a high boiling point: thus, sulphuric acid, which boils with violent jerks at 620° , is made to yield its vapor steadily, and quietly, by introducing a crumpled piece of platinum-foil. The substance added, however, must be such as has no chemical action on the liquids.

3d. *Pressure* has the greatest influence on the boiling point of liquids. The weight of the atmosphere (15 lbs. upon every square inch,) is the only obstacle which prevents many liquids from existing as vapors, at ordinary temperatures. Thus, ether and alcohol boil at the common temperature, under the exhausted receiver of the air pump, and water will boil, in a vacuum, at a temperature of 72° .

108. If water, heated to the boiling point, be withdrawn from the fire, the boiling will cease; if the vessel containing the water be placed under the receiver of an air pump and the air exhausted, ebullition will again take place, and will continue, till the temperature of the water has fallen below 72° .

109. It has been shown that atmospheric pressure raises the boiling points of all liquids 140° , higher than the temperature at which they boil in a vacuum. When the boiling point of a liquid is stated, it is to be understood that the barometer stood during the experiment, at the medium height, or 30 inches. If the mercurial column be higher than that, the boiling point will rise, if lower it will fall. The temperature at which watery, or other vapor, is able to overcome the atmospheric pressure and escape, may be used, instead of the height of the mercurial column, to ascertain the amount of that pressure; and since the weight of the air decreases in a constant ratio as we ascend, water will boil, more readily, on the top of a mountain, than on the plain below; so that we may ascertain the height of the mountain, by observing the temperature at which water boils on its summit, allowing 530 feet for each degree of Fahrenheit's thermometer.

110. The effect of diminished pressure may be satisfactorily shown as follows.

Exp. Fit a stop-cock to the neck of a glass flask; half fill the flask with water, and place it over the flames of a lamp, let it boil a few minutes, till the air is all expelled, and the steam escapes freely through the open stop-cock. On removing the lamp, and closing the stop-cock; the ebullition will instantly cease. But if the flask be suddenly plunged into a vessel of

108. Experiment to show that water boils with less heat when the pressure of the atmosphere is removed.

109. What is the effect with respect to the boiling point of a liquid when the barometer is higher or lower than the medium height? Why does water boil with less heat upon high mountains than at their base?

110. Why does a flask of water stop boiling when exposed to a certain degree of heat, and re-commence boiling on being plunged into cold water?

cold water, the steam within the flask, which by pressing on the liquid prevented the formation of vapor, will be partially condensed, and the boiling will re-commence, and continue till a new atmosphere of steam is formed. This may be condensed by a second immersion in cold water, and so on, till the temperature of the water within the flask, is reduced below the boiling point.

Steam.

111. As the boiling point of liquids *may be made lower by diminution of pressure*, so the contrary effect may be *produced by an increase* of it. If water be heated in a strong vessel, closed so that steam cannot make its escape, its temperature may be raised even to a red heat, without ebullition; the only limit, being, the strength of the vessel to resist the immense expansive force of the liquid. If an aperture were suddenly made in the vessel, a large quantity of the water would flash at once into steam, with explosive violence. When water is heated in a common tea-kettle, if the lid fits closely, so that the steam when formed, cannot escape, the accumulation of vapor in the upper part of the kettle, will soon cause an increased pressure on the surface of the water below, forcing a portion of it out at the spout; when the steam has thus made room for itself, or if the lid be removed, the spouting *jet* will cease.

112. Steam generated under pressure, at temperatures above the ordinary boiling point, is called *high pressure steam*; that formed in the usual manner under atmospheric pressure only, is called *low pressure steam*.

113. All vapors can be condensed into liquids, by coming into contact with a cold surface, whereby a part of their latent heat is taken away; or by subjecting them to pressure, in which case, also, they yield their caloric of expansion, and the vessels in which they are condensed become heated.

114. Steam, as it issues from an escape-pipe, is transparent, and nearly invisible; but it becomes opaque at a very short distance from the mouth of the pipe. This is caused by its being condensed by the cold air.

115. Instruments invented to prevent the *loss of heat* by evaporation are called *digesters*. *Papin's digester*, is a cylindrical copper vessel, having a lid nicely fitted to it, and secured by screws. "If such a vessel be about half filled with water, with the lid closely secured, and then put upon the fire, steam is soon formed; but having no escape, it presses upon the

111. Effect of increased pressure upon the boiling of liquids and consequently, in retarding the formation of steam.

112. High and low pressure steam.

113. How may all vapors be condensed into liquids?

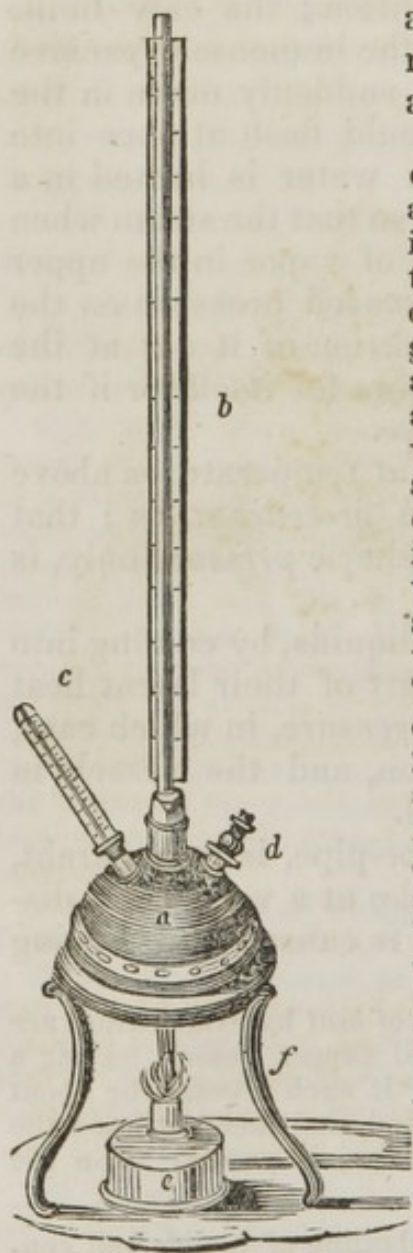
114. Transparency of pure steam.

115. Digesters. Papin's digester.

water, and prevents the further formation of steam, till the temperature of the water rises above the boiling point. This heat being conveyed to the steam, it now receives another portion of vapor without being condensed, and thus the *quantity* and the *elasticity* of the steam, are continually increasing with the temperature. Water has in this way been raised to the temperature of 419° ."

116. At the temperature of 419° , the elasticity of steam is 1050 times greater than that of atmospheric air; so that it exerts, upon the inside of the vessel in which it is pent up, a force of at least 14700 pounds pressure on each square inch; a pressure so enormous that few vessels can resist it, and hence have occurred

Fig. 25.



many serious accidents, which, in the applications of high pressure steam, are now guarded against, by safety valves and other similar contrivances.

117. Exp. (Fig. 25;) *a* is a strong brass globe, composed of two hemispheres screwed together; a portion of quicksilver being introduced into it, it is about half filled with water; *b* a barometer tube passing through a steam-tight collar, and dipping into the quicksilver at the bottom of the globe: *c* a thermometer graduated to about 400° , and also passing through an air-tight collar: *d* is a stop-cock, and *e* a large spirit-lamp. The whole is supported upon the brass frame and stand, *f*. Upon applying heat to this vessel, and closing the stop-cock as soon as the water boils, it will be found that the temperature both of the water and of its vapor, increases with the pressure, the extent of the latter being measured by the ascent of the mercury in the barometer. The thermometer, under an atmospheric pressure of 30 inches, being at 212° , will be elevated to 221° , under an additional pressure of 5 inches; and to 269° , under an additional pressure of 30 inches, (or one additional atmosphere,) each inch of mercury, above 30, producing by its pressure, a rise of about 192° , in the thermometer. The barometer tube also serves the purpose of a safety valve, the strength of the brass globe being such as to resist a greater pressure than that of our atmosphere.

118. The latent caloric of steam may be economically employed in heating large rooms, by conveying it in pipes; and this expedient is sometimes used in manufactories of ether, and other inflam-

116. Elastic force of steam.

117. Apparatus for exhibiting the elastic force of steam.

118. Economical applications of the latent heat of steam.

mable articles, where fire would be unsafe. Water soon becomes heated by a current of steam being condensed in it.

Distillation.

119. *Distillation* consists in converting substances into vapor, and condensing this into a liquid.

The distilling apparatus consists of retorts, receivers, alembics and the still and worm. In using them, the receiver, or the head of the alembic, must be kept cool by ice, moistened cloths, or otherwise. On a large scale, as in distillation of ardent spirits, the *still* and *worm* are used, the latter consists of a long, spiral, metallic tube, set in a vessel of cold water; the vapor being conveyed into this, condensed by passing over a great extent of cold surface.

120. *Exp.* (fig. 26.) Into a glass alembic *a* put one part of spirit of wine, and seven or eight parts of colored water. Before putting the mixture into the alembic, plunge into it a burning paper, and the flame will be extinguished. This will prove that the mixture is not inflammable. Apply the heat of a spirit lamp *b*, and the lower part of the apparatus will soon become dim with moisture; a portion of the alcohol will be raised in vapor and coming into contact with the sides of the vessel, will at first be condensed; but this vessel will very speedily become too hot to condense the vapor; it will then ascend into the head of the alembic *c*, and being there condensed, will run down into the receiver *d*, where, in a short time will appear a small quantity of pure, colorless liquid. If this be poured into an open vessel and a piece of burning paper applied, it will take fire and burn to dryness. Thus, it will be proved, that from a colored and unflammable mixture, a pure, colorless, inflammable spirit has been obtained by distillation.

Fig. 26.



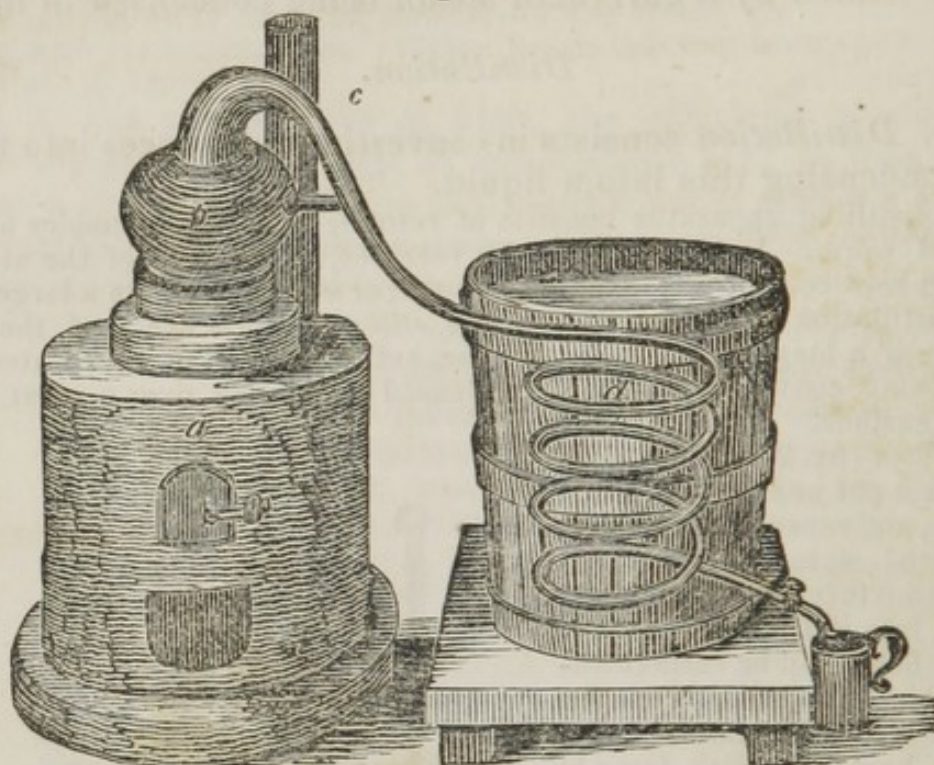
121. The form of still most commonly used, is represented in fig. 27: *a*, is the furnace; *b*, the capital, or head of the copper still; *c*, part of the chimney; *d*, the worm tub, containing cold water for condensing the vapor that enters the worm. The vapor, in passing through this cold, spiral, metallic tube, becomes condensed and liquefied, and passes from it, in its distilled form, into the vessel beneath.

119. What is distillation? How conducted?

120. Experiment to explain the changes in distillation.

121. Explanation of Fig. 27.

Fig. 27.



122. By the process of distillation, volatile bodies are separated from those that are more gross; for example, by distilling salt water, we may obtain fresh water; the saline matter, remaining in the retort.

Gases and Vapors.

123. Gases were long considered as permanently elastic fluids, differing essentially from vapors, which readily condense into liquids. But Mr. Faraday has succeeded, by means of intense artificial cold, and very great pressure united, in liquefying many of the gases; and it is now thought probable, that all of them are the vapors of liquids having boiling points very far below any natural temperature. The term *gas*, however, is still applied to those bodies which retain the æriform state under ordinary atmospheric pressure and temperature.

The different gases require very different degrees of pressure and reduction of temperature for their liquefaction; all of the liquids thus obtained, have so strong a tendency to resume their elastic state, that, on breaking the tube in which they are confined, they expand with great force, producing of course, intense cold, and frequently exploding, so as to endanger the operator.

124. Vapors, so long as they remain uncondensed, have all

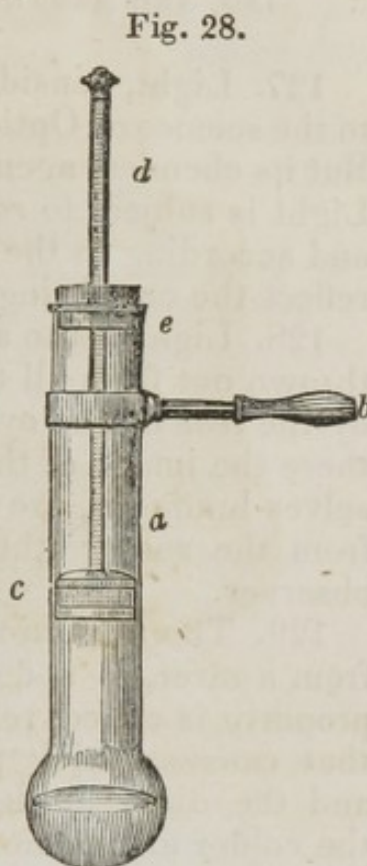
122. Distillation of salt water.

123. Distinction commonly made between gases and vapors.

124. Properties of vapors which render them useful as a motive power. The steam engine.

the physical properties of gases. Their *elasticity* and *condensibility* render them useful as a *motive power*. The action of the steam engine depends chiefly upon two properties of steam; viz. expansive force, and easy condensation.

Let *a*, (Fig. 28) represent a glass tube with a bulb at its lower end. It is held in a brass ring to which a wooden handle, *b* is attached, and contains a piston, *c*, which, as well as its rod is perforated, and may be opened or closed by the screw at top, *d*; it is kept central by passing through a slice of cork at *e*. A little water being poured into the bulb, and carefully heated over a spirit lamp, the aperture in the piston being open, the air is expelled; and when steam freely follows it, the screw may be closed. On applying cold to the bulb, the included steam is condensed, and a vacuum formed, which causes the descent of the piston, in consequence of the air pressing on it from above. On again holding the bulb over the lamp, steam is re-produced, and the piston again forced up, and these alternate motions may be repeatedly performed by the alternate applications of heat and cold. The *ascent* of the piston of a steam engine, is caused by the *expansive force*, or elasticity of steam, forcing the piston upward.



125. In former steam engines, the *descending* stroke was produced by injecting cold water, which condensed the steam and produced a partial vacuum; the atmospheric pressure then counterbalanced the force beneath the piston, and impelled it downward. Watt's great improvement in the steam engine consists in conveying off the steam after it has performed the office of raising the piston, and condensing it in a separate vessel; thus avoiding the great loss of heat, formerly incurred by cooling the cylinder at each stroke of the piston.

126. Mr. Dalton has deduced from experiments, the interesting law, that the vapors of all liquids have the same elasticity at the same distance above, or below their respective boiling points; thus the vapor of ether at 87° , has the same tension or elastic force as that of water at 202° , or that of alcohol at 163° , those temperatures being respectively ten degrees below the boiling points of the different liquids. From this, also, it results that the vapor of mercury at 60° , (the boiling point being 680°), has a tension equal to that of water 620° below its boiling point; that is, to that of water at 408° below zero; which is so small that it could not overcome the pressure of atmosphere. It is, therefore, concluded that mercury and other liquids having very high points of ebullition do not evaporate at common temperatures.

125. Manner in which the descending stroke of the steam piston was formerly produced. Watt's improvement.

126. Mr. Dalton's discovery of the law which governs the elasticity of vapors. Elastic force of the vapor of mercury at 60° .

CHAPTER V.

LIGHT.—DECOMPOSITION OF LIGHT.—ILLUMINATING, HEATING, COLORING, AND MAGNETIC RAYS.—FLAME.—PHOSPHORESCENCE.

127. Light, considered as to its physical properties, belongs to the science of Optics, which is a branch of Natural Philosophy. But its chemical agencies bring it within the scope of Chemistry. Light is subject to *radiation* and *reflection*, in the same manner, and according to the same laws, as caloric; the bodies which reflect the one, being also reflectors of the other.

128. Light is the agent of vision, or of seeing. Rays of light thrown out from all the points of a luminous body, are collected by the *lens* of the eye, and thrown upon the *retina*, producing there the image of the radiating body. Objects, not of themselves luminous, are seen by means of light thrown upon them from the sun or other sources, and reflected to the eye of the observer.

129. The refraction of light takes place when a ray passes from a rarer, to a denser medium as from air to water; this property is called refrangibility. It is the *refraction* of light, that causes a stick partly immersed in water to appear bent; and the different densities of the warm air over a stove, and the colder air on each side of it, cause objects, seen through both, to appear distorted. Objects seen through some substances, as Iceland spar, appear double in consequence of a double refraction.

130. Bodies which permit light to pass freely through them, are called *transparent*, those which do not, *opaque*. A *perfectly* transparent body cannot reflect light, and therefore cannot be visible. Although the solar rays possess calorific or heating power, transparent bodies are not heated when light passes through them; neither do reflectors of light absorb any of the caloric of the rays. For this reason, concave mirrors and burning glasses remain cool themselves, though they concentrate and transmit light and heat, to an intense degree, upon bodies in their *foci*.

131. It is remarkable that a close relation seems to exist be-

127. Definition of light. Why has light a relation with both Natural Philosophy and Chemistry? How does light resemble caloric?

128. Light the cause of vision.

129. Refraction. Double refraction.

130. Transparent and opaque bodies. Why reflectors and lenses are not heated by the calorific rays which they reflect or transmit.

tween the *combustible* and *refracting* powers of substances ; the most combustible, being also the most refractive, provided they be at the same time transparent. Hydrogen, the most powerfully combustible of the gases, has the highest refracting power ; oxygen, the most eminent supporter of combustion, is the most feeble refractor of light. The diamond, and water were pronounced by Newton to contain combustibles, long before their chemical nature was known.

132. The light of the sun and stars contains, 1st. Colorific, or illuminating rays. 2nd. Calorific, or heating rays. 3d. Chemical rays, or those which produce chemical effects.

133. *Colorific rays.* A ray of solar light received on a transparent, triangular prism of glass or other transparent substance, is found, after its passage, to be resolved into seven rays or colors ; their separation being caused by the different refrangibility of the rays. The colored image is called the *solar spectrum*. The phenomenon of the rainbow is produced by the decomposition of light in passing through drops of rain. Newton was led to discover this, by observing that drops of rain exhibited a variety of colors when the sun shone upon them, and also that the arrangement of the colors of the rainbow was always the same.

134. Certain bodies have the property of *decomposing the light* given out by substances burning in contact with them, and of yielding only *one* colored ray.

Exp. Moisten table salt with alcohol, and set it on fire in a dark room ; the flame contains only the yellow ray, and the human face seen by its light, has a ghastly hue, while a red handkerchief, or anything not capable of reflecting the yellow ray, appears black. Borax,* gives a green, and the salts of strontia a red tinge to the flame of alcohol. These effects are attributed to a decomposition of the rays of light by the salt, all the primary colors being absorbed, except that which is visible in the flame. Such lights are called *monochromatic*†.

Every variety of color can be produced by the action of chemical agents upon each other.

Exp. Red and indigo form violet.

Exp. Red vegetable infusion and an alkali, green.

Exp. The above infusion with an acid, red.

Exp. Into chloride of calcium pour sulphuric acid and a white solid will be formed.

* A salt comprised of boracic acid and soda.

† From the Greek *monos*, one, and *chroma*, color.

131. Connection between the combustible and refracting powers of substances.

132. Three kinds of rays of light.

133. Solar spectrum. Cause of the rain-bow.

134. *Exp.* With table salt and alcohol, borax and strontia. Cause of these effects.

Exp. To a dilute solution of persulphate of iron, pour tincture of nut-galls, and black ink will appear.

Exp. Sulphate of iron with terro-cyanuret of potassa forms indigo.

Exp. Sulphate of copper and aqua ammonia form blue.

135. The *illuminating* power of the different rays is by no means equal, the greatest being in the yellow and green, less in the blue and red, still less in the indigo, and comparatively little in the violet. This explains the familiar fact, that a room of which the walls are yellow or pale green, is much more easily lighted, than one painted blue, or any other color.

136. *Calorific rays.* The *heating* power of the colored rays is greatest in the red, and least in the violet; but it is found that there are *invisible rays*, beyond the red, (and, therefore, less refrangible rays,) *in which is contained the greatest heat of the spectrum.* It had been supposed by philosophers, that the heating power in the spectrum would be proportioned to the quantity of light, and therefore the *yellow* was accounted the warmest of the colored rays. But Dr. Herschel, by a series of experiments, proved that the heating power gradually increased from the violet ray to the red. He ascertained, moreover, that the thermometer continued to rise when placed beyond the red extremity of the spectrum, where not a single ray of light was seen. From these phenomena, he inferred that *there were invisible rays of pure caloric* in the light of the sun, which were less refrangible than even red light.

The following are the measures of the temperature of the different rays.

Color.	Temperature.
Blue, - - - - -	56° Fahrenheit.
Green, - - - - -	58° "
Yellow, - - - - -	62° "
Red, - - - - -	72° "
Beyond red, - - - - -	79° "

137. *Chemical rays.* There are in the spectrum, invisible rays beyond the violet, which give to light its power of producing certain *chemical* phenomena.

Exp. Moisten some white paper with solution of the *nitrate of silver*, (*lunar caustic*,) and lay it in the sun, the paper will be blackened; the nitrate being decomposed by the agency of light. The *durable ink* used for marking linen, is made of the same material, and is blackened by the same means. If the moistened paper is exposed to the action of the spectrum, the greatest

135. Illuminating power of the different rays. Experiments to show the effect of absorption on color.

136. Calorific rays. Heating power of the colored rays. Dr. Herschel's experiments. Temperature of the different rays.

137. Chemical rays. Experiments.

effect will be perceived just outside of the violet ray: and the action decreases, in receding from that till it becomes scarcely perceptible. The chemical agency of light is, therefore, attributed to certain invisible rays, more refrangible than the violet, and which are called the *chemical* or *deoxydizing rays*; and if any of the colored rays seem to possess the same power, in a degree, it is probably owing to the imperfect refraction, which does not completely separate them.

138. The most refrangible rays possess also the property of rendering steel or iron *magnetic*. This property is most remarkable in the violet. Photographic drawing depends on the agency of these rays.

Exp. Let one side of a plate of glass be covered with bees-wax, colored with lamp-black, and a picture be drawn on it by a sharp point which removes the bees-wax. On a piece of white paper spread a solution of salt in water, and pour upon it a solution of the nitrate of silver, there will be a formation of chloride of silver. Let this paper be placed over the glass, and thus exposed to the Sun's rays; these passing through where the wax is removed, a picture is formed upon the paper by changing the chloride black wherever the light strikes it.

Exp. In a saturated solution of bichromate of potassa let a piece of paper be soaked, then dry it quickly, and place it in the dark. Let drawings, dried plants, or writing be laid over this, and exposed to the Sun, a yellow copy of them will appear while the ground will be orange. To fix the image, the salt which has not been acted upon by the light should be dissolved by carefully washing, when the image will appear white, the orange ground still remaining.

Daguerreotype. This name has been applied to a method recently discovered by Daguerre, of fixing the impression of images on plates of silvered copper, cleansed with nitric acid and exposed to the vapor of Iodine.

The process is effected by placing a prepared plate in a Camera Obscura in such a manner that the light will come directly from the object to be impressed to the plate—where, if the light be sufficiently strong, a perfect image will be formed in 10 or 15 minutes. This plate must be heated to 167° Fahr., and exposed to a vapor of mercury, at an angle of 48° , it must then be submitted to the action of hyposulphate of soda—and cleansed in distilled water.

The chemical rays, are the *most* refrangible, the calorific, the *least* so, while the *colorific* possess a *mean* degree of refrangibility.

139. The principal sources of light, are; 1st, the *sun* and *fixed stars*; 2nd, *incandescent* or heated bodies; 3d, *phosphorescent* bodies.

140. A solid body heated to between 600° and 700° , begins

138. Magnetic rays. Refrangibility of the three kinds of rays.

139. Sources of light.

140. Incandescent bodies. Flame. Cause of the luminous appearance of flame. Faint light of the flame of hydrogen.

to be luminous in the dark, and glows by day light, at about 1000° ; it is then said to be *incandescent*. The color of incandescent bodies, changes as the heat is raised, passing through the shades of cherry red, dull red, bright red, up to a white heat. Flames consist of incandescent, gaseous matter, and their temperature is far above the white heat of solids. The luminous property of flame is derived from *solid matter diffused through it*; and its illuminating power is not at all in proportion to its heat: for the heat of flame is, under certain circumstances, known to be very intense, when the light which it emits is exceedingly feeble. Hydrogen gas is considered the purest form of flame which can be exhibited, and yet the light which it emits is so faint that, in day-light it can hardly be seen; while its heat is so intense, that an iron wire held in it, will soon be melted or burned. In this process, the hydrogen will become exceedingly luminous, as the metallic wire ignites. By scattering fine dust, such as sifted magnesia, or any other solid substance, not of itself inflammable, upon the pale flame of hydrogen, its light will be greatly increased.

141. The brilliancy derived from the flame of our common candles and lamps, is chiefly owing to the carbon blended with the oily substances, and burning in the flame. If this substance exists in too large a quantity, it will cause the flame to throw off a disagreeable smoke, offensive to the smell, and injurious to the walls and furniture of a room.

142. As flame depends upon an intense heat for its existence, consequently anything that will reduce its temperature, that is, anything that will cool it, will extinguish it. A small flame for instance, will be extinguished by bringing a large mass of cold iron near it; the metal absorbs the heat.

143. *Phosphorescence*. Some animal bodies during life, and some animal and vegetable bodies, such as fish and certain kinds of wood, in a state of putrefaction, give out silvery light, which is termed phosphorescent. The sea, also when agitated at night, appears phosphorescent. Thus the track of a vessel is often marked by a line of soft and beautiful light, formerly supposed to be owing to phosphorescent matter held in solution. But according to some late observations, this luminous property of the sea, is owing to collections of minute *ovae* or eggs of animalculae, which float in slimy masses over the water. Some bodies give out phosphorescent light only when heated; thus lard, tallow, &c. exhibit this property at, or near the boiling point. A mineral called Chlorophone, lime, and some other mineral substances, phosphoresce when heated. *Solar phosphori* are bodies which after having been exposed to the sun's rays, are luminous in

141. Flame of candles and lamps.

142. Flame extinguished by withdrawing caloric.

143. Phosphorescent light. Its cause. Photometers.

the dark, at common temperatures. Some suppose the phosphorescent property of these bodies, is owing to their absorbing the sun's light, and giving it off unchanged in the dark, the lighter body imparting light to the darker one, as a warmer body imparts caloric to a colder one. But as these are artificial substances prepared with sulphur, charcoal and other highly inflammable materials, the light which they give off in the dark, may be owing to slow spontaneous combustion, or the combination of the sulphur, &c. with the oxygen of the air.

The *Bolognian phosphorus* is prepared by making into small rolls, *sulphate of baryta*, and heating them in beds of fine charcoal. *Baldwin's phosphorus* is nitrate of lime fused at a low heat. *Canton's phosphorus* is made by heating oyster shells to redness, with sulphur.

*Photometers** are instruments for measuring the *intensity* of light; *Leslie's photometer* consists of a differential thermometer, of which one bulb is black, and the whole inclosed within a glass shade. It depends on the principle that solar light is always accompanied with an equal proportion of heat. The white bulb transmits all the light and heat, and therefore is unaffected by either; the black bulb absorbs all the rays, and heats the air within; the consequent expansion of air in the black bulb, will impel the liquid to rise in the white one, in a degree corresponding to the intensity of the light.

144. Theories respecting the nature of light. We have considered light under the head of imponderable agents, on account of its connexion with caloric and electricity. The Newtonian theory considers light as a material, imponderable fluid, proceeding from luminous bodies in all direction, and producing by its effect on the organs of sight, the sensation of vision;—Another theory, called the undulatory theory supposes rays of light to be produced by the rapid motion or vibration of an elastic medium which pervades all space; and that these vibrations produce by their action on the retina of the eye, the sensation of vision, as the vibrations of air produce upon the auditory nerve the sensation of hearing.

* From *phos*, light, and *metron* to measure.

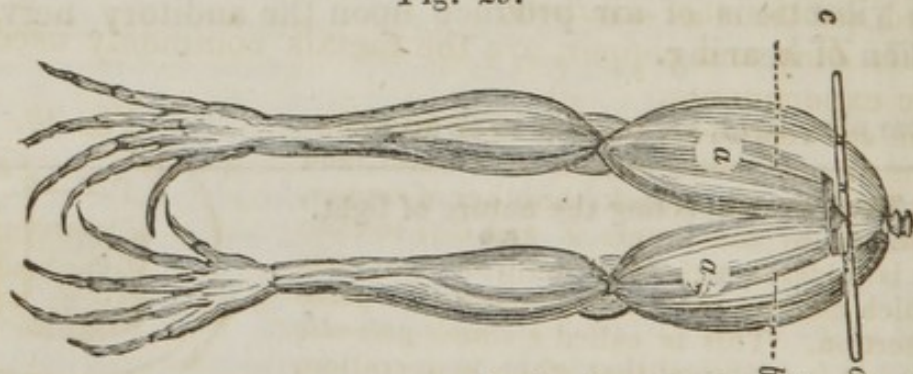
CHAPTER VI.

GALVANISM, OR VOLTAIC ELECTRICITY.

145. The subject of *Electricity** is intimately connected both with Natural Philosophy and Chemistry. As a *chemical* agent, it is chiefly confined to the department of *Galvanism*.

History of Galvanism. The earliest notice of any fact connected with Galvanism is found in a book entitled "The general theory of Pleasures," published in 1767, by a German metaphysician named Sultzer. It is there mentioned that a peculiar taste is excited when two slips of different metals, one lying on the tongue, and the other under it, are made to touch each other. This writer, however, gave no satisfactory explanation of the phenomena; and it attracted little attention till 1790, when it acquired importance from the discovery made by Galvani a distinguished professor of Anatomy at Bologna; this philosopher had for some time, entertained the opinion that electricity was concerned in producing the muscular motions of animals; and his belief was strengthened, by observing, that when the limbs of some recently skinned frogs, lying on his table, were accidentally touched with a knife (the electric machine being in operation at the same time) convulsive motions were produced. In pursuing his researches on the subject, he found that the same result would be obtained, whenever two metals were made to touch each other, while one was in contact with the *nerves*, and the other metal in contact with the *muscles* of the frog.

Fig. 29.



The figure represents, at *a a*, nerves in the leg of a frog, from which the skin is removed; at *b* is a silver wire passed under the nerves. A piece of zinc *c c*, being now brought into contact both with the silver, and a muscular or fleshy part of the legs, the Galvanic effects are exhibited.

* For a condensed view of Electricity see the author's large work on Natural Philosophy.

145. Electricity as a chemical agent. History of Galvanism. Observations and experiments of Galvani.

Galvani concluded that the nerves and muscles of living animals, are charged with electricity developed in the brain ; and that, whenever a communication is made between them by means of a conductor, the equilibrium is restored, and motion produced.

146. Among the many who zealously examined and discussed these new phenomena, was *Volta*, a distinguished electrician of Pavia. He made numerous experiments on the subject, and arrived at the conclusion, that the motions were, indeed, produced by electricity, not generated, however, as Galvani supposed, in the animal system, *but excited by the contact of the metals*, themselves. But notwithstanding the identity, now well established, of common electricity with the *Animal electricity* of Galvani, certain modifications of its character and applications, as well as the different modes of producing it, have caused the name *Galvanism* to be still retained. Volta constructed the *pile* of metallic plates which is distinguished by his name, and has greatly contributed to the advancement of chemical science ; it is now superceded by improvements upon the original invention.

Before we describe the effects of the Voltaic pile, it is necessary to premise the following facts.

1st. Whenever two plates of *different metals*, are made to touch each other by their broad surfaces, electric excitement is produced.

2nd. If the plates be separated by means of an insulating handle, one of them will be found *positively* and the other *negatively* excited.

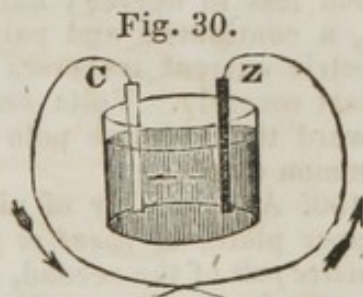
3d. The plates being of equal surfaces, the positive excitement of one, will be equal in intensity to the negative excitement of the other.

4th. Other circumstances being the same, the degree of excitement will be the greater, as the metals differ more in their degrees of affinity for oxygen.

5th. The more oxydable of the two metals will always become *positively* excited, and the other *negatively*.

147. Zinc and copper, are the metals commonly used in galvanic experiments.

The cut represents a vessel (Fig 30,) containing an acid, much diluted with water, and two plates, the one of zink, the other of copper, (as shown by the letters Z and C ;) to each plate is soldered a piece of wire, the two ends of which meet in the center, opposite the place of insertion. This is called a *simple galvanic circle*. It is supposed that when in operation, there is, in such a circle, a continued current of electricity, flowing in the direction of the *arrows* from the zink to the fluid, from the fluid to the copper, and from the copper back to the zink.



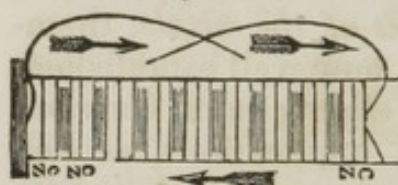
146. Conclusions of Volta. Voltaic pile. Facts connected with the developement of electricity by means of the Voltaic pile, or Galvanism.

147. Metals commonly used in galvanic experiments. Galvanic circle. Negative and positive poles.

When the wires do not communicate, the galvanic circle is said to be broken. The wire attached to the copper plate is *negative*, that to the zink plate *positive*. The wires are also called *poles*; thus we say, the *copper is the negative pole*, and the *zink, the positive pole*.

148. The quantity of electricity developed by a single pair of plates being very small, Volta endeavored to devise means of increasing it; and was finally led to the invention of the *Voltaic Pile*. This instrument consists of *pairs* of zink and copper plates, one above another. Each pair is called a *simple element* of the pile, the whole consisting of a *series* of simple elements or circles. Between each pair of plates is placed a piece of cloth wet with weak acid.

Fig. 31.



The figure represents a *Voltaic pile*, (Fig. 31,) commencing with zink, Z, and ending with copper C. The wires which meet in the center are the two poles. The direction in which the arrows point, is that of the electric current. In constructing the Voltaic pile, from thirty to fifty plates of copper, and as many of zink, are generally used; these are placed in regular order,

each pair of plates being separated by a piece of cloth; thus a regular succession of copper, zink and cloth, is kept up through the whole series. The pieces of cloth should be somewhat smaller than the metallic plates, and should not be so moist as to yield any of the liquid by the pressure of the superincumbent metals. The pile is contained in a frame composed of a base and cap of dry varnished wood, connected by stout rods of glass.

149. The *pile* is capable of affecting the electrometer, and of producing muscular action in a much greater degree than the *single pair of plates*. The zink being positive and copper negative, the electric equilibrium is restored on bringing them into communication by means of wires connected with each; as it is when the coatings of a charged Leyden phial are connected. But the causes of excitement being still in the pile, the equilibrium is instantly disturbed again, so that a continuous stream of the galvanic fluid is produced: that is one of the most striking differences between the action of the pile and that of the common electric machine. By means of the pile, the Leyden phial may be charged and the effects of the latter are precisely the same as when charged in the usual manner. If the two extremes of the pile are touched at once by the moistened fingers, a shock is felt differing little in kind from that produced by the phial, but much less in degree; but if, after the first effect, the contact be still kept up, a continuous and painful *thrilling* sensation is perceived; and if the electric current traverses any wound, burn, or excoriation, it causes it to smart severely. Volta remarked that the pain was greater on the side toward the negative pole; a circumstance in which Galvanism resembles common electricity.

150. Any number of piles may be combined by connecting the extreme copper plate, or *negative pole* of the first, with the extreme zink plate, or *positive pole* of the second, and so on; and all the effects of the pile will be increased according to the number of *simple elements*, or pairs of plates.

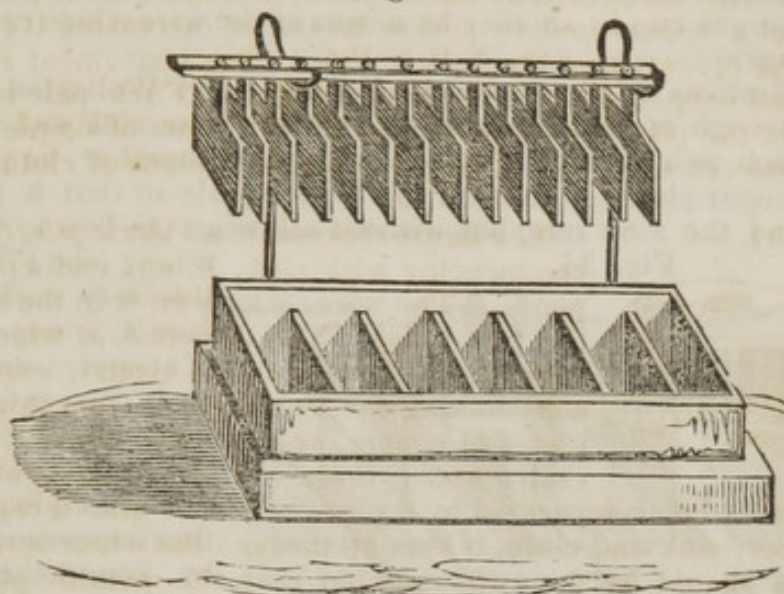
148. Construction of the Voltaic pile. Number and arrangement of plates.

149. Action of the Voltaic pile. Differences and resemblances in the action of the Voltaic pile and the electrical machine.

150. Connection of piles.

This form of the pile is not now in use, as others more powerful and more convenient have been substituted.

151. One of the first of these was Cruickshank's trough, (Fig. 32.) commonly called the *Galvanic battery*; it consists of a trough of dry wood, divided into cells, by partitions placed at equal distances; each partition is made

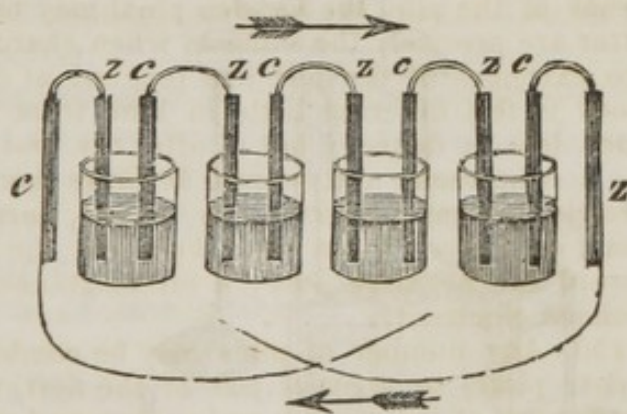


ded into cells, by partitions placed at equal distances; each partition is made of a plate of zink, and a plate of copper previously soldered together and fitted accurately into a groove cut in the wood; the joints being made perfectly tight with cement. The same order of arrangement must be observed as in the pile. This instrument is put into operation by filling all the cells about two thirds full of a saline or acid solution. Its effects are more powerful than those of the pile, and may be increased by connecting several troughs in the manner we have just described, (see § 150).

152. The actual contact of the metals, is not necessary, as is seen in the construction of Volta's chain of cups, (Fig. 33.) commonly known as the "*Couronne des Tasses*."* This

Fig. 33.

arrangement, of which the effects are greater than those of a pile of equal dimensions, consists of any number of pairs of zink and copper plates generally about one and a half inch square; the zink and copper plate of each pair are connected by a wire bent in the form of an inverted U: and the different elements are immersed in cups or glasses of acid, or saline liquids, in such a manner that the zink plate of one pair shall be in the same vessel with the copper of the succeeding. Thus the different cups are connected only by the wire which joins the two members of each element: and the different elements act on each other only



* *Couronne des Tasses*, pronounced *kouron da tas*, literally a crown of cups.

151. Galvanic battery.

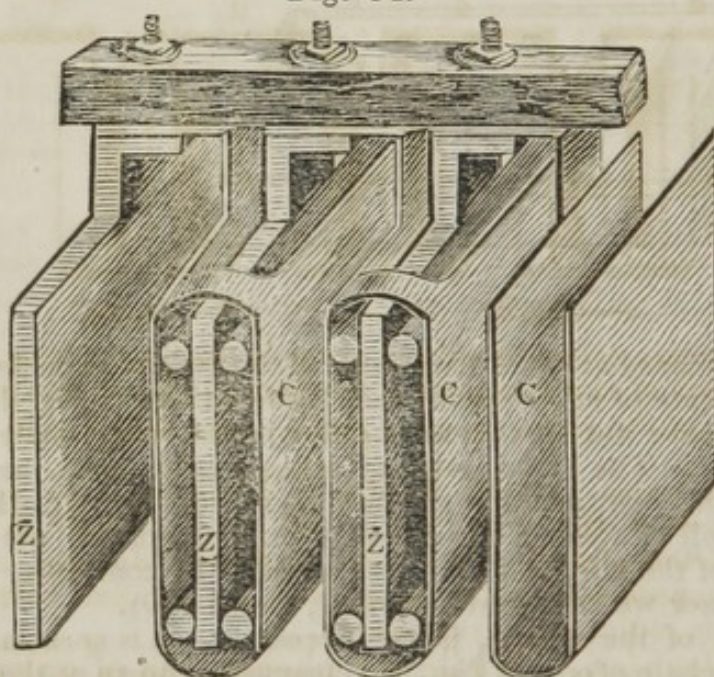
152. *Couronne des Tasses*.

through the medium of the intervening liquid. The two extreme plates which are not immersed in the liquid, are not taken into the account, and may be used as means of connecting the two poles of the row.

The electricity is supposed to be excited by the mutual action of the surfaces of zink and copper, opposed to each other in the same cup, and is conveyed from one cup to another by means of the wire which connects two successive cups.

153. *Modifications of the Galvanic Battery.* Dr. Wollaston observing that in the trough of Cruickshank, the effect of one zink and one copper surface in each pair was lost, by soldering them together, he proposed to use double copper plates or to bend the copper plate so that it should entirely surround the zink one, but without allowing the two to touch each

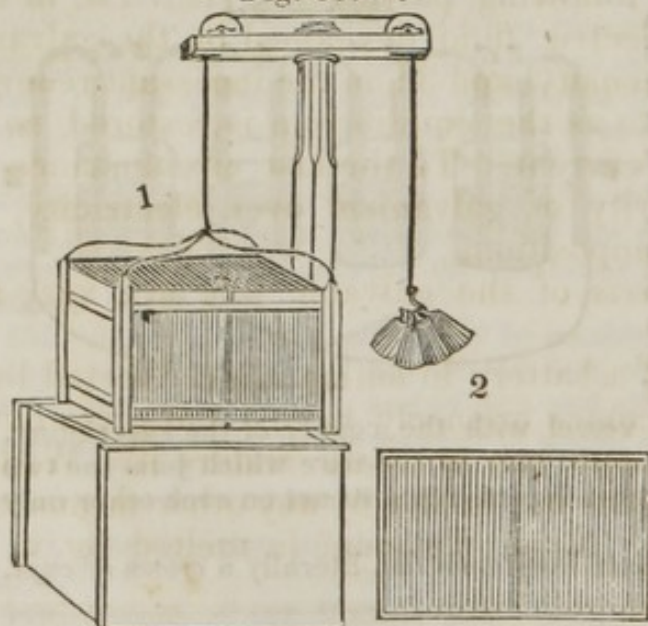
Fig. 34.



other, (see Fig. 34.) In this way each zink surface *z*, is opposed to one of copper, *c*, and the power is increased by one half. Batteries are now generally constructed on this principle: and a further improvement is made by connecting all the plates to a bar of dry wood, by means of which they can be removed at pleasure; the trough is made of porcelain or some other nonconductor, and is divided into cells by partitions of the same material.

The largest battery ever constructed is that of Mr. Children the plates of which were 6 ft. long, and 2 ft. wide.

Fig. 35. A.



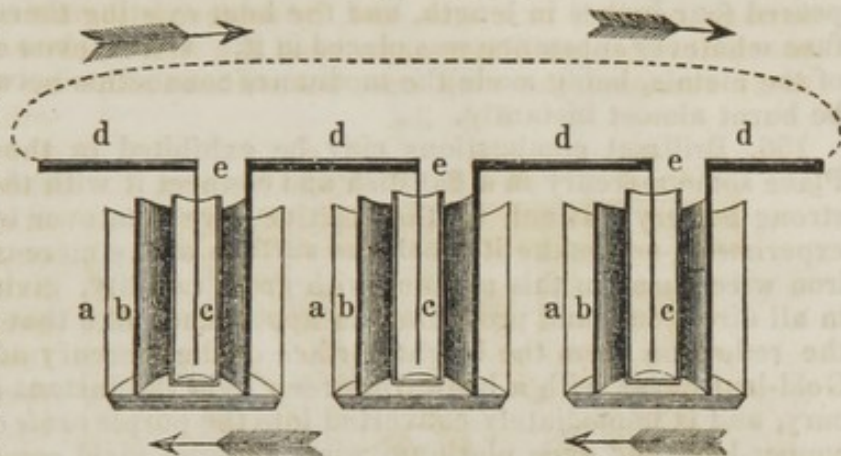
Hare's *Calorimeter*, (or mover of heat, (Fig. 35. A.) consists of a number of square zinc and copper plates of any convenient size, alternating with each other in a wooden frame. Two rectangular tubs accompany the apparatus, one containing the liquid acid for exciting the electricity, and the other to hold water for washing the plates. By means of an upright cross bar with a rope and pulley, the frame containing the plates may be at pleasure immersed in, or removed from the acid liquid: and this facility affords great advantages: for it is ascertained that the greatest action of the galvanic battery is

at the first instant of immersion; and it is, therefore, important to be able to immerse all the plates at once. Besides the effects of the calorimeter in igniting wires, during its action much hydrogen is evolved from the liquid, and the gas is sometimes inflamed by the great heat produced. (The figure at 1, represents the entire instrument ready to be plunged, and at 2, the top of the plates.)

Another modification of the battery by Dr. Hare is called the Deflagrator from its great power of burning the metals.

The battery most used at present, and which seems likely to supersede the use of all others, is called Groves' Constant Battery, a section of which is represented at (Fig. 35, B.) a, a, a, the outer glass vessels or tumblers; b, b, b, cylinders of zink, open above and below; c, c, c, porcelain cylinders closed at the bottom, to receive the platina slips; d, d, d, bars of zinc connecting the zinc cylinder in one tumbler with the platina slip of the next; e, e, e, platina slips attached to the end of the zinc bars.

Fig. 35. B.



When in use, the outer glass vessel is filled with dilute sulphuric acid, and the inner porcelain vessel with strong nitric acid, and a connection being established between the platina slip at one extremity and the zinc cylinder at the other as represented by the dotted lines, the galvanic current then flows in the direction indicated by the arrows.

154. *Effects of Galvanism.* While the phenomena of galvanism and electricity seem to be produced by the *same agent*, they differ remarkably in the following particulars, viz: 1st, in the greater quantity of the electric fluid developed by the galvanic battery, 2nd, in its low intensity, and 3d, in the incessant renewal of the excitement as often as the equilibrium is restored, so as to produce a continuous current. To the last circumstance, is attributable the superiority of galvanism over electricity, in producing chemical decomposition.

155. The *igniting effects* of the galvanic pile are very remarkable.

When the two poles of a battery in action are connected by a small wire, the latter becomes intensely heated and gives out a light so vivid, that the eye can scarcely endure it. With a powerful battery, substances not fusible by any other means, are melted almost instantly. Even platinum is melted by it, as

154. Difference between electricity and galvanism.

155. Igniting effects of galvanism. *E.cp.*

readily as wax by the flame of a candle. Of all substances, charcoal emits the most intensely, brilliant light.

Exp. Two slender slips of dense charcoal, or of plumbago,* should be selected, scraped to a point, and fixed to each of the connecting wires. The battery being now put into action, and the charcoal points made to touch by means of insulating handles attached to the connecting wires, they immediately become vividly ignited; and if very slowly separated, an arc of intense light will fill the space between them. With the great battery of the Royal Institution at London, consisting of 2000 pairs of plates an arc appeared four inches in length, and the heat existing there was so great as to fuse whatever substance was placed in it. Wires, even of the least oxidable of the metals, being made the medium of connection between the poles, may be burnt almost instantly.

156. Brilliant combustions may be exhibited in the following manner. Place some mercury in a flat dish and connect it with the negative pole of a strong battery; attach to the positive wire whatever is to be subjected to experiment, and make it touch the surface of the mercury. A point of fine iron wire burns in this manner with great rapidity, giving off vivid sparks in all directions, and producing an appearance like that of a brilliant star; the reflection from the bright surface of the mercury adding to its beauty. Gold-leaf burns with a beautiful green light the instant it touches the mercury, and is immediately converted into the purple *oxide of gold*. Silver and copper leaf, and even platinum wire, undergo vivid combustion. It is necessary to keep the surface of the mercury quite clean during these experiments, that its conducting power may not be impaired.

157. If the two connecting wires of a battery are immersed in water, so that their points shall be within a short distance of each other, an effervescence, arising from the evolution of gas, will be immediately observed; and the experiment may be so conducted, that the gas can be collected. When collected, it will be found to consist of oxygen and hydrogen, mixed in precisely the proportion for forming water. *The hydrogen is always evolved at the negative pole, and the oxygen at the positive, and by a contrivance of Dr. Wollaston, they may be collected and exhibited separately.*

Fig. 36.



* Black lead.

This little instrument consists of a bent glass tube. At the bend is a small hole through the lower side of the tube; each leg of the instrument is corked air tight. Through the corks, two platinum wires are passed, extending through the whole lengths of their respective portions of the tube, and almost meeting each other at the angle. If this instrument be immersed in a vessel of water, and each of the wires connected with one of the poles of a galvanic battery, the two portions of the tube will shortly be found to contain gas; that in the *positive* part will be *oxygen*, in the *negative hydrogen*; and the hydrogen will be in bulk, twice that of the oxygen; such being the proportions

156. Combustion of substances placed on mercury by means of the battery.

in which the gases unite to form water. But it is not necessary that the water decomposed, should be all in the same vessel. The experiment succeeds equally well, if two straight tubes, open at their lower end, are immersed in separate vessels of water, provided the two vessels communicate by means of moistened fibres of cotton. To effect the decomposition of water, only a weak galvanic battery is required; the voltaic pile, or a trough of 12 pairs of 4 inch plates being sufficient. Other compounds, of which the constituents are united by a stronger force, may be resolved into their parts by proportionally increasing the number of plates.

158. In proceeding to consider, the decomposing effects of galvanism, it is necessary to explain some of the Chemical properties of acids and alkalies.*

Chemical properties of acids and alkalies. *Acids* have the property of changing to *red*, the *blue* color of certain vegetable infusions, as that of violets, or of purple cabbage. *Alkalies*, on the contrary, change the same blue infusions *green*; and a color which has been changed by one of these substances, may be restored by a sufficient quantity of the other. *Salts* are chemical compounds of an acid and an alkali; and when the two are united in proper proportions, their characteristic properties are entirely disguised, and the salt is called *neutral*.

159. If we dissolve in water, Glauber's salt or *sulphate of soda*, (composed of *sulphuric acid* and *soda*,) and add to the solution, a little of the blue infusion of cabbage, the color will remain unaltered shewing that the compound is *neutral*. Let this solution be subjected to the action of a galvanic battery of sufficient power, the liquid at the positive tube, will soon become red, proving the presence of an acid there, while at the same time, the negative tube will exhibit an alkali, as will be shown by the liquid in it, becoming green. Now this acid and alkali could only arise from the decomposition of the sulphate of soda; and we are able, otherwise, to show that the contents of the two tubes, being mixed, will reproduce this salt. The sulphuric acid, and soda are both compounds, each containing oxygen,



* This subject is more fully explained at § 180.

157. Decomposition of water by means of the battery. Experiment with a bent glass tube. Experiment with two strait tubes.

158. Characteristics of acids, alkalies, salts.

159. Decomposition of a salt by the galvanic battery. What would be the ultimate analysis of Glauber's salt?

united to a peculiar combustible body;* and by a galvanic arrangement of high power, the acid and alkali are resolved into their elementary parts, that is, to their *ultimate analysis*.

160. In all cases of proximate† analysis of salts, by the galvanic battery, the acid will be found at the *positive* pole, and the alkali at the *negative*; and, whenever by ultimate analysis in this manner we resolve a substance into elements, of which one is *combustible*, and the other *non-combustible*, the *latter* will be found at the *positive*, and the former at the *negative* pole.

Mr. Faraday, who has paid much attention to the subject of galvanism, advances the following opinions:—

1st. That the poles have no attractive, or repulsive tendency. He prefers the term *electrodos*,‡ which signifies the way or door for electric currents.

2d. When a compound is decomposed by galvanism it is said to be *electrolyzed*; || the substances capable of decomposition are called *electrolytes*; the elements of an electrolyte are called *ions*.§ Electro-negative substances as oxygen, chlorine, acids, &c., he calls *anions*; ¶ the electro-positive as hydrogen, alkalies, metals, &c., he calls *calions*.**

3d. Most of the simple elements are *ions*, that is capable of forming compounds decomposable by galvanism.

4th. A single *ion* by itself has no tendency to pass to either of the *electrodes*, or is indifferent to the voltaic currents.

5th. To account for the decomposition of water by galvanism, Mr. Faraday supposes a line of particles between the two *electrodes*, along which the current passes. When a particle of oxygen is evolved at the positive electrode, its hydrogen is not at once transferred to the opposite electrode, but unites with the oxygen of the contiguous particle of water, on the side towards which the positive current is moving, then it passes to the next, and so on till it arrives at the pole. A similar row of particles of oxygen start from the negative electrode at the same moment and combine successively with the particles of hydrogen as they pass them on their way to the positive pole or electrode. This process is supposed similar to what takes place in all cases of galvanic decomposition.

161. *Discoveries of Sir H. Davy.* The Galvanic battery became in the skillful hands of Davy, the means of effecting the most brilliant discoveries. With this instrument, he ascertained the *compound nature of the alkalies and earths*, a fact which,

* Sulphuric acid is composed of *sulphur* and *oxygen*, soda of a metal called *sodium* united with oxygen.

† The analysis of sulphate of soda into the acid and the alkali is the *proximate* analysis; the farther analysis of sulphuric acid and soda into three simple elements is the *ultimate* or last analysis.

‡ From the Greek *electron*, and *odos*, a way.

|| From *electron*, and *lus*, to unloose or disengage.

§ Pronounced *i-ons*, from *ion*, going, participle of the verb to go.

¶ From *ana*, upwards, and *odos*, the way in which the sun rises.

** From *kala*, downwards, the way in which the sun sets.

160. What takes place in all cases of proximate and ultimate analysis of salts by the galvanic battery? Mr. Faraday's theory of decomposition.

161. Decompositions effected by Davy. Strong proof of the elementary nature of a body.

previously had been only suspected. This discovery has introduced a new era in the annals of Chemistry, and added several new metals to the list of simple elements. No known compound has been able to resist the decomposing power of galvanism; and it is regarded as the strongest proof of the elementary or simple nature of a body, when it gives no signs of decomposition, on being subjected to the influence of this agent.

162. To account for the decomposing effect of galvanism, it is necessary to recur to the principle of electric attraction and repulsion. If two particles, united to form a compound molecule, are both brought into the *same electrical state*, they will exert a mutual repulsion; and if this repulsion be more powerful than the force of their chemical attraction, they must necessarily separate, and the compound will be destroyed. Or, even if they be in *opposite states of electricity*, since they are both within the influence of the battery, that particle which has the strongest tendency to become negatively electric, will naturally become so by induction, and be attracted to the positive pole; and at the same time, a similar change in the opposite direction, will take place with the other particle.

163. Davy was led to infer that chemical and electrical attractions are effects of the same cause. Having brought a dry acid in contact with a metal, he found that the former became *electro-negative*; an alkali, treated in the same manner, became *electro-positive*; and when an acid and an alkali, both dry, were made to touch each other, electrical excitement was produced, the acid being negative and the alkali positive.

Furthermore, those bodies which exhibit the greatest tendency to chemical combination, are also prone to assume opposite electrical states; and though two bodies, *A* and *B*, which, if successively brought in contact with *C*, would each assume the same electrical state, may be in opposite electrical states when in contact with each other; yet if they combine, their compound *A B*, is held together by weak affinities, and is easily decomposed. Examples of this kind may be found in the instances of chlorine and oxygen; each of these bodies is strongly *electro-negative*, when in contact with hydrogen, and each forms with it, a well-defined compound. But chlorine, though *electro-negative* when compared with almost all bodies, is *electro-positive* with regard to oxygen, and may be made to combine with it; yet the compounds formed by chlorine and oxygen, are decomposed with remarkable facility.

164. The electro-chemical theory, supposes the same electri-

162. Explanation of the decomposing effect of galvanism. Why compounds are destroyed by electrical repulsion. Why there should be a decomposition when the particles are in opposite states of electricity.

163. Davy's experiments to prove the connection between chemical and electrical attractions. Electricity of acids and alkalies. A body may be *electro-positive* with one body, and *electro-negative* with another. Why chlorine and oxygen form compounds which are easily decomposed.

cal excitement to take place between *atoms* in contact with each other, as we have seen to be produced by masses; that the atoms remain in contact, that is to say, in *combination*, in consequence of the electrical attraction consequent on this excitement; and that their union ceases, whenever, by any cause, they are brought into the same electrical state, or when they are exposed to the action of any third body which is more highly excited than either; for, in the latter case, the highly excited body will attract the particle which is dissimilarly excited, and repel that which is similarly so; and this is what happens in the decomposition of a compound substance by the galvanic battery.

165. Following the same course of reasoning which led him to the discovery of the alkaline metals*, Davy made other useful applications of his theory. Although the metals, compared with oxygen, are *all* electro-positive, yet when compared with each other, as in the case of zinc and copper, they may have opposite natural *electric energies*; and from experiment, as well as from theory, it is shown, that the *positive metal will have the strongest tendency to combine with oxygen*. Thus copper is rapidly corroded in acid, or saline solutions; but in contact with zinc, iron and some other metals, copper becomes electro-negative, and remains bright, while the other metal is rapidly oxidized; this happens, also, in the galvanic battery.

Davy found that a slip of zinc or iron, would protect from rust 150 times its surface of copper, though constantly exposed to the action of salt water; and he proposed to apply this principle to the preservation of the copper sheathing of ships. The rusting of fine iron or steel instruments, may be effectually prevented by fixing a piece of zinc in their handles or elsewhere, so that it shall be always in contact with the blade.

Electro-Magnetism or Magnetic effects of Electricity.

166. The relations existing between magnetism and electricity are daily becoming more fully developed, and present a most curious subject of philosophical research; the facts already accumulated constitute a new branch of physical science called *Electro-Magnetism*.

167. Professor Oersted of Copenhagen, in 1819 discovered that the metallic wire of a voltaic circle causes a magnetic needle

* Sodium, potassium, &c. being metals found in the alkalies, soda, potash, &c. are termed *alkaline metals*.

164. Electro-chemical theory founded upon the preceding facts.

165. Applications made by Davy of his theory, with respect to the electrical attraction of the metals. Why copper is protected from rust or oxidation, by zinc or iron. Iron and steel protected by zinc.

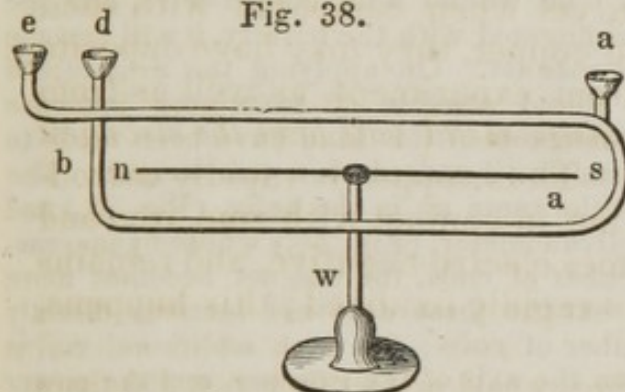
166. Electro-magnetism.

167. Discovery of Oersted.

when brought near it to deviate from its natural position. This discovery was a confirmation of what was generally supposed, viz; that electricity might be employed to communicate magnetic properties to iron or steel. It had been observed, that a ship having been struck with lightning, the magnetic needle often had its polarity destroyed or reversed, and that the iron about the ship became magnetic.

168. *Galvanometer.* It being proved that every part of a wire in a closed voltaic circuit exerts an equal force upon the poles of a needle, the combining force will be increased by increasing the number of points. This can be done by coiling the wire into the form of a circle or rectangle; the united force will depend on the number of coils, each coil exerting its own peculiar force.

Fig. 38.



d, e, (Fig. 38,) are the two ends of a copper wire bent in the form of a rectangle, in the centre of which, and in a plane perpendicular to the plane of the wire, is placed a magnetic needle. A graduated circular plane measures the degree of declination of the needle, which indicates the quantity of electricity circu-

*lating along the wires. If the positive voltaic current pass above the needle from north to south, or which is the same thing from *e* to *a*, and then pass around the south pole from *a* to *b*, the effect will be doubled. The deflection of the needle may be increased by multiplying the coils, until its directive power shall be wholly destroyed, or even reversed. If at the moment the needle has attained this point, the voltaic currents be sent in an opposite direction, it will perform a revolution. Thus a needle may be made to revolve rapidly by changing the direction of the currents.*

Influence of voltaic currents on soft iron or steel.

169. If instead of the common magnetic needle, an iron or steel needle be suspended in the galvanometer, at right angles to the conducting wires, permanent magnetism will be communicated to the steel, and the iron will become powerfully magnetic, but will lose this property when the voltaic currents cease to circulate. This discovery was made about the same time by M Arago and Davy.

168. Galvanometer. Explanation of the figure.

169. Discovery of Arago and Davy. Explanation of Fig. 39. Explanation of Fig. 40.

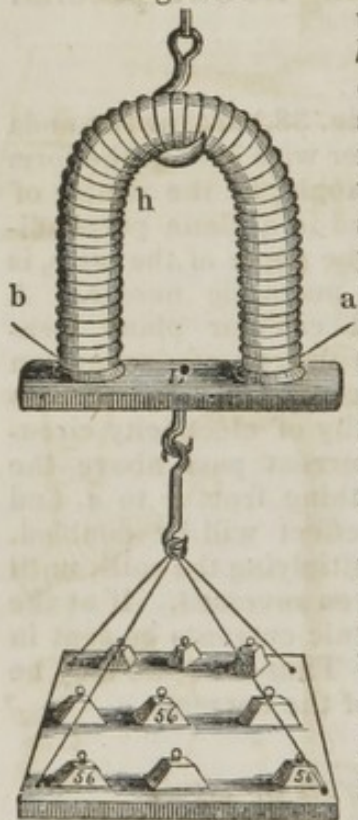


Fig. 39.

Let an insulated copper wire be coiled in the form of a helix, as at *d*, connect the two ends of the wire *b, b*, with the cups *c, z*, into which the poles of a battery may be inserted. If bars of soft iron or steel be placed in the coil, they will become magnetized the instant the voltaic currents begin to circulate around the coil. If the positive current flows from *z* around the coil, *n* will be the north pole and *s* the south pole. The poles will be reversed if the positive current flows from *c*.

The magnetic properties of soft iron, though not retained, are very powerful while the voltaic currents are passing around it.

Fig. 40.



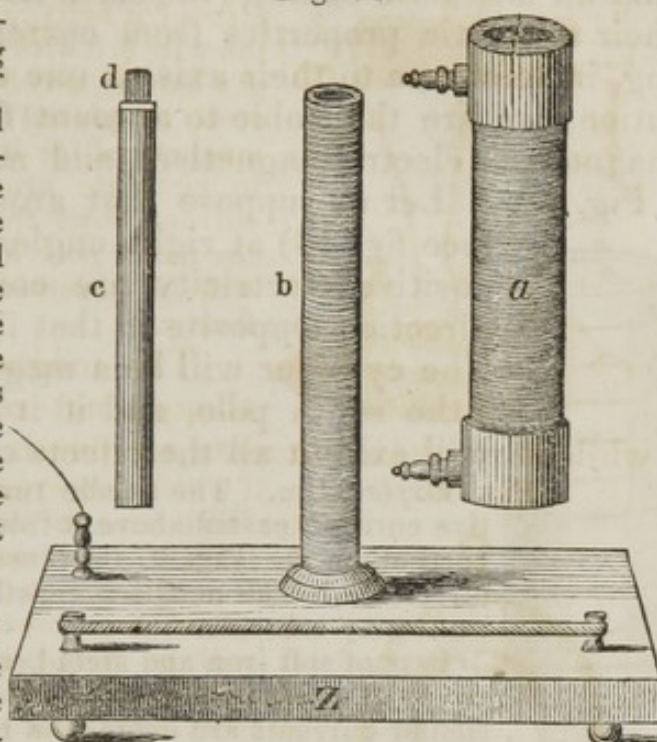
If a soft iron cylinder, about two inches in diameter and bent in the form of a horse-shoe magnet *h*, (Fig. 40,) be wound with copper-wire, and the ends *a, b*, connected with the battery, it will become a powerful magnet. On applying the armature* *d* it will be found capable of sustaining immense weights;—magnets of this kind have been made to support from one hundred to a ton weight. The principle is the same as in the helix, (Fig. 39,) and as in the galvanometer, (Fig. 38,) where by increasing the number of coils, the magnet becomes more powerful; but the force does not increase directly as the number of coils; for each additional coil is farther from the axis of the iron bar, and the power it exerts is inversely as the square of the distance from the axis.

170. *Volta-Electric Induction.* It having been found that an electrically excited body, induced electricity in other bodies brought near it, the fact was next discovered that the same effect is produced by electricity in motion. Let a copper wire be wound in the form of a helix, and the ends connected with a battery; let another wire be wound around this, but insulated from it, and the ends connected with a galvanometer, currents of electricity will be induced in the insulated wire, as often as the battery current is broken. All the effects of galvanism may be produced by the insulated wire.

* From *armo*, to arm a piece of soft iron applied to a loadstone, or connecting the points of a horse-shoe magnet.

Separable Helices, (Fig. 41.) exhibit the phenomena of volta-electric induction in a striking manner; *b* is a hollow coil of coarse wire fixed upon a stand *z*; one end of the wire is connected with the cup, and the other with the steel break-piece or non-conductor, which is fixed to the stand, by the side of the coil; *a* is a coil of fine wire which may be placed over the coil *b*; *d* is a bundle of wires which may be put into the copper coil *c*, and placed in the centre of the coil *b*. The entire apparatus is represented at Fig. 42.

Fig. 41.

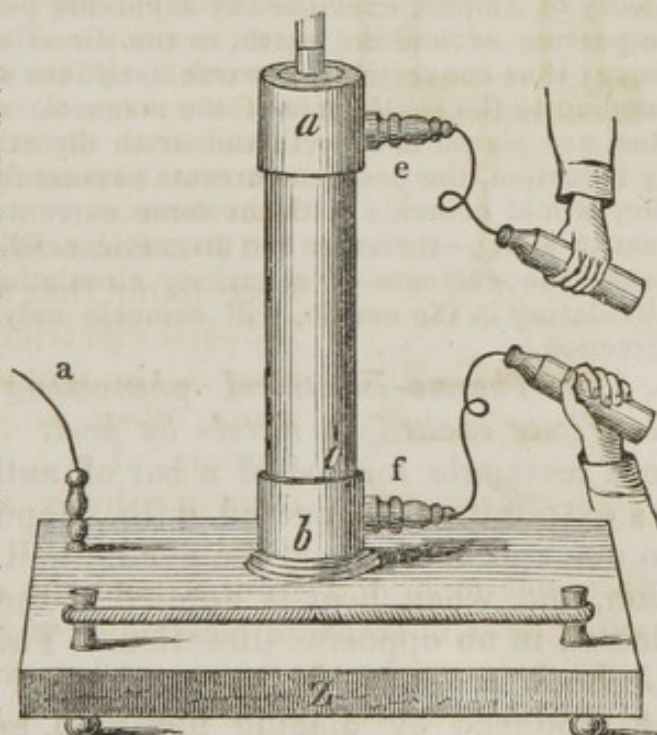


Exp. Connect one pole of the battery with the cup on the left of *c*, (Fig. 42,) and move the other pole along the break-piece; vivid sparks will be produced at each interruption.

Fig. 42.

Exp. Place the coil *a* upon *b*, and let the currents circulate as before. If the handles *e*, *f*, (Fig. 42,) which communicate with the extremities of the wire forming the coil *a*, be held in the hands, powerful shocks will be felt, as the wire conveying the battery current passes across the break-piece.

Exp. Remove from the wires *d*, the copper coil *c*, and insert them gradually in the coil *b* while the currents are circulating, and the sparks in the break-piece will increase in brilliancy until the wires reach the bottom, when the greatest effect will be produced.

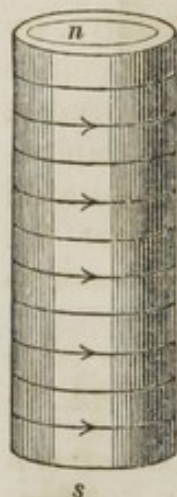


Ampere's Theory of Electro-Magnetism and Magno-Electricity.

171. When two positive or two negative currents are passing in the same direction, and parallel, they attract, and when passing in opposite directions, they repel each other;—Supposing

that all magnetic bodies, (the earth itself being included) derive their magnetic properties from currents of electricity circulating, in reference to their axis, in one uniform direction of revolution, we are then able to account for all the phenomena of magnetism, electro-magnetism, and magneto-electricity.

Fig. 43. Let us suppose that around the cylinder of steel (see fig. 43) at right angles to the axis, currents of positive electricity are constantly circulating in a direction opposite to that in which the sun moves. The cylinder will be a magnet, *n* the north pole and *s* the south pole, and if it be poised upon a pivot, it will exhibit all the effects of the magnetic needle.



Explanation. The needle turns to the east when the positive current passes above it from north to south, because the currents in the magnet, and those in the wire, move in different directions. The needle is repelled, and turns so that the currents may coincide.

Bars of soft iron and steel become magnetic when placed in the helix around which currents of electricity circulate, because similar currents are induced in them.

The cause of the magnetic needle standing north and south, is on the theory of Ampere explained by supposing positive currents of electricity to be passing around the earth, in the direction in which the sun appears to move; thus converting the earth itself into a magnet, its north pole corresponding to the south pole of the magnetic needle;—if soft iron or bars of steel are placed in a north and south direction, they will become magnets by induction, the positive currents passing from west to east, because then they would coincide with the same currents in the earth which pass from east to west;—therefore the magnetic needle stands north and south, because the currents of electricity circulating around the earth, and those circulating in the needle, will coincide only when the needle takes that direction.

172. *Thermo-Electrical phenomena result from currents of electricity excited in metals by heat.* If a magnet be suspended in a rectangle formed of a bar of antimony or bismuth, having its extremities connected with copper wires, and heat applied to one end of the bar, the needle will be deflected in one direction, and when heat is applied at the other end, it will be deflected in an opposite direction. This discovery was made by Leebeck in 1821. It has been found that a rotary motion may be produced by placing platinum and silver wires, soldered together in a circular form, upon a magnet, and applying heat.

173. The Electro-magnetic Telegraph is an invention by which voltaic electricity is applied to communicate intelligence between distant places. At one station is the battery with wires extending to the other station, and so connected with a magnetic needle,

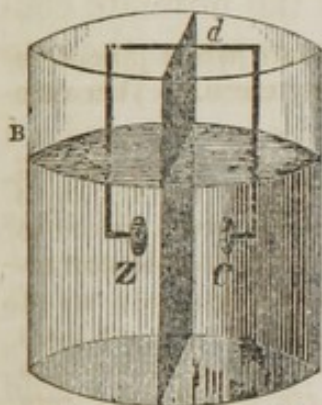
172. Thermo-electrical phenomena.

173. Electro-magnetic telegraph.

that when the wires are attached to the battery the needle is set in motion and by means of a pencil attached to it, those conventional characters are marked which are the symbols of certain words or ideas. The effects of this application of voltaic power in conveying intelligence with the rapidity of lightning, are beyond human calculations.

174. *Electrography* is an application of voltaic electricity, by means of which may be produced perfect metallic casts or copies of medals, coins, copper-plates, &c. The instrument used is called the *Electrotype*. Its effect depends on the decomposition of some metallic salt, by which the metal is precipitated upon the object to be copied, either forming a mould for the cast, or raising lines which may be used for making impressions on paper and other substances.

Fig. 44.



B is a glass vessel (Fig. 44,) with divisions made by placing across it some porous substance as thick paste-board. Into one of the divisions is put a saturated solution of sulphate of copper, and the other a weak acid solution. The object *C* to be copied is soldered to one end of a wire, *d*, and a piece of zinc, *Z*, to the other end; the object is then immersed in the solution of copper, and the zinc in the acid solution. Metallic copper then begins to be deposited upon the object *C*, copying, with perfect exactness the most minute lines and shades. In a few days a complete cast will be formed: this is separated from the matrix by gentle heat.

Explanation. The sulphate of copper is decomposed into sulphuric acid and oxide of copper;—The acid, with the oxygen of the decomposed water go to the zinc; while the hydrogen of the water and the oxide of copper go to the copper pole; the hydrogen unites with the oxygen of the oxide of copper, and the metallic copper is deposited upon the metal or object to be copied.

Theories of Galvanism.

175. 1st. The theory of Volta considers the *contact of the metals* to be the only cause of electric excitement; it attributes to the liquid used, no other agency than that of conveying the electricity by means of its conducting power, from one pair of plates to the next, and thus enabling it to accumulate at the poles.

2d. The *chemical theory* is so called, because it regards the chemical action which goes on in the pile, viz., the *oxidation of the zinc*, as the original disturber of electric equilibrium. This theory, Dr. Wollaston supports by arguments drawn from various experiments. It is perfectly true, that the contact of the metals will produce electric excitement; but it is also equally true, that electricity is developed during chemical action. Furthermore, it

174. Electrography. Explanation of Fig. 44.

175. Volta's theory of galvanism. The chemical theory. Electro-chemical theory. Mr. Faraday's theory. Dr. Hare's opinion respecting the eating effects of the battery.

is observed that the activity of the pile is increased, when, by using a more powerful acid, the chemical action is rendered more violent.

3d. Davy's theory, or the *electro-chemical* unites the two preceding ; it supposes that the electric equilibrium is first disturbed by the contact of the zinc and copper plates, and that the excitement is afterwards kept up, and increased by the chemical action between the liquid and the metal.

4th. Mr. Faraday has attempted to prove that the poles have no attractive or repulsive tendencies but merely afford a path for the voltaic currents to enter the liquid, or are doors for electric currents.

5th. Dr. Hare does not attribute the *heating* effects of the battery to electricity, but supposes the fluid evolved by this machine to be a compound of electricity and caloric, in which the proportions of the two constituents vary according to circumstances ; thus, in the use of his calorimoter, great heat is excited, while the electric tension is very small.

176. In examining the operations and effects of heat, light and electricity, it is not necessary that we attempt to theorize upon their nature, or to determine whether they are *substances*, or *qualities* of invisible substances. Such is the intimate connection between them that many philosophers suppose them to be modifications of the same power, or substance. We cannot but regard them with awe, as mysterious agents, whom the Almighty subjects, partially, to our will, but of whose essential nature we are ignorant. We know that they possess immense force, and though we seem to have them in some degree under our control, we are liable at any moment to be destroyed by their power. It is their Creator only, who knows the "hiding of their forces ;"—He only can restrain, and hold them in combinations so justly and wisely modified and balanced, as to maintain and preserve that beautiful harmony in the order of Nature and of Providence, which He has established.

CHAPTER VII.

CHEMICAL NOMENCLATURE.

177. An important change of subjects now presents itself. The bodies we are about to examine, are such as we can either see, or handle, or can prove to possess weight ; they are, therefore, *known to be material*, and are called *ponderable*, in distinction from the class of agents called imponderable.

178. The study of ponderable bodies naturally divides itself into two parts, called *Inorganic* and *Organic Chemistry*. By

176. Concluding remarks.

177. Meaning of the term ponderable.

178. Distinction between Inorganic and Organic Chemistry. The same elements enter into the composition of Organic and Inorganic matter.

Inorganic Chemistry is meant the study of the elementary bodies, with their combinations, as existing in inorganized matter as water, air, earths, minerals, &c. *Organic Chemistry* treats of the *chemical* constituents of plants and animals, but offers no *elements* not found in inorganic substances. It is owing to the *different proportions*, and *mode of combination*, that organic compounds differ in their qualities so essentially from compounds that are found in the inorganic kingdom; thus the blood of animals and the sap of vegetables, are peculiar fluids resulting from the action of a living principle, deprived of which, both animals and plants become the prey of the chemical and mechanical forces which are constantly in operation around them.

179. Before proceeding farther it is necessary to *explain the nature* of certain bodies, to which we shall have frequent occasion to allude; after which, will be given a brief exposition of the principles and rules on which *Chemical Nomenclature* is founded. The important subject of Chemical affinity, will next be examined, and the laws of chemical combination. These are necessary preliminaries to the consideration of the ponderable bodies. Though, at first, these subjects may seem obscure, the mists will gradually break away, and the science appear in its true and beautiful proportions;—each advance then made, will reveal new and striking evidences of the immutable basis on which it rests; convincing the student that Chemistry, if not itself a *divine* science, proclaims the divine origin of matter; clearly refuting the absurd idea, that a blind chance, brought the material atoms into existence, and presides over their combinations.

180. By the term *salt*, as used in Chemistry, is meant, a definite compound of an acid and a *salifiable** base.

An acid (see § 158,) is generally sour, soluble, capable of reddening the blue color of violets and of litmus†, and of combining with and neutralizing the salifiable bases. But some acids are not soluble in water, and therefore do not taste sour nor redden vegetable blues; others do not neutralize the salifiable bases, though they combine with them. According to a strict chemical definition of the term, an *acid* is a *substance which combines in definite proportions with salifiable bases to form salts*.

* Salifiable from the Latin *Sal* salt, with an English termination, means capable of becoming a salt.

† Litmus is prepared from a lichen, (*Lichen roccella*;) it is of a blue color, and paper dipped in its infusion furnishes a delicate chemical test.

179. Preliminary subjects to be considered.

180. Definition of a salt. Of an acid. Salifiable bases. Neutral, *super* and *sub-salts*. Soluble salts. Various properties of salts.

Salifiable bases are all *metallic oxides** except ammonia,† and the *vegeto-alkalies*.‡ All the soluble, salifiable bases, (including ammonia, but excluding the vegeto-alkalies,) have an acrid taste, and are highly caustic, turn to green, the blue of violets, restore the blue of litmus when it has been reddened by an acid, and combine with acids in definite proportions to form salts.

These are the properties which constitute an *alkali*; and hence the salifiable bases which do not possess them all, are not called alkalies. But there is no proof that the absence of these properties in certain salifiable metallic oxides is not owing to *insolubility*. The *insoluble*, salifiable bases possess only the last mentioned and most important of the alkaline properties, that of *combination* with acids.

Some salts exhibit the properties of neither acid nor base, and are called *neutral salts*; others are *acidulous*, which property generally arises from an excess of acid, but sometimes from the feebleness of the base; others are alkaline, generally from an additional quantity of the base, but sometimes from the weak neutralizing power of the acid. Acidulous salts are frequently called *super salts*, as super tartrate of potassa, &c.; and salts exhibiting the properties of the alkaline base, are sometimes denominated *sub-salts*, as *sub-carbonate* of soda.

Some salts are soluble, others are not so; all soluble salts have taste, and most frequently a disagreeable one; none of them have odor, but the carbonate of ammonia. Some are colored, others colorless, and many of them are capable of crystallization.

181. If every substance, examined by the Chemist, were to be named as caprice or fancy might suggest, the memory would be capable of retaining but a very small number of the names. To obviate so great an inconvenience, a systematic nomenclature, expressive of the constitution of substances, was adopted by Lavoisier, Guyton-Morveau, and other French Chemists, about the year 1784. It is founded on the principle, that the name of every substance ought to express its composition, if a compound, or some striking property, if it be a simple body. The simple bodies already known, were permitted to retain their established names.

In conformity with these principles, oxygen was named from

* By metallic oxides is meant a compound substance composed of a metal and oxygen. *Oxide* of iron is oxygen and iron; oxide of gold is oxygen and gold, &c. It is not to be understood that every metallic oxide is a salifiable base; some oxides are acids, and some neither acids nor bases.

† Ammonia is a compound of two gases, Nitrogen and Hydrogen.

‡ Vegeto-alkalies are compound alkaline bases, obtained in the analysis of Vegetable substance.

181. On what principle is the systematic nomenclature founded? Origin of the names of some of the elementary bodies. Names given to the combinations of simple electro-negative bodies with other bodies. Names of combustions of simple combustible bodies with each other. Nomenclature of acids. Nomenclature of salts. More definite mode of describing salts than by the terms *super* and *sub-salts*.

two Greek words, implying a *generator of acids*. Hydrogen literally means *the generator of water*. Chlorine signifies a green substance, &c. &c. The combinations of simple electro-negative substances with other bodies are designated by names ending in *ide*, as *oxides*, *chlorides*, *iodides*, and *bromides*. And where these elements form more than one combination with the same body, the different compounds are distinguished by prefixing Greek ordinals, marking the relative proportions; as *protoxide* of iron, *deuto-chloride* of mercury, *trito-iodide* &c., the highest compound being called *per*^{*}-oxide, *per-chloride*, &c., meaning that the body has been oxidized, &c. *through* all the stages possible. The termination *uret*, is given to names of combinations of simple combustible bodies with each other: as *sulphuret of lead*, *phosphuret of carbon*, *carburet of iron*, &c.

Where but one acid is formed by the union of the same elements, its name terminates in *ic*; as *muriatic acid*, *carbonic acid*, &c. But it frequently happens that oxygen, by uniting in different proportions with the same body, forms several distinct acids; when this is the case, the acid highest in oxidation is distinguished by *ic*, and a lower one by *ous*; and the intermediate degrees of oxidation are expressed by the prefix *hypo*, signifying *under*. Thus, sulphur forms with oxygen, the four following acids, viz; *sulphuric*, *hypo-sulphuric*[†], *sulphurous*, and *hypo-sulphurous*.

The termination *ate*, expresses the salt of an acid, ending in *ic*; and the termination *ite*, the salt of an acid, ending in *ous*. Thus we have *sulphates*, and *hypo-sulphates*, *sulphites* and *hypo-sulphites*.

It has been stated, (§180), that the same acid and base, by combining in different proportions may form different salts: and that the name *super-salt* is given to those containing more acid, and that of *sub-salt* to those containing more base than the neutral salt. These names are objectionable because they do not express the *proportions* by which either ingredient is in excess; so that different *super-salts*, or different *sub-salts* of the same base and acid are confounded under one general appellation.

To obviate this inconvenience, the number of *equivalents* or combining proportions of acid in the super-salts is denoted by Latin prefixes; while Greek numerals point out the proportions of base in the sub-salts.

Thus we have the *neutral oxalate*, the *binoxalate*, and the *quadroxalate* of *potassa*, the first of which contains *one* atom, the second *two*, and the last four atoms of oxalic acid to each atom of base. Again, among sub-salts are the *neutral acetate*, the *di-acetate* and the *tris-acetate* of lead; the first being composed of one equivalent of acid, and one of base, the second of one of acid and two of base, and the last, of one of acid to three of base;

* From the Latin *per* signifying through.

† *Hypo* signifies under, or below, thus *hypo sulphuric acid* means one which has a lower degree of oxidation than sulphuric acid.

and if there were a fourth compound consisting of one of acid to four of base, it would be the *tetra* acetate of lead.

182. The proportion of terms *proto*, *deuto*, *trito*, *per*, &c., when placed before the generic names of salts, refer not to the proportions of acid and base they contain, but to the degree of oxidation of the base. Thus the *proto*-sulphate of iron means the sulphate of the protoxide of iron, the *per*-sulphate of copper is the sulphate of the *per*-oxide of copper, &c.

Different salts may sometimes combine and produce what are called *triple salts*, or, more properly *double salts*. A double salt may consist of two acids and one base, of two acids and two bases, or, what is by far the most common, of one acid and two bases. The latter are *bi-basic* salts; such are the *double tartrate of potassa and soda*, which is the tartrate of potassa united with the tartrate of soda, commonly called Rochelle salt; tartar emetic is the *double tartrate of antimony and potassa*. Sometimes, the name of one base precedes, and that of the other, follows the generic name; as the *ammonic-sulphate of copper*, which is the double sulphate of copper and ammonia.

183. Acids which are formed by the union of oxygen with another simple substance, are called *oxacids*, those composed of hydrogen and a *radical* are *hydracids*; thus the proper chemical name of muriatic acid, (which consists of hydrogen and chlorine,) is *hydro-chloric acid*; hydrogen and iodine form *hydriodic acid*; and hydrogen with *bromine* constitutes *hydro-bromic acid*.

Specific Gravity.

184. The physical characters of bodies are often valuable aids in discriminating between different substances. Some of these characters, as the color, may be considerably affected by the presence of foreign substances. Among the most constant and valuable is specific gravity.

The specific gravity of a substance is its weight, compared with an equal bulk of some other substance, taken as the standard of unity. This standard for solids and liquids is water, and for æriform bodies, atmospheric air. If we weigh a solid body in air, and again weigh it suspended in water, it will be found, in the last instance, to weigh less than in the first; and the loss of weight is ascertained to be the exact weight of an equal volume of the fluid displaced: thus, it is an axiom in hydrostatics, that the *weight which a body loses when immersed in a fluid is equal to that of an equal bulk of that fluid*.

If, therefore, a solid body be not soluble in water, we take its exact weight in the usual manner; then weigh it suspended in pure water, and subtract this weight from the former,—the *difference* is the weight of a bulk of water equal to the solid. We now have the proportion, as the *difference*

182. The prefixes *proto*, *deuto*, &c., when placed before the generic name of the salts. Double salts.

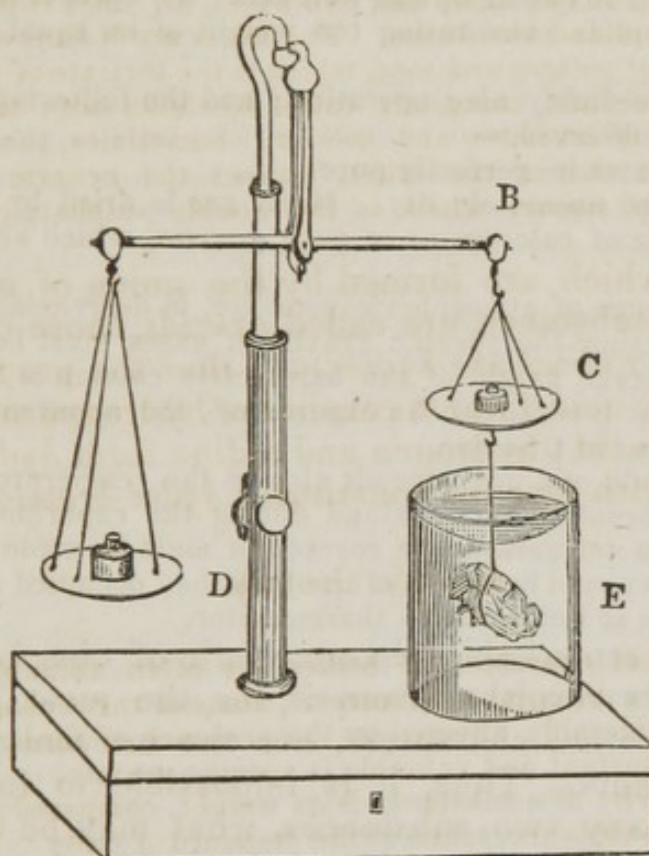
183. Oxacids and hydracids.

184. Definition of the term specific gravity. Standard of specific gravity for solids and liquids. Mode of finding the specific gravity of a solid not soluble in water.

just mentioned, is to the weight of the solid in air, so is one, (the assumed specific gravity of water,) to a fourth proportional, which is the specific gravity required.

185. The instrument used to determine the specific gravity of bodies is called the *hydrostatic balance*. B C D (fig. 45) is a balance; E a glass vessel containing water. Suppose we wish to determine the specific gravity of sulphur; we suspend a small bit, by a hair, or fine thread of silk, from the balance at C: we find it weighs in the air 12 grains. We then immerse it in the water as represented in the figure, and find it has lost weight: we add to the scale C, a sufficient number of grains to cause it to balance the

Fig. 45.



scale D. Suppose these grains are 6, this is then the weight lost by the immersion. We then say, as 6, (the difference between the bit of sulphur in water, and in air) is to 12, the weight in air so is 1, (the assumed specific gravity of water) to 2, the specific gravity required; or thus, as 6 : 12 :: 1 : 2.

186. If the solid, whose specific gravity you wish to find, is soluble in water but not in alcohol, ascertain first the specific gravity of alcohol and then take that of the solid with regard to alcohol just as before described. If the solid be soluble also in alcohol, any liquid in which it is insoluble may be substituted.

187. To find the specific gravity of a liquid, fill any convenient phial with distilled water and ascertain its exact weight, taking care that it shall be perfectly dry on the outside; then pouring out the water and drying the

185. Hydrostatic balance.

186. Mode of finding the specific gravity of a solid which is soluble in water.

187. To find the specific gravity of a liquid.

phial carefully, fill it with the liquid under examination and weigh it; the last weight will be to the former as 1 is to the specific gravity of the liquid.

Another mode consists in ascertaining the comparative heights of the columns of the two fluids which are necessary to support a given column of mercury; the specific gravities of the liquids are in the inverse ratio of their respective columns.

188. To ascertain the specific gravity of gas, it is first necessary to know that of atmospheric air. Sir George Shuckburgh states that 100 cubic inches of air weigh 30.5 grains and this estimate is generally adopted as correct.

Having exhausted a thin glass flask by means of the air pump, it is to be filled with the gas in question, and weighed. The proportion is exactly as in the case of liquids substituting the weight of an equal bulk of air for that of water.

This is an exceedingly nice operation; and the following circumstances must be strictly observed,—

1st. The gas must be perfectly pure.

2nd. It must be absolutely dry. Moist gas is dried by passing it over pieces of chloride of calcium, or of pure potassa, which absorb the moisture.

3d. The influence of atmospheric pressure, in decreasing the bulk, consequently increasing the specific gravity of gases must be taken into account. The average height of the barometric column is 30 inches; if it should be more or less during the experiment, the apparent sp. gr. will be more or less than the true one.

4th. As the bulk of a gas depends also on the temperature, if the thermometers of Fahrenheit do not stand during the experiment at 60°, the standard or mean temperature, a correction must be made upon the principle that gases expand by 1-180, of the bulk they occupied at 32°, for each additional degree of Fahrenheit's thermometer.

189. It is a remarkable characteristic of *chemical union* that the compounds resulting from it, for the most part, possess neither the external characters, nor the internal properties of their constituents. Thus, it is impossible to foretell from a knowledge of any two substances, what may be the nature of the body which will be formed by their combination. Chemistry requires, therefore, experiments, or trials, in order to prove, by every possible method, not only the nature of simple bodies, but the effects which may be produced by their union with each other.

188. To find the specific gravity of gas. Circumstances to be regarded in weighing gases.

189. Characteristics of chemical union. Why experiments are necessary in chemistry.

CHAPTER VIII.

CHEMICAL AFFINITY.

190. *Chemical affinity* is an attraction, which acts only at insensible distances, between particles of different kinds. The cause of affinity, is, at present, supposed to be, the same agent which produces galvanism and magnetism; viz. electricity; though other agents, as light and heat, modify the action of this primary cause. *Affinity*, is of three kinds, viz; *Simple, Elective, and double Elective Affinity*.

191. *Simple Affinity* is the union of substances without causing any decomposition; thus sulphuric acid added to soda, forms sulphate of soda, and potassa forms soap with oil and water. In these cases, no previous combinations are broken up.

192. *Experiments to show that affinity produces compounds whose properties differ, essentially, from those of the components.*

Exp. 1st. Common liquid Hydro-Chloric Acid consists of a gas dissolved in water; it is very sour, inflames the skin and changes to red, the blue color of vegetable infusions; these properties are derived from the gas it contains. *Liquid ammonia*, or spirits of hartshorn, is also a solution of a gas in water; it possesses a well known pungent odor, acts as a caustic on the skin, and changes blue vegetable infusions to green. If drops of each of these liquids be spread with a feather on the bottoms of two glass vessels, the gases will escape from the water and rise. Now invert one of the vessels over the other, placing their mouths together, and they will both become filled with dense white vapor. After standing in the cold for a time, the vapor will condense on the sides of the vessel, forming a white crust, which has none of the characteristics of either of the two constituents, and which, though solid, is composed of two gases; this is the common sal ammoniac, or *muriate of ammonia*.

Exp. 2nd. Pour diluted *nitric acid*, or aqua-fortis, on some fragments of copper, a violent action, attended with much heat, will take place, suffocating red fumes will rise,* and, at last, there will remain a *bright blue liquid*, which is a solution of *nitrate of copper*, and contains both of the materials used.

Exp. 3d. Pour *nitric acid*, slightly diluted, on powdered tin. As in the last experiment, red fumes will be given off, and the tin will be converted into a white powder, which is a compound of oxygen and tin, *oxide of tin*.

Exp. 4th. Pour strong *sulphuric acid*, into a strong solution of Hydro Chlorate of lime. The two transparent liquids will be converted almost instantly, with great evolution of heat, into a white solid, the *sulphate of lime*.

* These fumes are very poisonous, if inhaled by breathing, and should be avoided.

190. Definition of Affinity, its cause &c. Different kinds of affinity.

191. Simple affinity.

192. Experiments to illustrate simple affinity.

Exp. 5th. Caustic soda is very acrid to the taste, and blisters the tongue. Dissolve some of this in Hydro-Chloric acid and boil to dryness; and the result is common salt, Hydro-Chlorate of soda.

193. A complete change of properties results from the chemical union of bodies; affecting their color, taste, odor and temperature; causing them to pass from the solid, to the liquid or gaseous state, and *vice versa*; and producing as great an alteration of their chemical, as of their physical characters; so that we find it is impossible to judge beforehand, from the properties of two bodies, what will be the character of the compound they may form.

194. In most instances of chemical action, the temperature is altered. Sometimes, as in a case where the action is attended with the liquefaction of a solid, or the vaporization of a liquid, the temperature falls. But, in most cases, an elevation of temperature takes place, as is exemplified in the foregoing experiments 2nd, 3d and 4th, and in the following;—

Exp. Mix a portion of strong sulphuric acid, with one fourth of its weight of water; the liquid will become heated above the boiling point of water. In this, and many similar instances, the rise of temperature is attributable to a condensation and consequent diminution of volume, in the course of which some of the caloric of expansion is given off, and accordingly the above mixture will be found to measure less than the two liquids did before mixing them.

195. Change of properties affords a criterion by which it may generally be known whether chemical combination, or a mere mechanical mixture has taken place.

There are a few cases in which the properties of one of the constituents are apparent in the compound. For example, the mixture of sulphuric acid and water, (see § 194,) still exhibits all the properties of sulphuric acid and will continue to do so, even when very largely diluted with water; yet there can be no doubt that a chemical union exists between its two ingredients.

Again, if common salt be put into water, it will begin to dissolve, and will in a short time, disappear entirely. The disappearance of the salt, is owing to its uniting chemically with the water, yet every drop of the liquid exhibits the properties of salt. In these cases, the combining energy of the bodies concerned is but small, and their union can be overcome by means proportionably simple.

196. It is an important law of affinity, that a substance is very differently attracted by other substances; so, that, though

193. General truths established by the preceding experiments.

194. Temperature affected by chemical action.

195. What fact is supposed to be proved by this change of properties? Cases in which this change does not take place.

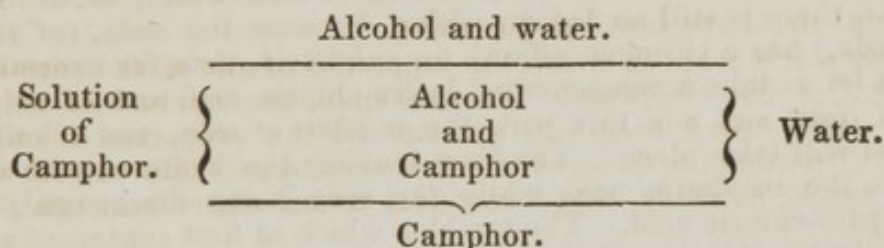
196. Different degrees of affinity.

it may have a very strong affinity for one, it will have a very weak one for another ; and in some cases, there may be no affinity whatever, between two bodies ; thus chalk and water may remain together for any length of time, without combining. Sometimes, in such cases, the union may be effected by the intervention of a third body, which may form, with one of the first, a compound capable of uniting with the other. For example, flint will not dissolve in water ; but if it be mixed with *carbonate of potassa*, and heated to redness in a crucible, a compound is formed which dissolves, readily, in water.

197. *Single Elective Affinity.* In elective affinity, there is an *election* or choice, and, of course, an *exclusion*. If we present to a compound, a substance which has for one of its constituents a greater affinity than they have for each other, the old compound will be broken up, and a new one formed, leaving one of the constituents of the old compound disengaged ; thus, *baryta* has an affinity for hydro-chloric acid, and forms with it hydro-chlorate of *baryta* ; if, into its solution, *sulphuric* acid be poured, a white powder will fall to the bottom of the vessel. This is *sulphate of baryta* ; the compound having been formed, because *baryta* has a greater affinity for sulphuric, than for hydro-chloric acid.

Exp. 1st. Camphor combines with alcohol, and forms a transparent solution ; but on adding water, for which the alcohol has a greater affinity than for camphor, the latter is precipitated in the form of white scales.

The following diagram illustrates this change :



The compound solution of camphor is represented at the left of the diagram. The interior of the figure, shows the constituent principles, (alcohol and camphor,) and at the right is the substance added, (water,) to produce a decomposition. Above and below are the results of this decomposition. The lower horizontal line is turned downwards in the center, to designate that the camphor is precipitated ; while the upper line, being straight, shows that the new compound, water and alcohol, remains in solution.

Exp. 2nd. If sulphuric acid be added to carbonate of lime, sulphate of lime will be precipitated, and carbonic acid disengaged in the form of gas.

198. Precipitation is of great use in Chemistry, separating solids from solutions in which they may be held, and reducing the molecules of a body

197. What is implied by the term elective affinity ? Example. *Exp. 1st.* *Exp. 2nd.*

198. Precipitates.

to a state of separation, which cannot be attained by any mechanical division. Thus, *precipitates* possess their medical activity. They are also in a state favorable for entering into new combinations. For example, *silex* pulverized as fine as possible, may be boiled with liquid *potassa* without dissolving; but when *silex* is precipitated from a chemical solution, it not only dissolves, readily, in solution of *potassa*, but yields to the action of some of the acids.

199. *Double Elective, or Complex Affinity* takes place when two compound bodies, on being brought together, exchange their bases, and form new combinations.

We will now compare the three kinds of chemical affinity:

1st. Let the simple substance, A, be presented to the simple substance, B, if there is an affinity, they will combine and form a new compound; this is a case of simple affinity.

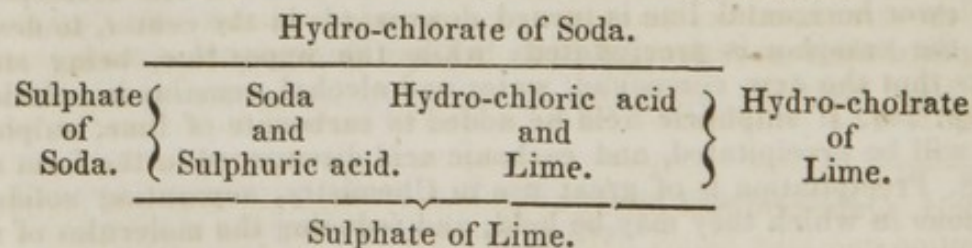
2nd. Let a simple substance, A, be presented to a compound one B C, and if A, have a stronger affinity for B than C has, the compound, B C, will be decomposed, and a new compound, A B, will be formed; this is a case of single elective affinity.

3d. If a compound, A B, be presented to another compound, C D, the old compounds may be broken up, and A, uniting with D, leaves B, to unite with C, forming the two new compounds, A C, and D B; this is a case of double elective affinity.

In single elective affinity, *three substances* are present, and *two affinities* in action; while in complex affinity, *four substances* are present, and *four affinities* in action.

200. *Exp.* Add to lime water a solution of *sulphate of soda*; there is no decomposition, because the sulphuric acid of the sulphate, has a stronger affinity for soda, than for lime. If, instead of lime-water, we use *Hydro-chloric acid*, there is still no decomposition, because the soda, (of the sulphate of soda,) has a stronger affinity for sulphuric, than for hydro-chloric acid. But let us take a compound of hydro-chloric acid and lime, (hydro-chlorate of *lime*) and mix this with the *sulphate of soda*, and a double decomposition will take place. The lime leaving the hydro-chloric acid, is attracted to the sulphuric acid, while the soda being disengaged, unites with the hydro-chloric acid. The tumbler which at first contained a liquid mixture of hydro-chlorate of lime, and sulphate of soda, now contains a solid precipitate, which is the *sulphate of lime*, (plaster of Paris,) over this solid stands a solution of hydro-chlorate of *soda*, or common salt, which is at once recognised by its taste.

This experiment may be illustrated by the following diagram.



199. When Double Elective Affinity takes place. Examples of the three kinds of affinity.

200. *Exp.* To shew the effects of complex affinity.

The original compounds appear on the right and left, without the brackets, while their constituent principles are near them, within the brackets. The new products are above and below the horizontal lines. The upper line being straight, indicates that the muriate of soda remains in solution, and the dip of the lower line, indicates that the sulphate of lime is *precipitated*.

201. We here perceive a conflict of two series of attractions: 1st, those which tend to preserve the original compounds, and 2nd, those which tend to destroy those compounds, and to form new ones; the former are termed *quiescent affinities*, the latter *divellent affinities*. Double decomposition can take place, only when the divellent affinities are greater than the quiescent. Taking for example, the substances used in our last experiment, the affinities may be stated in numbers, thus.

The attraction of lime for muriatic acid,	.	.	.	.	.	42
Of soda for sulphuric acid,	.	.	.	.	.	78
Quiescent affinities,	.	.	.	.	.	120
Attraction of soda for muriatic acid,	.	.	.	.	.	52
Of lime for sulphuric acid,	.	.	.	.	.	71
Divellent affinities,	.	.	.	.	.	123

The original compounds are then held together by a force equal to 120, while the force which tends to draw these apart, and to form new compounds, is equivalent to 123, the latter, therefore, or the divellent affinity being the greater, overcomes the former or the quiescent affinity.

202. Bergmann, of Sweden, first taught the doctrine of *elective* attraction. So much was he delighted with this wonderful law of nature, that he seemed not to observe how much affinity is modified by peculiar circumstances. Succeeding Chemists following his steps, seemed also to consider affinity as absolute and independent in its operations. Berthollet, a French Chemist of the present age, advanced some new opinions upon this subject. He considered affinity as a mode of attraction, differing from gravitation only, in the subject upon which it operates, and that, in this respect, there is no real distinction between Chemistry and Natural Philosophy. Thus, according to the principles of Newton, the quantity of matter, must have an influence upon combination; and it is, therefore, by Berthollet, laid down as an axiom, that "affinity, is manifested by quantity of matter, or that the chemical action of a body, is exerted in the ratio of its affinity, and quantity of matter." It follows from this doctrine, that quantity of matter may compensate for feebleness of affinity. Its supporters, not content with showing, what every Chemist must admit, that chemical action is, *in a degree*, influenced by *quantity of matter*, &c., endeavored to prove that there is, in fact, no such law in nature as affinity; but that decompositions are caused by the circumstances that merely go to modify affinity. Sir Humphrey Davy opposed the innovations, of Berthollet, and showed that in many respects, his doctrine was false.

203. The enlightened Chemist unites himself to no leader, to take for

201. Quiescent and divellent affinities. In what case only double decomposition can take place. How illustrated by the last experiment?

202. Errors of Bergmann and others with respect to the unlimited power of elective attraction.

203. *Dangers of allowing prejudice to affect the mind in search of scientific truth.*

granted all his opinions, and reject all which he does not approve. Even the young student, whose mind is unclouded by prejudice, is more likely to form correct opinions, upon the phenomena of nature, than that partial philosopher who has so long contemplated an object in one particular light, that he can see it in no other; or, who, delighted with some discovery of his own, regards the whole fabric of science of less magnitude, than the one atom which he has added to it.

204. *Causes which modify Chemical Affinity.* Chemical affinity is so governed by fixed and immutable laws, that under *the same circumstances*, its effects will always be uniform, and although disturbing causes do often influence its operation, and modify its results, yet this no more disproves the existence of those laws, than the fact, that a body does not fall to the earth when suspended by a cord, disproves the existence of the laws of gravity. In either case, the force of attraction is all the time acting, but is counteracted by opposing forces. Indeed, we are acquainted with most of the disturbing causes, and with their mode of acting; and, in many cases, are able, from this knowledge, to predict what will be the variation from ordinary results.

205. The most important of the causes which modify affinity, are, *cohesion, elasticity, quantity of matter, gravity* and the *action of the imponderables*.

206. *Cohesion* forbids freedom of motion among the particles, and prevents them from coming into that contiguity which is essential to chemical action. Two substances in the solid state, seldom act on each other, although they may have a strong tendency to do so. The most favorable state for combination, is the liquid one; the particles have perfect freedom of motion, and if they do not combine, when in this condition, it is fairly inferred, that they have no affinity for each other. Caloric is frequently used to overcome cohesion, and to bring bodies into the liquid state, by *fusing* them.

207. When a solid disappears in a liquid, without disturbing its transparency, it is said to *dissolve*; the body which disappears is said to be *soluble*; the liquid is called a *solvent*; the act of dissolving is called *solution*; the liquid containing the dissolved body, is also called a *solution*. When the body dissolved has changed its nature, and cannot be obtained in its original state by evaporation, it is said to be in a state of *dissolution*;

204. How far the laws of chemical affinity are fixed. The existence of these laws not disproved by a variation under peculiar circumstances.

205. Some of the causes which modify affinity.

206. Effect of cohesion upon chemical affinity. State most favorable for combination. Modes of overcoming cohesion, for purposes of chemical combination.

207. Solution. Difference between a solution and a dissolution.

thus, *mercury* dissolves in *nitric acid*, but when the fluid particles are evaporated, we do not obtain mercury again, but the *nitrate of mercury*. The combination of the mercury and nitric acid, is an example of strong chemical affinity, the nitrate of mercury having no resemblance to either of its constituent parts. On the contrary, after evaporating a *solution* of common salt, we have the same substance as we dissolved.

208. A *solution*, though transparent, need not necessarily be colorless. For example, blue vitriol gives a blue solution, which is yet transparent; but the color of ink is occasioned by very minute particles of black, solid matter, *mechanically suspended*, not dissolved in the liquid.

Exp. Add to common ink, some drops of *nitric acid*; the ink becomes colorless; add a little potash in solution, and the ink is again black. This experiment may be thus explained:—the coloring principle of the ink, which is a combination of *gallic acid* and *iron*, called the *gallate of iron*, is mechanically suspended in the liquid. When nitric acid is introduced, the iron having a greater affinity for it than for gallic acid, combines with it, forming *nitrate of iron*, and the coloring principle being now decomposed, the liquid is no longer black. On adding potash, the nitric acid withdraws itself from the iron and unites with the potash. The iron being now left disengaged, returns to the gallic acid, and the coloring principle, *gallate of iron*, manifests its existence by the blackness of the liquid in which it is suspended.

209. The property of dissolving, called *solubility*, is possessed by some bodies, in a much greater degree than by others. A body may be soluble in one *menstruum*,* and not in another; almost any liquid, may for some particular purposes, be used as a solvent, but the most common solvents are water and alcohol.

210. When a soluble body is put into its *menstruum*, it goes on dissolving, till a certain quantity has disappeared, after which the liquid can dissolve no more of the same body; it is then said to be saturated, and the *solution* so obtained, is a *saturated solution*. A solution saturated with one body, may still dissolve another.

The point of saturation of the same solid and solvent, varies with the temperature; in general, the quantity dissolved is increased by raising the temperature.

211. Some bodies, of which common salt is an example, are no more soluble in hot, than in cold water; and there are a few, as lime, magnesia, &c., which are even less so.

* A *menstruum*, signifies a solvent.

208. The coloring principle in ink not in solution. Exp.

209. Different degrees of solubility.

210. A saturated solution. When saturation takes place. Effect of temperature in varying the point of saturation.

211. Some bodies not more soluble in hot, than cold water.

212. *Neutralization* is the mutual destruction, or change of properties, which sometimes takes place when two substances combine in certain proportions.

213. It might be supposed that the solubilities of different bodies, were in direct proportion to their affinities for the solvent; but this is not the case. Two bodies of equal affinities for water, may be differently affected by cohesion; and, as cohesion is an obstacle to the operation of affinity, that will be least soluble which has most cohesion. The boiling point of a saturated solution is at present the standard of comparison; for as the affinity of the dissolved body for the solvent, must necessarily oppose the escape of the latter in vapor, the boiling point will be higher as the affinity is greater. Accordingly, all saline solutions boil with more difficulty than the solvent alone. Sea water, for instance, has a higher boiling point than fresh water; but, by boiling it in distillatory vessels, the water may be collected in a pure state, and the salts will be left behind in the vessel.

214. Bodies in solution, may, generally, be obtained again in the solid state, by evaporating the solvent; for the volatility of the latter and the cohesive attraction of the dissolved body, are more than sufficient to counteract affinity.

Evaporation is usually performed in open, shallow vessels, placed over a sand bath and kept moderately warm. When the operation is slowly, and uniformly conducted, the solid usually separates in the form of regular, geometrical figures called *crystals*. The process of the formation is called *crystalization*. When the evaporation has been carried far enough for crystalization to take place, the fact may be known by the solution becoming covered with a film or pellicle. Another test, is, to place a few drops of the solution on the cold surface of glass or some other polished substance, if, in such case, a solid is deposited the point of crystalization has been reached. The evaporating vessel should then be removed, and set aside in some secure, dry place to cool.

215. The cohesion of insoluble bodies, may be overcome by *fusion* and *vaporizing*; thus, brimstone, on being subjected to heat, passes first into a state of vapor, and then condenses into the *flour of sulphur*, which, when examined with a microscope is found to consist of small, crystalline grains. Bismuth and some other metals may be crystalized in the same manner.

216. In opposing caloric to cohesion, in order to promote affinity we must not go so far as to bring bodies into the state of vapor; for then their *elasticity*, will tend to remove the particles from the sphere of their action upon each other. Sometimes indeed, two gases or vapors unite; but the æriform state is generally unfavorable to combination; indeed, a compound of a fixed and a volatile body may be generally decomposed by heat, which increases the elasticity of the latter, as, when limestone, (*carbonate of lime*,) is heated strongly, the gaseous, carbonic acid flies off, and quicklime remains. Strong pressure, by bringing the particles nearer to each other, sometimes causes two gaseous bodies to unite. When one of the gases to be combined is inflammable, the union may be effected by setting fire to the mixture, or by

212. Neutralization.

213. Solubility not always in proportion to affinity. Effect of cohesion with respect to solubility.

214. Evaporation. Formation of crystals. Effect of a rapid evaporation upon the crystals. Various crystalline forms.

215. How may the cohesion of insoluble bodies be destroyed?

216. Effect of the elasticity of vapors.

the electric spark; in these cases, there is commonly a violent explosion, and it should only be done in strong vessels.

217. *Experiment to show the effects of cohesion and elasticity on Chemical Affinity.*

Heat, as we have seen, (§ 216,) decomposes carbonate of lime; but no degree of heat has yet been able to decompose carbonate of potassa; this circumstance would lead us to infer, that the affinity of potassa for carbonic acid is greater than that of lime; but,

Exp. 1st. If limewater, (*solution of lime*,) be poured into solution of carbonate of potassa, the insoluble carbonate of lime will fall as a white precipitate, and the potassa will remain in solution. This would seem to show that the affinity of lime for carbonic acid, is greater than that of potassa. But, in this case, it is supposed that the cohesion of the carbonate of lime, co-operating with the affinity of lime for the gaseous carbonic acid, effects the decomposition in opposition to the real order of affinities.

Exp. 2nd. If solutions of hydro-chlorate of lime and carbonate of ammonia be mixed, there will be a double decomposition; carbonate of lime will be precipitated, and hydro-chlorate of ammonia will remain in solution.

Exp. 3d. Mix hydro-chlorate of ammonia and carbonate of lime in the solid and dry state, place the mixture in a long necked vessel, and apply heat to it, the decomposition will now be the reverse of that which takes place in the preceding experiment. Carbonate of ammonia will rise in vapor, and be condensed in the cool part of the apparatus, while hydro-chlorate of lime will remain in mass at the bottom.

Each of the acids used in the last two experiments, has affinities for both the lime and the ammonia; the preponderance of one pair of those affinities over the other pair, is determined, in Ex. 2, by the cohesion of the carbonate of lime, and in Ex. 3, by the volatility of the carbonate of ammonia. Generally, when the affinity would admit of the formation of several modes of arrangement, one of which would produce an insoluble compound, (as the carbonate of lime for example,) that compound would be formed in preference to the rest, provided the materials are used in solution. But if the materials be in the dry state, and the operation be performed with the aid of heat, elasticity will determine the formation of a volatile compound, if such an one be among those which the substances present are capable of producing.

218. In respect to quantity of matter as modifying affinity, it may be remarked that there are some cases where the use of a large excess of one substance, enables us to decompose another contrary to the established order of affinities; the decomposition, however, is seldom complete.

219. Gravity sometimes interferes with chemical union, by causing the heavier body to sink, and thus be removed out of the sphere of the other's

217. Circumstance which shows the affinity of potassa for carbonic acid, to be greater than that of lime for the same acid.

Experiment showing that cohesion, combining with a weaker affinity may effect decomposition.

Substances which result from the mixture of solutions of muriate of lime and carbonate of ammonia.

Effect of mixing dry muriate of ammonia and carbonate of lime. Explanation of the changes which take place in experiments 2d and 3d.

218. Effects of using a large excess of one substance in producing decomposition.

219. Effects of gravity on chemical action.

action. The effects of gravity are illustrated, in the fusing together of two metals of different specific weights; the alloy being cast into an ingot, different portions of it will be found to be unlike in composition; the part which was lowest in the mould, will contain a greater proportion of the heavier metal than the other end. The interference of gravity, is obviated by *agitation* and by stirring.

220. The effects of *heat* and *galvanism*, in producing decomposition have been noticed under the heads of the *imponderables*; we may farther observe, that the *electric spark* sometimes decomposes a compound gas through which it passes, and sometimes causes the union of two gases; in the latter case, there is usually an explosion. These effects are commonly attributed to the heat of the electric fluid.

LAWS OF CHEMICAL COMBINATION.

221. *Some substances* unite in *indefinite* proportions, as when we mix water and alcohol, water and sulphuric acid &c.; though but a drop of one be mixed with a very large quantity of the other, every drop of the resulting mixture will contain proportions of both.

In such mixtures, there is, at first, an evolution of heat, sometimes, (as in the case of sulphuric acid and water,) very considerable: and when the mixture has become cool, its bulk will be less than that of the two liquids before mingling them.

222. *Another set of bodies*, unite in all proportions up to a *certain point*, beyond which no combination takes place. Examples of this, are the solutions of salts in water, alcohol, &c., when any quantity of the salt not greater than that necessary to saturate the solvent, will be dissolved.

In compounds of these two kinds, the affinities of the components are comparatively feeble; neutralization does not take place, for the properties of all the substances concerned are quite apparent; and the combination is destroyed by comparatively feeble means, as evaporation and the like. But these kinds of compounds are highly useful and important, as by their means we are enabled to present bodies to each other, under the circumstances most favorable to action.

223. There is a *third* class of combinations, far more numerous as well as interesting, than the other two. *They are those in which the proportions of the constituents are regulated by certain fixed and invariable laws.* In such compounds, the affinities of the elements are more energetic, than in the two former classes; the number of combining proportions of the same bodies is small, never, so far as is yet known, exceeding *six*; and the elements *neutralize* each other.

220. Effects of the imponderables, especially the electric spark, in producing decomposition and combination.

221. Bodies which unite in indefinite proportions.

222. Bodies which unite in indefinite proportions up to a certain point.

223. Combinations where the proportions are always definite.

224. 1st. *Law of combination.* Certain bodies combine in only one proportion. Thus chlorine and hydrogen, unite in the proportions of 36 parts, by weight, of the former, to 1 of the latter, and there is no method known of bringing them into combination, in any other proportions; for if we mix 36 parts of chlorine gas, with 2 parts of hydrogen, there will, always, be 1 part of hydrogen remaining uncombined; or if we mix 72 parts of chlorine and 1 of hydrogen, only the proportions first stated will combine, the additional 36 parts of chlorine remaining in a separate state.

225. 2nd. *Law of combination.* When any two elements combine in more than one proportion, the larger quantities of one are multiples by 2, 3, 4, or 5, of the smallest quantity of the other. Oxygen and hydrogen, form two compounds with each other; the first is

Water, composed of hydrogen 1 part + oxygen 8 parts

Deutoxide (or binoxide of hydrogen) 1 " + " 16 "

Nitrogen and oxygen unite in five different proportions, forming compounds whose names and composition are as follows:

Name.	Parts of Nitrogen.	Parts of Oxygen.
Protoxide of Nitrogen, contains	14 for every	$8=8\times 1$
Deutoxide of " "	14 "	$16=8\times 2$
Hypo-nitrous acid	14 "	$24=8\times 3$
Nitrous acid	14 "	$32=8\times 4$
Nitric acid	14 "	$40=8\times 5$

No other compounds of the above elements are known: and if oxygen and nitrogen be mixed in any other proportions, one or more of the above named bodies, would be the result, but no intermediate compound.

226. To the second law of multiples, there are a few apparent exceptions; thus iron and oxygen combine in two proportions, which are 28 parts of iron to 8 oxygen, and 28 iron to 12 oxygen: the first quantity of oxygen being to the second as 1 to 1 1-2.

Lead has three oxides, of which the composition is,

Protoxide	Lead 104	Oxygen $8=8\times 1$
Deutoxide	104	$12=8\times 1\ 1-2$
Peroxide	104	$16=8\times 2$

But examples of this kind, are not sufficiently numerous to overthrow the general rule; and they can all be explained by the following hypotheses;

1st. We may suppose that the apparent anomaly, results from our not being acquainted with all the combinations of the same two bodies. Thus, if we should hereafter discover the existence of a compound containing 28 parts of iron to 4 of oxygen the oxides of iron would then accord with the law of multiples, viz.,

224. 1st. Law of combination.

225. 2nd. Law of combination or law of multiples. The law of multiples illustrated in the compounds of nitrogen and oxygen.

226. Apparent exceptions to the law of multiples. Suppositions on which the apparent anomalies in chemical combinations may be explained.

	Iron.	Oxygen.
1st, oxide	28 (this is the supposed oxide.)	$4=4\times 1$
2nd, "	28	$8=4\times 2$
3d, "	28	$12=4\times 3$

The same reasoning would apply to the oxides of lead, and to other like cases; and it is in accordance with facts which have already been discovered.

2nd. We may suppose the anomalous compound to be formed, not by the *direct combination* of the two elementary substances, but by the union of two or more of the *other compounds* of those elements. Thus the first and last oxide of lead, might combine as follows,

	Lead.	Oxygen.
Protoxide	104	8
Peroxide	104	16
producing a compound	208	24

where the lead and oxygen are in the exact ratio of 104 to 12, that is, in the same ratio as in the compound now called *deutoxide* of lead. This latter may be, therefore, not a distinct oxide, but a compound of two oxides; which in that case would not furnish an exception to the law of multiples. This mode of explanation not only applies to *exceptions* in the third class of combination, (see § 223,) but to the whole of the first and second classes; where the apparent great diversity of proportions, *may* be occasioned merely by the combinations of five or six definite compounds.

227. 3d. *Law of combination.* The quantities of two bodies which respectively combine with a given quantity of a third body, are the precise quantities in which the first two combine with each other; and these are also, the quantities in which they would unite with a fourth body. Thus 36 parts of *chlorine* combine with 8 of *oxygen*, to form *protoxide of chlorine*; and 36 parts of *chlorine* combine with 1 of *hydrogen*, to form *muriatic acid* (called *hydro-chloric acid*); now 8 of *oxygen* and 1 of *hydrogen* are precisely the proportions of those two bodies necessary for their combining to form water.

228. Bodies that unite according to *proportional numbers*, and the numbers expressing the combining proportions, are called *proportionals, or equivalents*.

229. By analyzing several compounds of a particular body, and reducing the numbers expressing the proportions of the constituents to their lowest terms, the combining proportions, or equivalent of that body is established. And if we do this for a great number of different substances, referring, always, the number determined to some particular standard, a scale of chem-

227. 3d. Law of combination.

228. Proportionals and Equivalents. Different senses in which the word equivalent is used.

229. How may the combining proportions of a body be ascertained? Scale of chemical Equivalents, how established? What substance is taken as the standard of unity in the scale of equivalents most commonly used, and what are the combining numbers of some simple bodies in relation to this standard?

ical equivalents is determined, which greatly facilitates the operations of the laboratory. Such a scale has been established by Chemists. It is of no importance what number is taken as the basis of the scale, nor what substance is the standard of unity, provided the *proportions* be duly observed. In the scale most in use, *hydrogen* is taken as 1, and consequently,

Oxygen is	8
Sulphur	16
Chlorine	36
Nitrogen	14
Potassium	40
Sodium	24*

230. The operation of the laws of combination is not confined to the simple substances, but has an equal influence over compound bodies. Thus 40 parts of sulphuric acid, which neutralize 48 parts of potassa, combine with 32 parts of soda: the same acid combines with potassa and with soda in other proportions, namely, 80 ($=2 \times 40$) to 48 and 80 to 32: so that the law of multiples, (see § 225,) likewise governs these combinations. The third law is equally uniform, (§ 227,) for the 48 of potassa and 32 of soda, which are equivalent to 40 of sulphuric acid, will also neutralize 54 of nitric acid, 37 of muriatic acid, &c.

231. The *equivalents* of compound bodies are found by taking the sum of those of their constituents; thus, *sulphuric acid*, containing 1 equivalent of *sulphur*, 16, and 3 of *oxygen*, (3 times $8=24$,) is 40; nitric acid consists of 1 equivalent of nitrogen, 14, and 5 of oxygen, (5 times $8=40$,) and its equivalent is 54.

232. From the difference of the *combining proportions* of the acids and alkalies, it follows that their *neutralizing powers* must differ; for it is evident that the greater this power, the smaller must be the quantity necessary to produce the effect. Thus the neutralizing power of soda is greater than that of potassa, in the inverse ratio of 48, the combining number of the latter, to 32, the equivalent of the former.

233. So well established are the laws of combination, and so sure is their operation, that it is very often possible to calculate the composition of a

* In Dr. Thomson's scale of chemical equivalents, oxygen is employed as the basis and is assumed at 1, and therefore hydrogen must be $1/8$ or $1/25$, sulphur 2, chlorine $4\frac{1}{2}$, &c. Dr. Wollaston, in his scale, calls oxygen 10, Berzelius takes it at 100; but in all these scales the same proportions are observed. The system of numbers which makes hydrogen the unit or 1 is generally preferred, as containing small numbers and few fractions.

230. Compound bodies influenced by the laws of combination, and the law of multiples.

231. How are the combining numbers of compound bodies found?

232. Ratio of the neutralizing powers and combining proportions of acids and alkalies.

233. What fact would lead to suspect an error in analysis?

body before it is analyzed. And if the result of an analysis is at variance with these laws, it is a sufficient reason for suspecting error in the operation, and for repeating our experiments.

234. The discovery of these laws of combinations, is justly considered as one of the most important events in the history of Chemistry. It has rescued the science from a chaos of confusion, and established it on the basis of certainty and demonstration. For this discovery, science is indebted to the genius and industry of Mr. John Dalton of England.

Atomic Theory.

235. Before proceeding to treat of the theoretical explanation of the laws of combination, and the *atomic theory*, it will be necessary to caution the learner against confounding the one with the other. The *theory of Atoms* is founded on *supposition*: and however strong may be the arguments by which it is supported, it may possibly be, hereafter overthrown. Not so with the laws of combination. The proof of *their* existence is founded on multitudes of experiments, and is wholly free from speculation; whether the *atomic theory*, therefore, be admitted or denied, the doctrine of laws of combination remains unshaken.

236. This ingenious hypothesis was published by Mr. Dalton, to explain and account for the laws of combination which he discovered. This it does, on the assumption that *all matter is composed of certain minute indivisible particles, aggregated by attraction; that the particles of the same kind of matter have the same form, size and weight: and that they are inconceivably smaller than any division of matter, which can be obtained by mechanical operations.* The word *atom*, implying a thing so small that it cannot be further cut or divided, is frequently used to designate these supposed indivisible particles. The term *molecule*, is sometimes used in the same sense.

237. This theory being granted, the laws of combination, which seem inexplicable on any other ground, would follow of course. For since chemical combination would take place between the atoms; as, for instance, if a particle of water consists of one atom of oxygen, and one atom of hydrogen, and the former atom weighs eight times as much as the latter, it is clear that *any quantity* of water must contain these bodies in the ratio of 8 to 1. Again, since no addition could be made of either constituent in a less quantity than an atom; that is, if A and B form any other compound than A B, it must be 1 A to 2 B, 1 A to 3 B, &c., or 2 A to 1 B, 3 A to 1 B, &c. Thus one atom of oxygen to one atom of hydrogen, constitutes a particle of water, or *protoxide of hydrogen*, and two atoms of oxygen to one of hydrogen compose a particle of *deutoxide of hydrogen*; and as the oxygen is to the hydrogen, in water, as 8 to 1; so in the deutoxide of hydrogen, the compounds *must be* in the ratio of 16 to 1. Thus the law of multiples, is a necessary consequence of the atomic constitution of matter; and this necessity is as peremptory in the case of compound particles, as in that of elementary atoms.

234. Discovery of the laws of combination.

235. Distinction between the Laws of combination and the atomic theory.

236. How did Mr. Dalton attempt to explain the laws of combination?

237. How does the atomic theory explain the laws of combination and of multiples?

238. The terms *Equivalents*, *combining proportions*, &c., of bodies, are therefore only other names for the weights of atoms in comparison with the particular body which is chosen as the *unit*.

239. Some years ago, it was a received axiom that matter is *infinitely divisible*, and the question remained at rest till revived by Mr. Dalton. The preponderance of proof seems, now, on the side of the atomic theory; and the laws of combination alone appear sufficient to establish it.*

The Volumic Theory.

240. A curious law was discovered in 1808, by Gay Lussac, which governs the proportions *by measure*, in which æriform bodies combine. It appears from his experiments, together with those of many other eminent Chemists, that when two gases or vapors, combine, it is in the ratio by *volume* of 1 to 1, 1 to 2, or some other simple ratio. Thus 1 *volume* of *oxygen* unites with two of *hydrogen* to form water; 1 *volume* of vapor of *sulphur* with 1 *volume* of *hydrogen* to form *sulphuretted hydrogen*, 1 *volume* of *nitrogen* and 3 *volumes* of *hydrogen*, form *ammoniacal gas*; 1 *volume* of *muriatic acid gas* and 1 *volume* of *ammonia*, constitute *muriate of ammonia*.

241. Further, from various considerations, it is inferred that the same law holds with regard to solid bodies which cannot be converted into vapors by the action of heat; so that when such bodies enter into gaseous combinations, their vapors are in a simple ratio with those of the other constituents. Thus, *carbonic acid* is composed of 1 *measure* of the vapor of *carbon* to 1 of *oxygen gas*.

242. Gaseous bodies sometimes undergo a condensation in combining, and sometimes not; but whenever a diminution of volume takes place, it likewise bears some definite and simple relation to the original bulk of the constituents, being one half, one third, &c. For example, no condensation takes place in the formation of *muriatic acid gas*, but one *volume* of *chlorine* and one of *hydrogen* form two *volumes* of the acid gas, on the other hand two *measures* of *ammoniacal gas* consist of one *measure* of *nitrogen* and three of *hydrogen*; so that here the two simple gases in uniting, are condensed to one half. Again two *measures* of *nitrogen* and one of *oxygen*, form one of *protoxide of nitrogen*; the condensation is, therefore, one third.

243. Another curious result seems to flow from these facts. Water is considered as a compound of *one atom* of each of its constituents; by experiment it is found that it contains *two measures* of *hydrogen* and one of *oxygen*. The *protoxide of nitrogen*, also consists of two *volumes* of *nitrogen*

* Dr. Wollaston advocated the Atomic Theory in a very able dissertation upon the "Finite extent of the atmosphere," published in England in the Philosophical Transactions for 1822; and Professor Mitscherlich has treated of the same subject in his lucid observations upon the connections between the form and composition of bodies.

238. By what terms are the weights of atoms designated?

239. The atomic theory not undisputed.

240. Law of volumes discovered by Gay Lussac. Explanation of this law.

241. Solids supposed to be subject to this law. Examples.

242. Condensation of gaseous bodies explained in reference to the volumic theory.

243. The volume of an atom of oxygen compared to the atoms of hydrogen and nitrogen.

and one of oxygen ; it contains, nevertheless, one atom of each. It therefore follows, that the atom of oxygen is but half as large as the atoms of nitrogen and hydrogen. There are several other bodies, whose combining proportions, like that of oxygen is represented by half a volume ; but for the greater part of substances, a *volume* and an *equivalent* are synonymous.

244. It is evident that the laws of combination by weight, and those which govern the proportion by volume must depend on the same circumstances, *the atomic constitution of matter*. There is, however, one striking distinction between them. The proportions by weight in which two bodies unite, have no very remarkable dependence on each other. For example, 6 parts of atoms of carbon and 8 of oxygen form carbonic oxide ; now 6 is not to 8 in any simple ratio. The proportions by weight exist between the different quantities of the *same* body that combine successively with a given quantity of another body. But by the law of volumes, not only is there the dependence just referred to, but also an evident relation between the bulks of the two substances.

244. On what must combinations by weight, and by volume depend ? Distinctions between the two cases.

END OF PART FIRST

PART II.

CHAPTER IX.

CHEMICAL CLASSIFICATIONS.—DIVISION OF PONDERABLES.—OXYGEN.

245. By chemical analysis ponderable bodies are reduced to their ultimate elements ; these are divided into,

1st. *Non-Metallic*,

2d. *Metallic*.

246. The *electro-chemical theory* furnishes a convenient system of classification. The *Non Metallic elements* are divided in *two classes*, according to their *electrical affinities* ; those which are attracted to the *positive pole*, possess the opposite or *negative* electricity, and are called *electro-negative*. Those which are attracted to the *negative pole*, possess the opposite or *positive* electricity, and are called *electro-positive*.

1st. Class.		2d. Class.	
Oxygen	} Electro Negative.	Hydrogen	} Electro Positive.
Chlorine		Nitrogen	
Bromine		Carbon	
Iodine		Boron	
Fluorine		Silicon	
		Phosphorus	
		Sulphur	
		Selenium.	

There are 42 *metals*, all of which are *electro-positive*.

247. The *Electro-negatives* combine with the *electro-positives* ; the former are called *supporters of combustion* ; the latter *combustibles*.

The *electro-negative* substances unite, also, with each other ; and, in this case, one of them is negative and the other positive. Such combinations, however, are extremely feeble, and their elements are, consequently, easily disunited ; but the facility of their decomposition causes them to act with great energy upon other bodies.

245. Division of elementary bodies.

246. System of classification. Division of *non-metallic* bodies. Number, and electrical character of the metals ?

247. Supporters of combustion and combustibles. *Combinations of the electro-negative substances with each other.*

OXYGEN.*

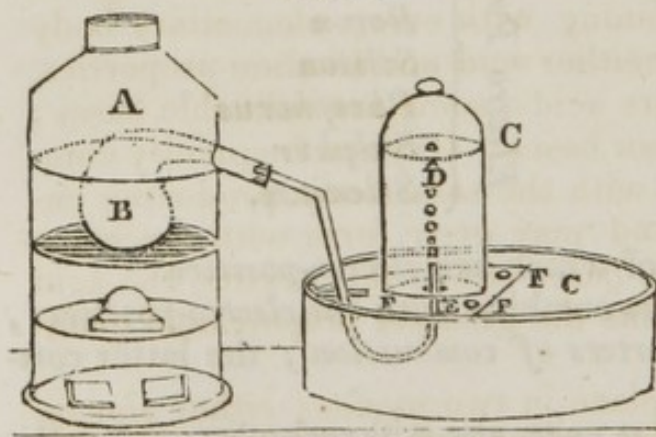
$$248. \text{Equiv.} \left\{ \begin{array}{l} \text{by vol. } 50 \\ \text{" weight } 8 \end{array} \right\} \quad \text{Sp. gr.} \left\{ \begin{array}{l} 1. \text{ Air}=1. \\ 16. \text{ Hyd.}=1. \end{array} \right.$$

The simplest form under which we are acquainted with *oxy*gen is, that of a gas: in which state, like all other gases, it is conceived to be a compound of a solid, ponderable basis, with caloric, and, perhaps, with light and electricity.

Oxygen was discovered by Dr. Priestly in 1774; a discovery which was the cause of very important changes in the state of chemical science. It has been called *dephlogisticated air*, *emphyreal air*, and *vital air*. Lavoisier gave it the name of Oxygen, supposing it to be the only acidifier in nature and it retains the name, though it is now known that there are some *acids which contain no oxygen*, and that many of the *oxides have no acid properties*.

249. *Mode of obtaining Oxygen Gas.* Most of the oxides are decomposed by red heat; and if the operation be performed in proper vessels, the expelled oxygen gas may be collected. Red Lead, which is the *deutoxide of lead*, yields oxygen when heated to redness in an iron retort; by this loss of oxygen it is reduced to a *protoxide*. Red oxide of mercury, treated in the same way, is resolved into oxygen and metallic mercury; *nitrate of potassa*, (nitre or salt-petre,) kept at a dull red heat in an iron or earthen retort, yields oxygen gas in considerable quantities. The residue is *hypo-nitrite of Potassa*. This mode is dangerous without a cautious regulation of the heat.

Fig. 46.



A, represents a furnace in which is placed the retort B, containing the substance which is to furnish the gas. C, is the *pneumatic cistern* (Fig. 46.) or water tube, D, the bell-glass receiver, E F, a shelf in the cistern on which the receiver being filled with water and inverted, is placed. The water in the cistern rises a few inches above the shelf, so that the water in the receiver is

supported by atmospheric pressure. The gas issuing from the retort passes through a bent tube, and is conducted by it under the shelf, into the mouth

* From the Greek *oxus*, acid, and *gennao*, to generate. The German Chemists call it *sauerstoff*, which, literally signifies sour stuff.

248. Equivalents and sp. gr. of oxygen. State in which we are acquainted with oxygen. Its discovery. Synonymes. The name founded in error.

249. Substances from which oxygen may be obtained. *Pneumatic cistern* &c. *Mode of obtaining oxygen*.

of the receiver, and being lighter than water, it rises in bubbles and displaces the water in the upper part. This process continues until all the water in the receiver has gradually disappeared, and the vessel is filled with oxygen gas.

250. The *black oxide of manganese*, when pulverized and heated in a retort, also furnishes oxygen gas. From the state of *peroxide*, it is thus reduced to that of *deutoxide*, losing about 128 cubic inches of oxygen for each ounce of the material. As this mineral often contains carbonate of lime which would introduce carbonic acid into the oxygen, it ought to be previously purified by digesting it with very dilute muriatic or nitric acid. The same oxide yields twice as much oxygen, if after being purified, it is made into a paste with sulphuric acid and heated in an earthen retort. In this case it is converted into protoxide of manganese, losing a whole equivalent of oxygen, instead of half a proportional as in the former case. The residue is *Sulphate of Protoxide of Manganese*: the sulphuric acid combining readily with this oxide of manganese, though it cannot with the deutoxide or peroxide.

251. A process, eligible in small operations, but too expensive for large ones, is to heat *chlorate of potassa* in a green glass retort.* A spirit lamp is the best source of heat for this experiment. The salt may be made to yield, for each 124 grains, 48 grains or 141 cubic inches of oxygen gas; and there will remain in the retort 76 grains of *chloride of potassium*. The gas thus obtained is absolutely pure. In all these processes the gas may be collected over water.

252. *Properties.* Oxygen gas is transparent and colorless; and the least powerful refractor of light among the gases. It is said to emit *light* as well as heat, when suddenly and strongly compressed. It is tasteless and inodorous, a non-conductor of electricity, and is only very sparingly absorbed by water. It is the most perfect *negative electric*, having extensive and energetic chemical affinities, and combining with every elementary body without exception. It has neither acid nor alkaline properties, but some of its compounds are acids, some are salifiable bases; and some are neither acids, nor bases. Oxygen frequently combines in several proportions, with the same body, producing entirely distinct compounds; and may even form with the same metal an acid, and a salifiable base—when this occurs, the acid is the compound which contains the greatest proportional quantity of oxygen.

253. *Oxidation* may take place in two modes; either *slowly*, in which case the progress of the chemical change is not perceptible; or *rapidly*, when heat and light are emitted, and the phe-

* Green glass is preferable, because without great care, the more fusible white glass would be melted.

250. Oxygen obtained from the black oxide of manganese.

251. Oxygen from chlorate of potassa.

252. Properties of oxygen. Its compounds.

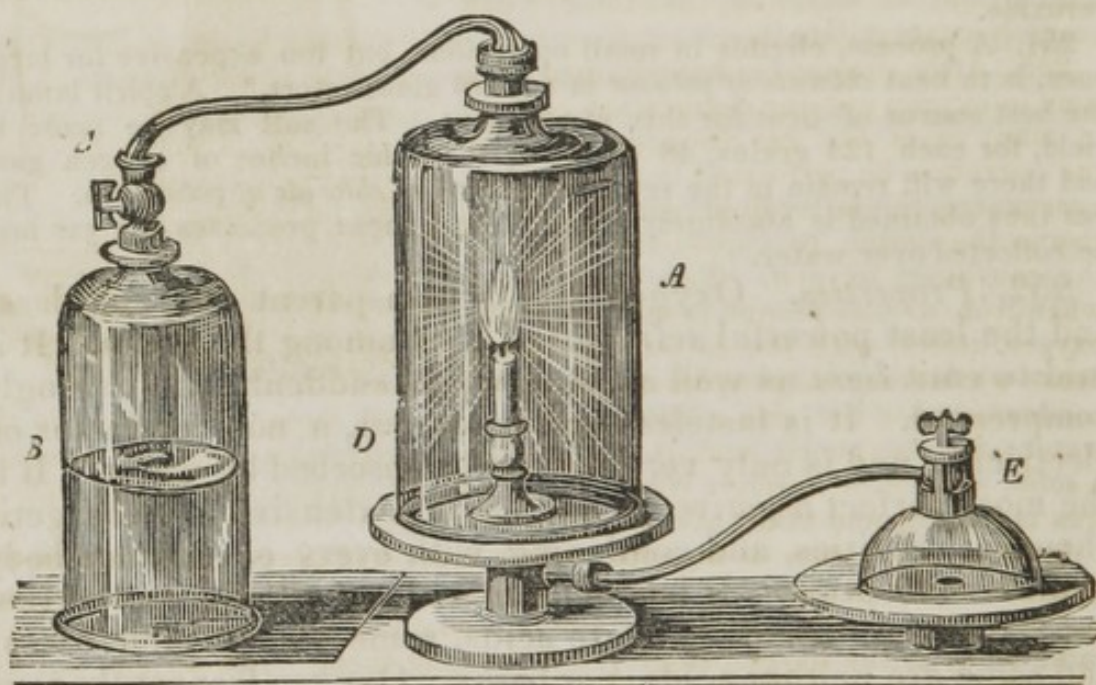
253. Two modes in which oxidation may take place. Rusting of metals. Combustion of wood, candles, &c.

nomena of combustion exhibited. Of the former, the gradual *rusting* of metals in the air, is an example; while the combustion of wood, candles, &c., is an instance of the latter.

254. It sometimes happens that a higher oxide of a particular body, is produced by rapid, rather than by slow oxidation; but, on the other hand, the same compound may be formed by either mode. Thus the brilliant sparks that fly from iron on a smith's forge, and those struck from steel by a flint, are iron burning in the oxygen of the air; and when cold these are found converted into the same oxide which is the basis of *iron rust*.

The oxygen of the air, is the sole cause of its supporting combustion; and, since this gas constitutes only $\frac{1}{5}$ part of the whole bulk of the atmosphere, it might be supposed that bodies which burn in air, would burn much more vividly in oxygen gas.

Fig. 47.



Exp. 1st. Let there be two bell glasses *A* and *B*, communicating with each other by a flexible leaden pipe, with a stop cock at *C*. Suppose *A* to be placed over a lighted candle on the plate *D*, which communicates with an air-pump plate as represented at *E*. It will be found that the candle will gradually burn dimly, and will at last go out, if no fresh supply be allowed to enter the bell-glass; if, on repeating the experiment, the air be withdrawn by means of the pump, the candle will be rapidly extinguished. It is therefore proved, that a candle will not burn in a vacuum, and that it can burn but for a short time in a small portion of atmospheric air.

Let the experiment be repeated with the following change. Let the air be exhausted from both vessels, the stop cock *C*, remaining open, until the bell *B*, is filled with water from the pneumatic cistern. The stop cock being closed, fill the bell glass with oxygen gas. Now introduce a candle under the bell *A*, then having placed the bell again on the plate of the air-pump, exhaust the air, until the candle is nearly extinguished, and then open

254. Effects of rapid and slow oxidation. Why the air is a supporter of combustion. Ex. 1st.

the stop cock so as to allow the oxygen from *B*, to enter. The candle will burn much more brilliantly, and for a longer time, than in the same portion of atmospheric air.

Exp. 2nd. A slip of pine wood of the size of a match, ignited at one end, but not flaming, will be kindled instantly into flame, on being immersed in oxygen gas.

Exp. 3d. A coil of fine iron wire, (Fig. 48.) burns in oxygen with beautiful scintillations. The wire must be tipped with sulphur, or some other combustible matter and ignited to commence the combustion. The globules of melted and burnt iron, if they fly against the bell glass, always break it; and they have even been known to perforate, and pass through it.

Exp. 4th. Phosphorus burns in oxygen, with a light so dazzling, that the eye can scarcely contemplate it.

255. After substances have burned for a time in oxygen gas, the combustion ceases; in many cases the gas disappears, and if the operation be performed in a bell glass over water, the latter fluid will be seen to rise in the vessel, to supply the place of the consumed oxygen. This is the case when iron or phosphorus is used; for the oxygen unites with the latter, producing dense white fumes of *phosphoric acid*, which condenses upon the side of the vessel as the acid cools, or dissolves in the water; for phosphoric acid, though it first appears as a vapor, is naturally a solid, soluble in water. When iron burns in oxygen, the black *oxide of iron* is formed, and takes at once the solid state.

In some cases there is no apparent diminution of oxygen gas, because the new compound is gaseous; thus sulphuric acid, and carbonic acid, produced respectively, by burning sulphur and charcoal in oxygen, are gases, of the same bulk, as the oxygen employed in forming them. But oxygen gas has nevertheless been consumed; for on examining the residual gas, it will be found to exhibit an entirely new set of properties, being in fact a new body, a compound of the combustibles with oxygen. Accordingly, no combustible will burn in it.

256. Oxygen was formerly supposed to be the only supporter of combustion; but, more recently, many other bodies are found to evolve light and heat, in combining with each other. This is particularly the case during the combustion of electro-positive

Fig. 48.



Exp. 2nd. Exp. 3d. Exp. 4th.

255. Why water will rise in the bell glass after oxygen has been consumed. Production of phosphoric acid. Formation of the oxide of iron. Why in some cases, there is no apparent diminution of oxygen gas. Production of sulphuric acid—of carbonic acid.

256. Oxygen not the only supporter of combustion. Terms supporters of combustion and combustibles, to what classes of bodies applied? Light and heat sometimes emitted by electro-positive bodies. The term combustion, how used at present?

with electro-negative bodies ; and the term, *supporters of combustion* has been applied to all the latter, as distinguishing them from the former, which are called *combustibles*. But light and heat are often emitted by two electro-positive bodies, while combining with each other, as in the case of iron and sulphur, and copper and sulphur ; so that the term *supporters of combustion*, can scarcely be regarded as proper, though, in accordance with custom, we may use it. The term *combustion*, also, is now used in a more enlarged sense than formerly, including not only, rapid oxidation, but *all other cases of chemical combination in which heat and light are eliminated*.

257. One of the first who attempted to explain the cause of combustion, was Stahl, a German. He supposed that a certain substance, which he called *phlogiston*, (from the Greek *phlogizo*, to burn,) formed a part of all combustible bodies, and that, in every case of combustion, this inflammable principle was disengaged. Now, as a metallic wire, after burning in oxygen gas, is heavier than before combustion, it follows, that instead of having parted with something in the process of combustion, it has actually gained in weight. Therefore, instead of giving out this imaginary phlogiston, it is found to have united with oxygen.

Lavoisier, finding that the new discovery of oxygen gas destroyed the phlogistic doctrine, published the theory that *oxygen is the only supporter of combustion*. On this supposition, he conceives that in all cases of combustion, the *solid base* of oxygen gas unites with the combustible body ; and that the light and heat of the oxygen, being thus set free, give rise to the phenomena of combustion ; from this theory it would follow, 1st, that the specific caloric of the new compound, is always less than the mean of those of the constituents. And, 2d, that all combustibles, in consuming the same quantity of oxygen gas, must give out the same quantity of light and heat. Now both of these conclusions are contrary to experience ; besides which, as before stated, the fundamental proposition, that oxygen is the only supporter of combustion, is likewise untrue. So that the theory of Lavoisier, is liable to serious objections. But, as Dr. Turner justly remarks, "It is easier to perceive the fallacy of one doctrine, than to substitute another that shall be faultless."

258. Substances which have been burned in oxygen, are no longer capable of combustion ; they are new bodies, having an entirely new set of properties. They have gained weight, and their increase is precisely equal to the oxygen consumed. Some bodies, on being heated after combustion, yield precisely the same quantity of oxygen which disappeared during the experiment, and thus return to their original condition.

259. *Respiration*. Oxygen is the only gas which supports respiration, and it is owing to the presence of this gas, that ani-

257. Stahl's theory of combustion. Lavoisier's theory.

258. Change in substances which have been burnt in oxygen.

259. Agency of oxygen gas in respiration. Exp. Showing the effect of oxygen upon the blood. How does oxygen affect the blood in respiration ? Arterial and venous blood. Change which takes place in the blood, in passing through the lungs.

mals can live in common air. Physiologists agree that its effect in supporting life, depends on its action upon the *blood*. If a portion of this fluid be drawn from a *vein*, it is perceived to have a dark color, approaching to black; put it into a bell glass filled with oxygen gas, and it will very soon become florid red; and the same change will ensue, though not quite so rapidly, if the blood be exposed to common air. The air in the jar being examined, is found to have lost oxygen, and to have acquired an equal bulk of carbonic acid.

This is precisely what takes place in respiration. The blood as it issues from the left cavity of the heart into the *arteries*, and is distributed by them through the system, is called *arterial blood*, and has the florid color. Having completed its circulation, it returns through the *veins*; and *here* it is found to have acquired a larger quantity of carbon, and become dark colored; in this state it is called *venous blood*. Before it goes again into circulation, it passes through the spongy organ, called the *lungs*; throughout which it is distributed in the countless microscopic tubes into which the veins have branched out, so as to expose the greatest possible surface. Here it comes in contact with the air with which the lungs have been inflated by the last inhalation; the excess of carbon in the blood combines with oxygen, and forms carbonic acid gas, which is exhaled with the nitrogen of the air; the blood thus purified and rendered fit for circulation, passes on through the appropriate vessels to the left cavity of the heart, and is again distributed through the system. The air which is exhaled, having exchanged oxygen for carbonic acid, is no longer fit for supporting combustion and respiration; and this is one of the reasons why *crowded* and *strongly illuminated* rooms, are unhealthy.

260. But although oxygen gas is the sole supporter of respiration, *it is too stimulating in its effects on the human system to be inhaled in an unmixed state*. If inhaled in any considerable quantity, it produces fatal inflammation of the lungs. It is supposed that warm climates are beneficial to consumptive persons, because the air being warmer, is less dense than in cold climates, and each inspiration, therefore, brings a smaller quantity of oxygen into contact with the lungs, which, in a debilitated state, are unable to bear the more oxygenated, and consequently more stimulating air, of a colder climate.

One cause of the unhealthy effect of breathing the air of crowded rooms.

260. Effect of breathing pure oxygen. Why persons with weak lungs require a warm climate.

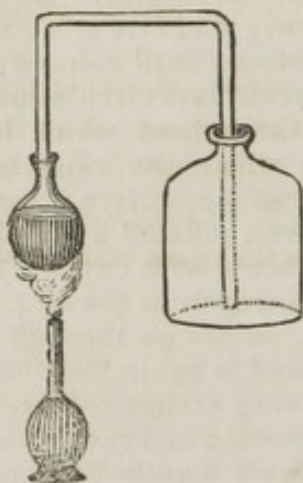
CHAPTER X.

CHLORINE.

$$261. \text{Equiv.} \left\{ \begin{array}{l} \text{by vol. } 100 \\ \text{" weight } 36 \end{array} \right\} \quad \text{Sp. gr.} \left\{ \begin{array}{l} 25. \text{ Air}=1. \\ 36. \text{ Hyd.}=1. \end{array} \right.$$

Chlorine gas was formerly called *Oxymuriatic acid*, from the belief that it was a compound of muriatic acid and oxygen. It was discovered by Scheele in 1774, who called it *dephlogisticated marine acid*.

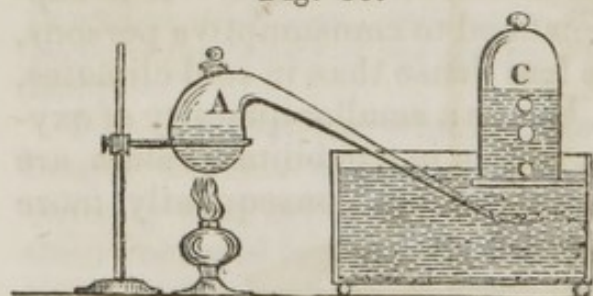
Fig. 49.



262. Chlorine gas may be obtained by mixing strong *muriatic or hydro-chloric acid* and *per-oxide* of manganese, and heating the mixture gently. An effervescence arises, owing to the escape of the gas, which may be collected in a bell glass (Fig. 49.) over *warm water*; or the gas may be made to pass through a tube bent twice at right angles, a leg of which passes into a glass bottle. The gas, by its superior gravity, displaces the atmospheric air; when the bottle is full, which is known by the green color of the gas, it should be carefully closed. In this process, a portion of the *hydro-chloric acid* is decomposed; its *hydrogen* combines with one atom of the *oxygen* of the manganese, and forms *water*, while the *chlorine* is disengaged.

Another process for obtaining Chlorine is used when very large quantities are required. It consists in heating in a retort, A, (Fig. 50,) three parts of common salt (*chloride of sodium*) and one of peroxide of manganese, thoroughly mixed, and two parts of sulphuric acid, diluted with its own weight

Fig. 50.



of water. The lamp being placed under the retort, the mixture heats gradually, the chlorine gas being driven off, passes through the beak of the retort under the inverted bell glass C, which is at first filled with water; as the gas rises, the water subsides, until the whole receiver is filled with chlorine.

The chemical changes in this experiment are as follows; The *sulphuric acid* acting upon the solution of *chloride of sodium*, disengages *hydro-chloric acid*; the latter is decomposed by the *peroxide of manganese* (as explained in the former experiment); the *sulphates of soda and manganese* remain in the retort.

263. Chlorine gas is of a green color, slightly yellowish, and derives its name from the Greek word which signifies green. It

261. Equivalents and specific gravity of chlorine. Various synonymes.

262. Mode of obtaining chlorine with muriatic acid and peroxide of manganese. Rationale of this process. Mode of obtaining chlorine with common salt and peroxide of manganese. Explanation.

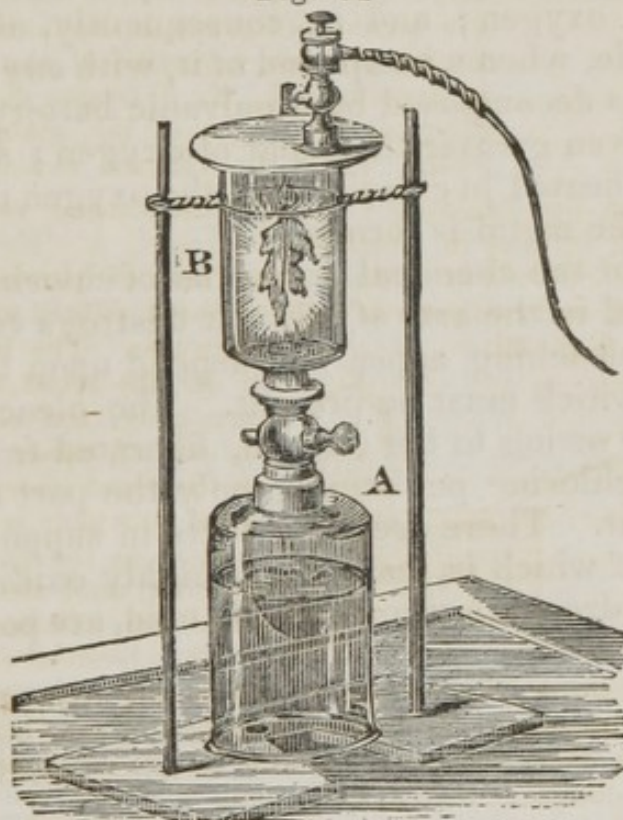
263. Some properties of chlorine. Effects of cold on chlorine gas.

has an astringent taste, and a disagreeable, suffocating odor. It is exceedingly deleterious to the lungs, when inhaled, even though diluted with air. It is said to give out *light*, when suddenly compressed with great force; a property belonging to no other gases but oxygen and chlorine. A pressure of 4 atmospheres, (about 50 lbs to the square inch,) reduces it to a bright yellow liquid which resumes the gaseous form instantly, when the pressure is removed.

Cold water dissolves about twice its bulk of chlorine, forming a solution which has the color, odor and general properties of the gas itself; and hence the necessity of heating the water over which chlorine gas is to be collected. If exposed to a temperature of 32° Fahrenheit, while mixed with watery vapor, it forms a solid *hydrate*,* which appears in the form of crystals, on the sides of the bottle; this hydrate is liquefied by the warmth of the hand.

264. *Chemical character.* Neither heat, light, electricity, nor galvanism has been able to decompose pure chlorine; it is therefore considered, a simple element. When chlorine is in a *moist state*, the watery vapor may be decomposed, the chlorine combining with the hydrogen of the vapor, and the oxygen which form-

Fig. 51.



* A hydrate is a compound of water with another body, often in *definite proportions*.

264. Why considered a simple element. Chlorine decomposes watery vapor in contact with it. Is an indirect oxidizing agent.

ed part of the same being liberated. As oxygen must be liberated whenever chlorine decomposes water, if an oxidable body be at the same time present, it will become oxidized; so that chlorine is often an indirect, oxidizing agent, of great power. Chlorine supports the combustion of some bodies.

265. A lighted candle being immersed in it, goes out after burning a short time, with a dull red flame. Phosphorus, and some of the metals, take fire spontaneously in this gas. In these cases, combination takes place between the burning body and chlorine, and the compound resulting is a *chloride*.

Exp. The bell glass B, (Fig. 51.) represents the combustion of gold leaf in chlorine gas. The lower bell glass A, being filled with chlorine over the pneumatic cistern; the upper bell glass is exhausted of air by means of an air pump, and the pipe which is connected with the apparatus. On turning the stop-cock between the two bell glasses, the gas from the lower one rushes up to fill the vacuum, and the gold leaf is immediately inflamed, and burns with great brilliancy, forming *chloride of gold*.

266. As chlorine unites with simple bodies it cannot be an *acid*; for acids combine only with metallic oxides, and not with the metals themselves. Besides, it has none of the other properties of acids. It is the most intensely *electro-negative* body known except oxygen; and is, consequently, always found at the *positive* pole, when a compound of it, with *any other substance than oxygen*, is decomposed by a galvanic battery. Its affinity for metals is even greater than that of oxygen; so that if a metallic oxide is heated in chlorine gas, the oxygen is expelled, and a chloride of the metal is formed.

267. Some of the chemical properties of chlorine render it extensively useful in the arts of life. It destroys vegetable colors rapidly; the bleaching appears to depend upon the decomposition of water which must be present. The bleaching effect is supposed to be owing to the oxygen, liberated from the decomposed water, chlorine performing only the part of an indirect, oxidizing agent. There are other facts in support of the same opinion, one of which is, that certain highly oxidized bodies, as duetoxide of hydrogen, and manganesic acid, are powerful bleaching agents.

For bleaching, on a small scale, as in removing from linen and cotton, the stains of fruit or other vegetable substances, a solution of chlorine gas in water, may be used. But this solution in large quantities, gives off so

265. Chlorine an imperfect supporter of combustion. Compound which results from the burning of a metal with chlorine. *Exp.*

266. Proof that chlorine is not an acid. Its electrical affinity. Its affinity for metals.

267. Various uses of chlorine. Its bleaching properties. The particular office of chlorine in the bleaching process. Proofs that oxygen is the active agent. Experiment to prove the bleaching power of chlorine.

much gas as to be deleterious to the workmen; and the resulting hydrochloric acid is injurious to the texture of cloth. Both these inconveniences are avoided by using the *chloride of lime*, commonly known as *bleaching powder*.

Exp. Immerse a piece of litmus paper, or of printed calico in a solution of chlorine, or of chloride of lime, or into a jar of the gas itself; (in the latter case, the calico or paper must be moistened;) the color will be discharged in a short time.

268. Chlorine destroys animal and vegetable poisons, whether existing as miasma in the atmosphere, or in other forms.

The air of a sick room is purified by sprinkling the floor with a solution of chloride of lime or of soda. The putrescence of meat is arrested, and taint removed by the same substances, which, likewise, in a dilute state, form an admirable wash for the mouth. Chlorine, in the gaseous state, and in solution in water, is a certain antidote for Prussic acid; and it seems highly probable that the bite of a rattlesnake, or of a rabid animal would not be followed by such fearful consequences, if, as soon as they occur, the wounds could be dressed with a solution of this gas.

It is not ascertained whether chlorine acts directly upon the poisonous matter, or whether it is as in its bleaching property, an indirect, oxidizing agent. In either case, affinity for hydrogen* is probably the cause of the *phenomena*.

269. When chlorine is passed into a cold solution of a fixed alkali, it is absorbed in considerable quantity, and forms a compound which exhibits the odor, the bleaching effects, and the antiseptic properties of chlorine. (A disinfecting liquid, prepared by M. Labarraque, is a form of chloride of soda.) If this compound be heated, water is decomposed; 5 atoms of chlorine, take 5 of hydrogen, and form 5 of *hydro-chloric acid*, which unite with 5 of the alkali, forming a *hydro-chlorate*; the 5 atoms of oxygen disengaged from the water, combine with 1 of chlorine, and constitute a particle of *chloric acid*, which also combines with 1 of alkali, and forms a *chlorate*. The solution thus contains nothing but two neutral salts, a hydro-chlorate and chlorate, and has no longer the distinguishing characters of chlorine.

270. Chlorine is detected by its bleaching properties, and by producing, in a solution of *nitrate of silver*, a white precipitate, the *chloride of silver*, which soon becomes dark colored, on exposure to light.

* Wherever we commence in our instructions in science, we must occasionally, refer to what is yet unexplained. This is peculiarly the case in Chemistry. The three most important of the elementary bodies, are Oxygen, Hydrogen, and Nitrogen; they form combinations with all other known elements. But in our system of arrangement, according to *electro-chemical agencies*, oxygen stands at the head of one division, and hydrogen at the head of another. We must therefore, in adhering to our arrangement, leave the consideration of *hydrogen* and *nitrogen*, till we have treated of the simple electro-negative bodies, though some of the latter are of much less importance.

268. Effect of chlorine upon animal or vegetable poisons. *Practical applications.* Probable cause of its action upon poisonous matter.

269. Disinfecting liquid, how prepared? Effect of heating it.

270. Tests of chlorine.

Compounds of Chlorine and Oxygen.

271. These two important electro-negatives having for each other very weak affinities, cannot be made to unite by any direct method; but, indirectly, we are able to produce several distinct compounds; the most striking characteristics of these combinations is the extreme facility with which they are decomposed, either by heat, or by the action of other substances. This is owing to the very weak affinity of chlorine and oxygen for each other. None of these compounds has ever been found in nature.

272. *Protoxide of chlorine* 1 atom of chl. 36 to 1 ox. $8=44$.

Peroxide of chlorine 1 do chl. 36 to 4 ox. $32=68$.

The former of these compounds is sometimes called *Hypo-chlorous acid*, as also *euchlorine*, it being *greener* than chlorine. The peroxide is also called *chlorous acid*. The properties of these two substances may be advantageously studied by comparing them with each other. They are both gaseous, of a greenish-yellow color, and are copiously absorbed by water, to which they communicate their color, odor and some of their chemical properties. They are highly explosive, and dangerous compounds: the protoxide explodes by the heat of the hand, and the peroxide, at about the boiling heat of water. They bleach powerfully, but the protoxide reddens a vegetable-blue before it bleaches it, while the peroxide whitens it, at once. They inflame phosphorus spontaneously; explosion takes place, and the phosphorus continues to burn in the two component gases, forming a compound of each.

273. *Expansion* is a necessary consequence of the decomposition of these gases; for in each of them the two elementary gases are in a state of condensation. In the *protoxide*, 4 measures of chlorine and 2 of oxygen, making 6 measures, are so condensed by combination as to form but 5 measures of the oxide. In the *peroxide*, the contraction is still greater, for 4 measures of this gas contain 6 of the component gases, of which 2 are chlorine and 4 are oxygen. The peroxide, therefore, explodes more violently than the protoxide.

274. *Chloric acid* is obtained in solution, by adding sulphuric acid to a solution of *chlorate of baryta*. The insoluble *sulphate of baryta* is precipitated, pure *chloric acid* remains in solution, and may be obtained in a solid state, by evaporation. It was formerly called *hyperoxy-muriatic acid*, its salts are still called, by some, *hyperoxy-muriates*.

275. *Properties*. Chloric acid combines with the alkaline

271. Names and composition of the compounds of chlorine and oxygen. Their most striking character. These compounds not found native.

272. What are the component parts, and chemical equivalents of the protoxide and peroxide of chlorine? Comparison of these two substances with each other. Their properties.

273. Why expansion is a consequence of the decomposition of the protoxide and peroxide of chlorine.

274. How is chloric acid obtained? Synonyme.

275. Properties. Names of its salts. Its effect on oxidable bodies. De-flagrating properties of its salts. Action of sulphuretted hydrogen with chloric acid.

bases, forming salts, called *chlorates*. It readily affords oxygen to oxidable bodies, acting on them with great violence. The *chlorates*, have the same property, deflagrating with great violence on hot coals, and producing a violent explosion when mixed with phosphorus or sulphur and struck with a hammer or heated. The explosion arises from the rapid oxidation of the combustible part of the mixture, at the expense of the chloric acid. Chloric acid is also decomposed by *sulphuretted hydrogen*, the hydrogen forming water with the oxygen of the acid, while the sulphur and the chlorine are set free.

276. *Perchloric Acid* may be obtained by heating 1 part of water, 3 of sulphuric acid, and 5 of perchlorate of potassa. White vapors arise in the receiver which become condensed into a liquid, on being mixed with sulphuric acid, and distilled pure crystals, of perchloric acid appear. It is volatile, decomposable in heat at a higher temperature than that necessary to decompose chloric acid, and forms a class of salts, which, like the acid itself, deflagrate with combustibles. Its salts like the chlorates, are convertible by heat into oxygen and chlorides of metals. Perchloric acid is important, as affording the best method of distinguishing and separating potassa from soda; for if it be poured into a solution containing these alkalies, or their salts, it precipitates the perchlorate of potassa, which is nearly insoluble, while the perchlorate of soda is extremely soluble and remains in solution.

277. The constituents of the two *oxacids* of chlorine are as follows;

Chloric acid. 1 chl. 36, add 5 ox. 40=76.

Per-chloric acid. 1 chl. 36, add 7 ox. 56=92.

CHAPTER XI.

ELECTRO-NEGATIVE SUBSTANCES.—BROMINE, IODINE, FLUORINE.

BROMINE.

278. *Equiv.* $\left\{ \begin{array}{l} \text{by vol. } 100 \\ \text{" weight } 75 \end{array} \right\}$ *Sp. gr.* $\left\{ \begin{array}{l} 3 \\ 5,4017 \end{array} \right\}$ $\begin{array}{l} \text{Water}=1 \\ \text{Air}=1 \end{array}$

Bromine was discovered by M. Ballard, (of Montpelier, in France, about the beginning of 1826,) in sea-water and, on this account, was at first called *muride*; after it was found to be

276. *Perchloric acid.*

277. What are the constituents of the two oxacids of chlorine?

278. Chemical equivalents and specific gravity of bromine. Its discovery, &c.

nearly allied, in some of its characteristics, to chlorine and iodine, its name was changed to *bromine* (from the Greek *bromos*) signifying rank odor. It exists but in very minute quantities in sea-water, and has been found in the water of some mineral springs. In all cases, it is found, in nature, in combination with *hydrogen*, forming *hydro-bromic acid*, and united with potassa, or soda.

279. In affinity for hydrogen bromine ranks next below chlorine; the latter body, therefore, affords the means of procuring it in a separate state. In order to obtain it, sea-water is evaporated till all but the most deliquescent and least crystallizable salts are deposited; the residual liquid, called *bittern*,* is then drawn off. Into this, chlorine gas is passed. The *chlorine* combines with the *hydrogen* and forms *hydro-chloric acid*, and thus the *bromine* of the *hydro-bromic acid* is set free.

Bromine is very soluble in *sulphuric ether*; therefore, in pouring some of this liquid into the decomposed *bittern*, an ethereal solution of bromine is formed, which being lighter than water, will float in a distinct stratum on the top, and can be poured off. The next step is to add potassa to the ethereal solution; *bromide of potassium* is formed, from which bromine is obtained by the addition of sulphuric acid and peroxide of manganese, for the same reason that chlorine is obtained by the same process, from chloride of sodium, (see § 262;) but bromine being a liquid, instead of a bell glass, (as in the case of chlorine,) we must attach a cold receiver to the neck of the retort.

280. *Physical properties.* Bromine is very volatile giving off at common temperatures dense red vapors, when in an open vessel.

Exp. Pour a few drops of liquid bromine into a glass flask, a beautiful vapor somewhat resembling that of iodine will appear.

It becomes congealed into a brittle solid at about 4° below zero. In mass, it is a blackish-red colored liquid like venous blood; but in a thin stratum, especially when held to the light, it is of a bright hyacinth-red. Its vapor is acrid and corrosive. It is noxious when inhaled, and very poisonous when swallowed. A single drop upon the beak of a bird destroys life instantly.

281. *Chemical properties.* Bromine is considered a simple body, having never been decomposed by the most powerful chemical agents. It is soluble in water, forming with it, at 32° a hydrate in red crystals. Its vapor extinguishes a candle, but supports the combustion of phosphorus, potassium and a few other substances, which take fire, spontaneously, and explode, in contact with liquid bromine. In all cases of combustion in bro-

* Bittern is an uncrystallizable residue, after having extracted the common salt from sea-water. It contains several deliquescent salts, among which is the *hydriodate of soda*.

279. Mode of obtaining it through the agency of chlorine. Second mode of obtaining bromine.

280. *Physical properties.*

281. *Chemical properties.*

mine, a *bromide* of the burning body is found. Bromine possesses bleaching properties; to solution of starch it gives an orange color. A lighted taper burns for a few moments in its vapor, with a flame green at the base and red at the top.

282. *Compounds of bromine and oxygen*;—*Bromic Acid* is the only known compound, and has many of the properties of chloric acid. It consists of 1 equiv. of *bromine*, and 5 of *oxygen*; is decomposed by heat, and forms a class of salts, called *bromates*, which deflagrate with the more oxidable bodies. This acid is obtained by acting on bromate of baryta, with sulphuric acid.

283. *Bromine and Chlorine* unite, (probably in the proportion of one atom of each,) to form the *Chloride of bromine*, a dense liquid, of a reddish yellow color, and very volatile, giving off acid and strongly odorous vapors. It dissolves freely in water, without decomposition; the bleaching properties of the two constituents, still remaining in solution. Its vapors set some substances on fire, producing at once a chloride and a bromide of the combustible.

IODINE.

$$284. \text{Equiv. } \left\{ \begin{array}{l} \text{by vol. } 100. \\ \text{" weight } 124. \end{array} \right\} \text{ Sp. gr. } \left\{ \begin{array}{l} 4 \\ \text{Water} = 1 \end{array} \right.$$

Iodine is a solid substance, of a bluish black color, resembling in its appearance, the cuttings of a lead pencil. It was discovered by M. Courtois of Paris, a manufacturer of salt-petre, in 1812. He found that the residual liquor, after the preparation of soda from the ashes of sea weeds, had the property of corroding metallic vessels. On the application of sulphuric acid a dark colored substance was deposited which by the application of heat was changed into a violet colored vapor. He referred this phenomena to M. Clement, who described it as a newly discovered element. Gay Lussac in France, and Davy in England, soon experimented upon it, and proved it to be a simple non-metallic, electro-negative substance, analogous to chlorine. The name *iodine** was given from the beautiful *violet* color of its vapor. It fuses at 225° , and vaporizes at 347° .

Exp. Put a few scales of iodine into a small glass flask, and hold it near the flame of a lamp. The solid will soon disappear, and the phial be filled with a vapor of a beautiful, violet color, and hence its name, *iodine*. As soon as the phial is removed from the lamp, the iodine is again seen in the

* From the Greek *iodus*, violet colored.

282. Bromine with oxygen.

283. Bromine with chlorine.

284. Equiv. and sp. gravity, of Iodine. History of its discovery. Origin of its name. Exp.

solid form, and without any apparent change in its nature. The vapor of iodine is exceedingly heavy, having more than eight times the weight of air. If the vaporization be performed in a long tube or matrass, the vapor on reaching the cool part of the vessel, is condensed into minute, shining crystals.

285. *Chemical Properties.* Iodine is considered a simple body, because, like chlorine and bromine, it has never been decomposed. It requires 7000 times its weight of water to dissolve it, giving a slightly brownish-yellow solution. With alcohol and ether, it dissolves much more copiously, forming a deep brown solution. Although iodine, alone has a much higher vaporizing point than water, yet on account of the affinity of these two bodies, the aqueous solution of iodine, is distilled without separating them. Iodine acts powerfully on the animal system, as an irritant poison; but in some diseases, it is employed medicinally, both externally and internally, in small doses, with great advantage. Iodine possesses strong affinities for the simple bodies, and weak ones, for oxides and other compound bodies. In general, whatever combines with chlorine or bromine, will unite also with iodine, forming analogous compounds.

286. Combinations of iodine with simple bodies are called *Iodides*. Some substances, when brought into contact with iodine, take fire, especially in open air; of these are phosphorus and potassium.

Exp. Drop into a wine glass containing a few grains of iodine a small bit of phosphorus, immediate combustion will take place.

Iodine destroys vegetable colors, but, instead of bleaching or whitening them, it usually changes them yellow. It leaves a yellow stain on the skin, which like that of bromine, gradually disappears, on account of the volatility of this substance.

287. *Tests.* To detect free iodine, the color of its vapor and its odor, which is like that of muriatic acid, but less strong, are sufficient; if, in combination, the iodine must be set free by chlorine, or by oxide of manganese and sulphuric acid. But in very minute proportions, iodine requires a more delicate test. A drop of the alcoholic solution of iodine added to a cold solution of *starch* will cause a beautiful blue *iodide of starch* to appear. Another mode of testing the presence of this *substance*, is to dissolve a little starch in a solution of pure potassa and add this solution to the liquid supposed to contain iodine, and afterwards drop in a little sulphuric acid, if a blue compound appears, it is caused by iodine.

288. *Natural History.* Iodine, exists in sea-water, by which it is also imparted to marine plants and animals. It is also

285. Why is Iodine regarded as a simple body? Its solubility. Effect on the animal system. Affinities.

286. Iodides. Exp. Effect of iodine on vegetable colors and on the skin.

287. Tests of iodine.

288. Natural history from whence obtained. Uses.

found in the water of some mineral springs, it bears, however, a very small proportion to the other bodies with which it is mixed. Like chlorine and bromine, it is always in combination with hydrogen, constituting a hydracid, which is combined with a salifiable base. Sea water is believed to contain hydriodate of soda, or potassa, from which the iodine is extracted. Most of the iodine of commerce is obtained, from the impure carbonate of soda, called *Kelp*, which is merely the ashes of sea-weed. Great quantities are prepared on the coasts of Scotland. It is used for the *goitre* (a swelling of the neck) and other glandular diseases.

289. Exp. Iodine may be obtained by adding sulphuric acid to *bittern*, and applying heat. A portion of the sulphuric acid takes the soda of the *hydriodate of soda*, and liberates the *hydriodic acid*. This reacts on the remaining sulphuric acid, the oxygen of the latter uniting with the hydrogen of the former to constitute water. The iodine of the hydriodic acid is thus disengaged, and the *bittern* becomes dark colored, on account of the free iodine. Let this liquid mass be now introduced into the retort *a*, (Fig. 52.) through the tubulure *b*; on placing the retort over the flame of a lamp, the violet colored vapors of iodine fill the retort, and rising into the receiver *c*, are condensed. If the receiver be covered with a wet cloth, (as represented in the figure) it will assist in keeping it cool. The crystals of iodine are washed out of the receiver with a small quantity of water, and dried upon blotting paper which serves as a filter, the liquid passing through its pores, and the solid particles remaining on its surface.



290. *Iodic Acid*. 1 Iod. 124, to 5 ox. 40 = 164. This is of the same class with chloric, bromic and nitric acids. It is a solid body, very soluble in water and even deliquescent; soluble in nitric and sulphuric acids, from which solvents it may be separated in crystals. It forms with the alkalies and other bases, a class of deflagrating salts called *Iodates*.

The superior affinity of iodine for oxygen enables it to decompose the oxide of chlorine, and form iodic acid; at the same time, the chlorine combines with another portion of iodine to form *chloriodic acid*. The latter body being exceedingly volatile, is easily separated by a gentle heat. Iodic acid is otherwise obtained by boiling iodine in nitric acid, by which means the latter is decomposed and furnishes oxygen to the former.

289. Exp. Mode of obtaining iodine.

290. Equiv. of iodic acid. Properties. Iodates. Formation of iodic acid.

291. *Iodous Acid*, is another compound of oxygen and iodine, which is proved to exist, but has never been indisputably obtained in a free state. There is probably, still another oxide of iodine, containing even less oxygen than iodous acid.

292. *Chloriodic Acid*. 1 Iod. 124, to 2 chl. 72=196. This is a combination of chlorine and iodine, procured by passing chlorine gas into a dry bottle containing iodine. It is solid, of an orange yellow color, very volatile, very soluble in water, and deliquescent. Its solution is strongly acid; but when an alkali is added, instead of forming a chloriodate, we obtain a hydrochlorate and an iodate. This is owing to the decomposition of water; the oxygen of which combines with iodine and the hydrogen with chlorine. The iodic and hydrochloric acids thus formed, take, each, its portion of the alkali.

Bromine and iodine combine and form *bromide of iodine*.

FLUORINE.*

293. Fluorine has never been obtained in an uncombined state owing, as is supposed, to its very energetic affinities for other substances. It is one of the constituents of *fluor spar*, from which the compounds of fluorine are commonly obtained. It is considered an electro-negative body, as possessing intense affinities for simple substances, and forming with hydrogen, an acid called *hydrofluoric*.

294. *Hydrofluoric Acid*. This acid is obtained by heating a mixture of *sulphuric acid* and powdered *fluor spar* (*fluoride of calcium*).

Fig. 53.



Exp. The mixture must be made in a metallic retort, (Fig. 53.) (on account of the peculiar action of the acid on glass) and the vapor of hydrofluoric acid must be received in a close vessel *c*, of one of those metals. The vapor passing through the tube *b* into the receiver, which is kept cool, by ice or cloths wet in cold water, is condensed into a liquid. This is *hydrofluoric acid*, and must be preserved in a closely stopped metallic bottle.

295. Hydrofluoric acid, in the liquid

* Silliman justly remarks, that "it appears premature to place fluorine, a principle purely *hypothetical*, along side with chlorine and iodine, whose distinct existence and peculiar energy are manifested in so many remarkable forms."

291. Iodous acid.

292. Composition of chloriodic acid. How procured? Properties. Bromide of iodine.

293. Why is it supposed that fluorine has not been obtained in a separate state? From what mineral are its compounds obtained; supposed properties of fluorine.

294. How is hydrofluoric acid obtained? *Exp.*

295. Its affinity for water. Its effects on animal and vegetable bodies.

state, is very volatile, giving off dense white fumes if exposed in an open vessel, at the temperature of 60° F. Its specific gravity when pure, is but little above that of water; but when combined with some water, it forms a less volatile hydrate of the specific gravity of about 1.25. This acid has an affinity for water, even much greater than that of sulphuric acid. In combining with water, it produces very great heat, and causes a hissing like that produced when hot iron is quenched. It corrodes animal and vegetable bodies more powerfully than any other substance, producing a deep and dangerous ulceration when it is put on the skin. This action is the result of the powerful affinity the acid has for water.

296. It also acts on glass, dissolving the siliceous matter of that substance and destroying its transparency; or even perforating it when a sufficient quantity of acid is used.

By this action, two compounds are formed; the oxygen of the silex forms water with the hydrogen of the acid; while the silicon unites with the fluorine to form a colorless acid gas, called *fluosilicic acid*.

This property of hydrofluoric acid affords means of etching or engraving on glass. The glass must be covered with a thin and uniform coat of wax, after which a figure is traced on it with a sharp steel point. If it be now exposed to the fumes of the acid, or wet with the liquid acid the glass will be corroded where the wax has been removed by the steel point, while the covered parts will be left untouched.

297. With oxides, hydrofluoric acid acts variously, combining with some to form *hydrofluates*, and decomposing others, in which case, water and a fluoride of the metal are the result. It is a powerful solvent, dissolving rock crystal, flint, and other siliceous matters, besides several other bodies which are not attacked even by nitro-muriatic acid.

Sulphuric acid displaces this acid from any of the hydrofluates; and then the hydrofluoric acid can be detected by exposing glass to the fumes as they rise.

298. Some Chemists are disposed to regard this acid, (instead of fluorine and hydrogen,) as a compound of *fluorine* and *oxygen*, called *fluoric acid*; and all phenomena relating to it are capable of explanation under this view. Thus fluor spar may be considered a *fluuate of lime* instead of a *fluoride of calcium*; so that when sulphuric acid acts on this mineral, it may be supposed simply to combine with the lime and liberate *fluoric acid*. Some recent experiments, however, seem to yield conclusive evidence in favor of the first mentioned view of the subject, or, that the acid in question, is *hydro-fluoric*, consisting of fluorine and hydrogen.

299. *Fluoboric Acid* was discovered by Gay Lussac and Thenard, in an experiment intended to prove that the acid we have described under the

296. Action of hydro-fluoric acid on glass. Compounds formed by this action. Etching on glass.

297. Action of this acid with oxides. Its solvent properties. Is displaced by sulphuric acid.

298. Theory which considers this as fluoric rather than hydrofluoric acid.

name of hydrofluoric acid is an *oxacid*. Boracic acid being a compound of boron and oxygen, they endeavored by its aid, to obtain fluoric acid from fluor spar. If they succeeded, it would establish their opinion on the disputed point; for there being nothing present in the experiment but boracic acid and fluor spar, both anhydrous,* there could be no hydrogen in the product.

But instead of hydrofluoric, (or fluoric,) acid they obtained a new gas, which does *not act on glass*; is very soluble in water, which it attracts so strongly as to produce dense white fumes in the air when the least moisture is present; and decomposes by water, forming *boracic* and *hydrofluoric acids*, *borate of lime* remaining in the retort. The discoverers believed that a portion of the boracic acid united to the lime and liberated fluoric acid; and that the latter immediately combined with another portion of boracic acid, to form the *fluoboric* gas which is therefore a compound of the two acids.

The decomposition of the fluoboric gas by water, and the consequent deposition of boracic acid, they attributed to the superior affinity of water for fluoric acid, by which the latter was taken from its combination with boracic acid.

300. The chemical changes in this experiment appear to be as follows.—The two materials *boracic acid* and *fluor spar* (*fluoride of calcium*) being mixed and heated strongly in an iron tube or retort, the *oxygen* of a portion of the boracic acid, combines with *calcium* to form lime, *fluorine* combines with the *boron*, which has thus been deserted by oxygen, and forms the *fluoboric gas*; and, finally the remaining boracic acid unites with the newly formed lime, and *borate of lime* remains in the retort. The fluoboric gas being a compound of the electro-negative fluorine with the electro-positive boron, when it is passed into water the fluid is decomposed; its hydrogen unites with the fluorine, and its oxygen with the boron, forming thus, *boracic* and *hydrofluoric acids*, of which the latter is wholly dissolved, while much of the former is deposited. The moisture of the air effects the same decomposition of this gas, the fumes being rendered quite opaque by the particles of solid boracic acid. On account of the formation of these fumes, fluoboric gas is of use in testing the minutest quantities of vapor in gases. The strong affinity of this gas for water, enables it to char animal and vegetable bodies with their oxygen and hydrogen, thus developing their carbon.

301. Fluoboric acid unites with alkalis forming salts called *fluoborates*. When potassium is heated in this acid, the fluorine combines with it, and boron is liberated; the same decomposition occurs when potassium is heated with an alkaline fluoborate, which furnishes the best method for obtaining boron. This acid gas is always generated when boracic acid is brought into contact with hydrofluoric acid; and, accordingly, an easier process for obtaining it, than the one given, (see § 299,) is to mix those two bodies in a retort and apply heat. Or it may be obtained by heating a mixture of boracic acid, fluor spar and sulphuric acid. The gas should be collected over mercury.

* *Anhydrous* signifies without any water, entirely dry.

299. Discovery of fluoboric acid. Nature of the gas obtained by Gay Lussac and Thenard with boron and fluorine. Its attractions for water. Opinion of the discoverers of this gas respecting the changes which accompany its formation.

300. Another explanation of the chemical changes in this experiment. Use of this gas as a test. Why it chars animal and vegetable bodies.

301. Salts of this acid. Other modes of obtaining fluoboric acid.

302. *Fluo-silicic acid gas*, is a compound concerning the nature of which the same question may be raised, as in the case of fluoboric gas. It is generated when hydro-fluoric acid comes in contact with silex, and may either be composed of fluorine and silicon (in which case the oxygen of the silex unites with the hydrogen of the acid,) or, it may be considered, as a compound of fluoric acid and silica. We shall treat of it under the first supposition. It may be obtained by mixing, in a retort, powdered fluor spar and fine sand, (or powdered glass, of which silex is a principal constituent,) and heating with a lamp. The gas is to be collected over mercury.

303. *Properties of fluo-silicic acid gas*. It is colorless and transparent, a non-supporter both of respiration and combustion, and forms dense white fumes in moist air. Its affinity for water, enables it to corrode the skin and to char vegetable matter. The fluorine in this gas being saturated with silex, it does not attack glass. It is soluble to a great extent in water, but is decomposed by it, with formation of hydrofluoric acid, and of silex which is deposited. The decomposition, however, is not total; some silex remains in solution; and constitutes with the hydrofluoric acid, what is generally considered a distinct compound and called *hydro-fluosilicic acid*. If the watery solution be filtered to remove the deposited silex and then evaporated, the vapor of hydrofluoric acid is expelled, and the original gas is given off unaltered; but if the evaporation be performed without filtration, the silex is redissolved, and the fluosilicic gas is reproduced.

If this gas be passed into an alkaline solution the whole silex is deposited, and a hydrofluat of the alkali is formed.

304. The acidity of fluosilicic, and of fluoboric gases is by some, considered doubtful. It can only be exhibited with the aid of water, in which case decomposition takes place, and other acid compounds are formed, to which alone the acid reaction might be owing. Accordingly, some Chemists consider these gases as only the *per fluorides of boron and of silicon*.

The acid property, however, seems to be sufficiently established by the fact that these gases unite with gaseous ammonia and form solid compounds or salts.

305. The hydro-fluosilicic acid unites with alkalies and other bases. Its combination with potassa is of difficult solubility, and therefore this acid is sometimes advantageously used to remove *potassa from solutions*.

302. Nature of fluo-silicic acid gas disputed. When the gas is generated. Composition. How obtained?

303. Properties. Formation of hydrofluosilicic acid. Effects of passing this gas into an alkaline solution.

304. Arguments against, and in favor of the acid nature of fluosilicic and fluoboric acids.

305. Affinities of hydrofluo-silicic acid.

CHAPTER XII.

SIMPLE ELECTRO-POSITIVE SUBSTANCES.—(*Not Metallic.*)

306. The *Non-metallic, electro-positive*, substances are, as follows, viz :

1 Hydrogen,	5 Silicon,
2 Nitrogen,	6 Phosphorus,
3 Carbon,	7 Sulphur,
4 Boron,	8 Selenium.

Hydrogen and nitrogen are *gases* : carbon, boron and silicon, are dark colored, insoluble and infusible powders, scarcely affected by acids, and forming weak acids by oxidation. Phosphorus, sulphur and selenium are fusible, volatile, and combustible solids, producing strong acids by combinations with oxygen. They have affinities for the *electro-negatives* and are found at the *negative pole* where their compounds and those of the *electro-negatives* are decomposed by galvanism. They have, also, more or less tendency to unite with each other, and several of this class combine with the metals.

HYDROGEN.

307. *Equiv.* $\left\{ \begin{array}{l} \text{by vol. } 100 \\ \text{" weight } 1 \end{array} \right\}$ *Sp. gr.* $\left\{ \begin{array}{l} 0,694 \\ 1 \end{array} \right\}$ *Air*=1
Hyd.=1

HYDROGEN is so named from the Greek *hudor*, water, and *gennao*, to generate, because it enters largely into the formation of water. It was formerly called *inflammable air* from its combustible nature and *phlogiston*, from the supposition that it was the matter of heat. It is one of the most important of all the inflammable substances ; existing in nature in a variety of combinations, and forming $\frac{1}{9}$ part by weight, of water. Though known for centuries before, Mr. Cavendish, in 1766, first ascertained the nature of this gas as a distinct elementary substance, and experimented upon its properties.

308. Hydrogen is obtained by the decomposition of water, which may be effected in several ways.

306. How are the Electro-positive substances divided ? General characteristics of these bodies.

307. Equivalent and sp. gr. of hydrogen. Origin of the name. Synonyms. Where existing. Discovery.

308. From what substance is hydrogen usually obtained ? *Exp.* 1. Decomposition of water by galvanism. *Exp.* 2. Decomposition of water by heated iron. *Exp.* 3. Agency of sulphuric acid in promoting the decomposition of water.

Decomposition of Water by Galvanism.

Fig. 54.

Exp. 1. Let the two poles* of the voltaic pile, (Fig. 54.) be immersed in a vessel of pure water; the liquid will be decomposed; oxygen will be given off at the positive pole D, and hydrogen at the negative pole N. The gases may be collected by inverting over each pole a glass tube O, and H, closed at one end, and filled with water.

As opposite electricities attract each other, the oxygen is considered as *electro-negative*, and hydrogen *electro-positive*; and thus these two gases are placed at the head of their respective divisions.

Hydrogen may also be obtained by *decomposing water with red hot iron*.

Exp. 2. Put a coil of iron wire into a gun barrel, (Fig. 55.) open at both ends. The gun barrel is then passed through a furnace. To one end of the iron tube or gun-barrel is luted the neck of a retort A, containing water; and to the other, a bent tube E, of iron wire. A fire is now lighted in the furnace, and the water in the retort is boiled by means of an Argand lamp. The steam of the boiling water is decomposed in passing through

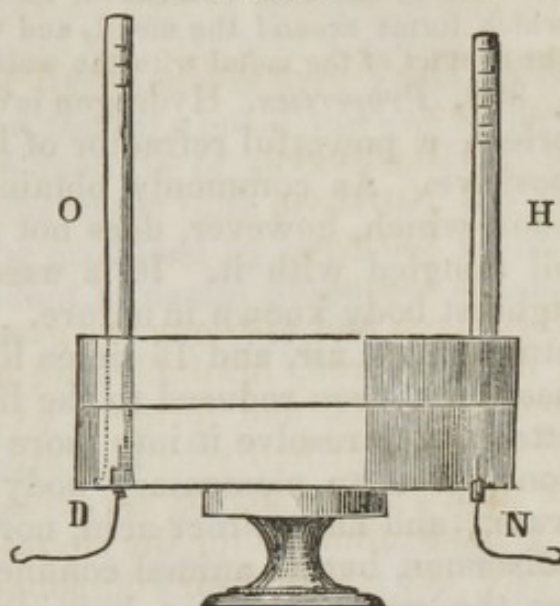
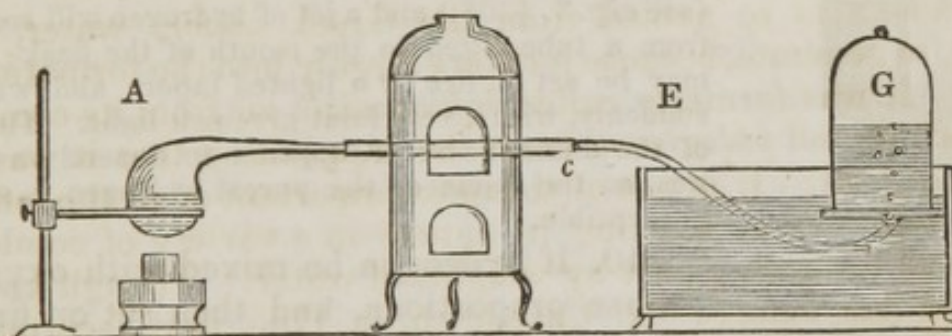


Fig. 55.



the coil of iron wire in the gun barrel; the oxygen combines with the iron which is found to be converted into the *black oxide of iron*; the hydrogen passes off into the receiver G.

Exp. 3. Another mode of obtaining hydrogen by the decomposition of water, is very simple. Dilute some sulphuric acid with 8 or 9 times its bulk of water, and pour it into a retort, or bottle containing zinc or iron filings.† A violent effervescence will immediately ensue, owing to the es-

* The wire used for the poles should be of platinum, as the oxygen would combine with iron wire.

† The great heat evolved by mixing sulphuric acid and water would endanger the vessel without due care. The acid should be gradually poured into the water; not the water into the acid.

cape of hydrogen gas, which is always to be received over water. Here the oxygen of the water unites with the metal, forming an oxide; the latter next combines with the acid forming a sulphate of zinc or iron (according as the one or the other metal is used) and the hydrogen of the water is liberated. The use of the acid consists in its uniting with, and dissolving the oxide which forms around the metal, and which would, if not taken up, prevent the contact of the metal with the water.

309. *Properties.* Hydrogen is combustile, transparent and colorless, a powerful refractor of light, and very strongly electropositive. As commonly obtained, it has a faint, disagreeable odor, which, however, does not belong to the gas, but to volatile oil mingled with it. It is used for filling balloons, being the lightest body known in nature. It is about 14 times lighter than atmospheric air, and 16 times lighter than oxygen. Hydrogen has never been reduced to the liquid state. It has resisted all attempts to resolve it into more simple parts, and is, therefore, considered an elementary body. It is scarcely absorbed in water, and has neither acid, nor alkaline properties. It is not poisonous, but an animal confined in it, dies for want of oxygen; for the same reason, a burning body is extinguished on being immersed in this gas.

Fig. 56.



A lighted candle placed under a jar of hydrogen gas, (Fig. 56.) is extinguished, though by its flame it will set the gas at the mouth of the jar on fire, and may be re-lighted, by having the wick brought in contact with the flame, when the combustion goes on, because there is oxygen to support it.

Exp. *Hydrogen is highly inflammable.* Let some iron filings, water, and sulphuric acid, be put into a flask, (see exp. 3. §308.) and a jet of hydrogen will soon issue from a tube fitted to the mouth of the flask; this jet may be set on fire by a lighted taper; and will burn suddenly, with a very faint greenish light. The color of the flame, however, appears to depend on impurities, as the flame of the purest hydrogen, is scarcely perceptible.

310. If hydrogen be mixed with oxygen in proper proportions, and then set on fire, the whole burns at once, with a loud explosion. The detonation takes place also, but not so violently, if air be used, instead of oxygen gas; the proportions for producing the most powerful explosion, are two measures of hydrogen, to one of oxygen, or five of air. These explosive mixtures may be kindled, not only by flame, and an ignited body, but also by the electric spark, and by platinum in that particular form called

309. Properties of hydrogen. Its elementary nature, &c. Exp. *Inflammable nature of hydrogen.*

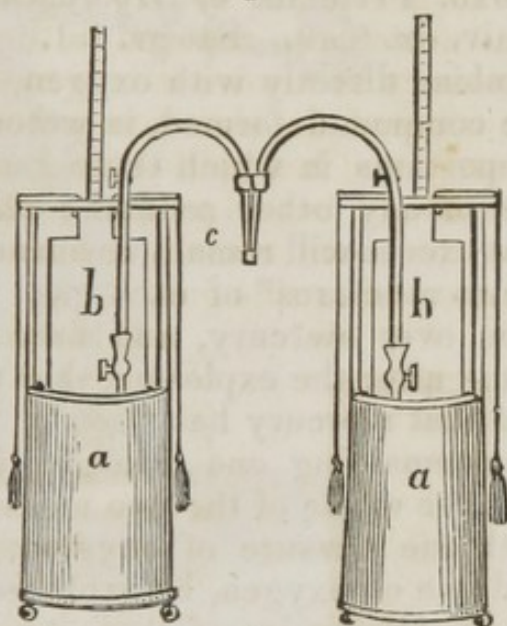
310. Explosive and inflammable nature of hydrogen and oxygen.

spongy platinum. If a jet of hydrogen gas be directed against a piece of spongy platinum, the latter becomes red-hot, and sets fire to the stream of gas.

An apparatus for procuring instantaneous light by means of spongy platinum and hydrogen gas will be explained under the head of platinum.

311. The heat of the flame of hydrogen is very great, even when a jet of the gas is burned in the air; but if the gas be previously mixed with oxygen, the quantity of caloric evolved, is greatly increased; the heat of the flame thus produced, is considered the greatest that can be produced by artificial means. For the first application of this fact to useful purposes, science is indebted to Dr. Hare, in the construction of the oxyhydrogen, or compound blow-pipe.

In this apparatus, the gases are confined in separate reservoirs *a a*, (Fig. 57.) from which they are expelled through tubes *b b*, meeting in a conical piece *c*, in which the gases mix just before they are to issue. By this plan, all danger is avoided; for the utmost that can happen, is the explosion of the mixed portion of the gases contained in the conical jet; a quantity too small to do any mischief. The flame



of the compound blow-pipe, fuses the most refractory substances in nature, as platinum, which is quite infusible in the most powerful furnaces. This flame is not extinguishable by water.

312. *Flame.* The reason why the flame of the mixed gases is so much hotter than that of hydrogen, burning in an atmosphere of oxygen, will be obvious, if we reflect, that no combustible can burn, unless it be in contact with some other substance, which acts as a supporter of combustion. Now, when a column of the inflammable gas escapes into an atmosphere containing oxygen, only the *surface* of the column is in contact with the supporter, and consequently, only its *exterior coat* can burn. This being consumed, another layer of hydrogen is exposed, and burns in its turn; so that the column is constantly growing smaller as it rises, till at last it terminates in a point. Accordingly an

311. Heat of the flame of hydrogen. Increase of heat from a mixture of oxygen and hydrogen. Compound blow-pipe. Dr. Hare's blow-pipe.

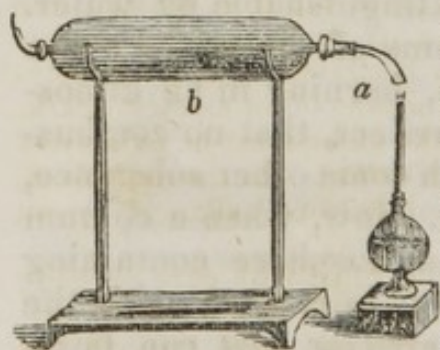
312. Flame. Cause of the great heat of the mixture of hydrogen and oxygen gases. Difference between ordinary flame and that of the mixture of hydrogen and oxygen gases.

ordinary flame, (as a candle or lamp, or the blaze on the hearth,) is conical, and a mere shell of ignited matter; the interior consisting of unburnt, inflammable gas. In the compound flame, however, each part of hydrogen being already in contact with its particle of oxygen, the whole column is in combustion, throughout its mass. The simple flame, therefore, bears to the compound one, the same relation that the surface of the cone bears to its volume

COMPOUNDS OF HYDROGEN AND OXYGEN.

313. *Protoxide of Hydrogen, or water.* 1 equiv. hyd. 1 to 1 equiv. ox. $8=9$. Sp. gr. =1. Whenever hydrogen is made to combine directly with oxygen, either by explosion or otherwise, the compound formed, is water; nor will any variation of the proportions in which these gases are mixed, cause the formation of any other product; and when either gas is in excess, that excess will remain unconsumed after the experiment. Thus, if two measures* of each gas, be mixed in a proper detonating tube, over mercury, and fired by the electric spark, it will be found after the explosion, that three measures have disappeared, and that mercury has risen in the tube to supply their place. The remaining one measure, consists entirely of oxygen; so that the whole of the two measures of hydrogen, have combined with one measure of oxygen. If three measures of hydrogen and one of oxygen, be exploded in the same manner, there will be a condensation of three measures, and the residual measure will be hydrogen.

Fig. 58.



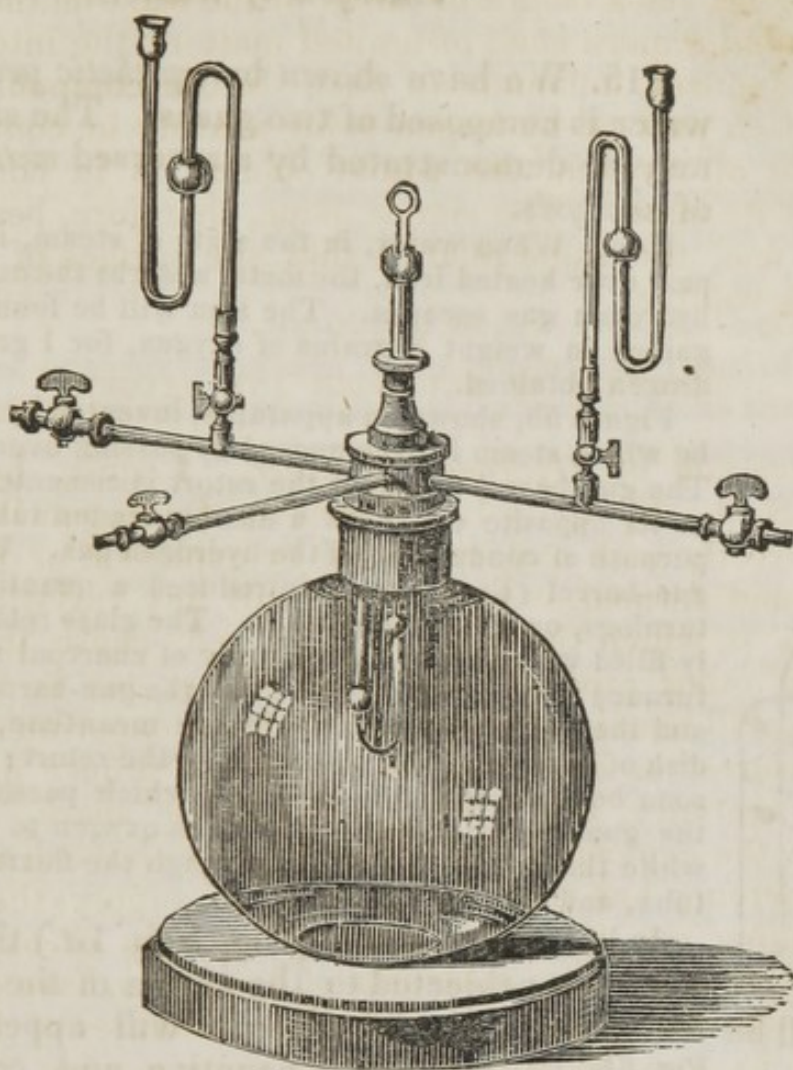
314. *Water formed by the combination of hydrogen and oxygen gases.* *Exp. 1st.* Hold a perfectly clean, and dry, glass vessel over a jet of hydrogen gas, the oxygen of the air combining with the hydrogen, will form an aqueous vapor, which will appear on the inner side of the glass. *Exp. 2nd.* Let a current of burning hydrogen pass into the mouth of the tube *a*, (Fig. 58.) the glass cylinder *b*, will soon appear covered with dew from the condensation of the aqueous vapor, produced by the oxygen of the air uniting with the burning hydrogen.

* By *measure* or volume, it is found that the atom of hydrogen is twice as large as that of oxygen; thus, as one atom of each unite to form water, and the weight of the atom of hydrogen is found, in comparison to oxygen to be, as 1 to 8, it follows that the specific gravity of hydrogen is 16 times less than that of oxygen.

313. Equiv. and sp. gr. of water. Combination of hydrogen and oxygen. What proportions, in volume, of these gases unite to form water?

314. *Exp. 1st.*

Fig. 59.



Exp. 3d. A more complicated apparatus for shewing the formation of water by means of the combination of oxygen and hydrogen was invented by the French chemist, Lavoisier. "This apparatus consists of a glass globe (Fig 59.) with a neck cemented into a brass cap from which three tubes proceed, severally communicating with an air pump, and with reservoirs of oxygen and hydrogen. It has, also, an insulated wire, for producing the inflammation of a jet of hydrogen, by means of an electric spark. In order to put the apparatus into operation, the globe must be exhausted of air, and then supplied with oxygen to a certain extent. In the next place, hydrogen is to be allowed to enter in a jet, which is to be inflamed by an electric spark."—*Dr. Hare.*

Exp. 4th. Let *a* (Fig. 60.) be a glass cylinder, filled with pure oxygen ; *b*, a bell glass containing hydrogen, and partly immersed in a vessel of water, *c*. On opening the stop cocks, *d d*, the hydrogen rises through the capillary tube *f*, and on being inflamed by an electric spark, it burns with great force, and drops of water soon collect in the cylinder.

Exp. 3d. Lavoisier's apparatus.

Exp. 4th.

Fig. 60.

Analysis of Water.

315. We have shown by *synthetic proof*, that water is composed of two gases. The same fact may be demonstrated by a reversed *method*, that of *analysis*.

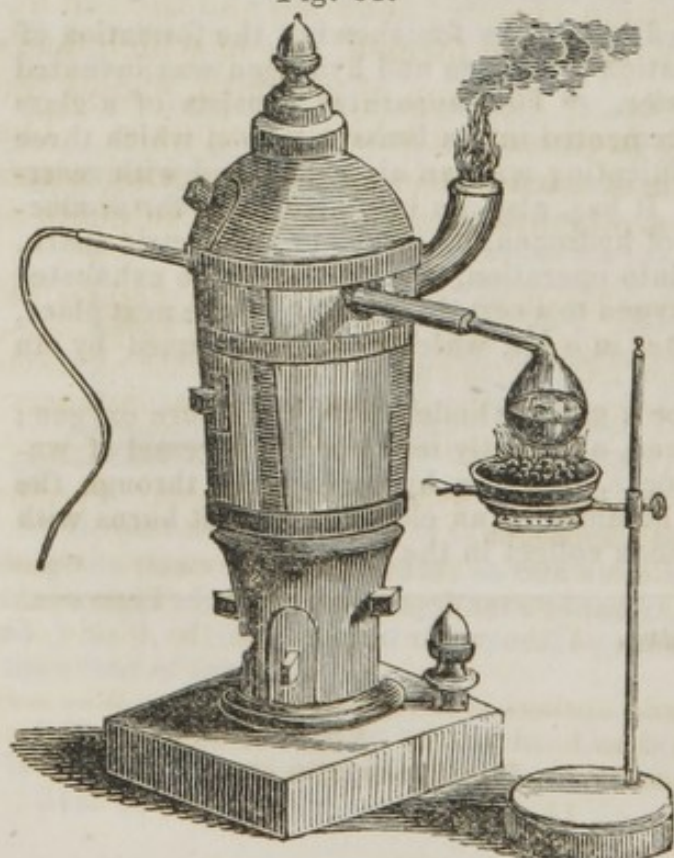
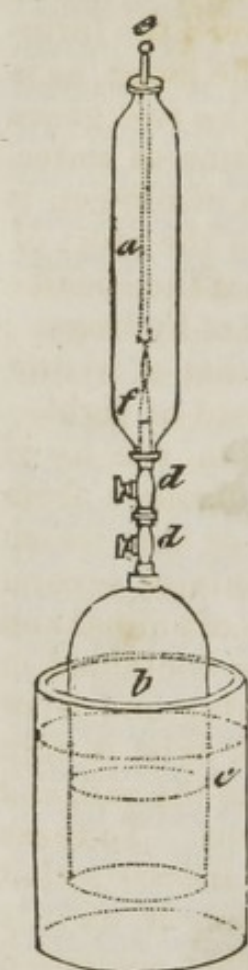
Exp. When water, in the state of steam, is made to pass over heated iron, the metal absorbs the oxygen, and hydrogen gas escapes. The iron will be found to have gained in weight 8 grains of oxygen, for 1 grain of hydrogen obtained.

Figure 55, shows an apparatus, invented by Dr. Hare, by which steam is decomposed by passing over hot iron. The gun-barrel to which the retort is cemented, is fitted at its opposite end with a flexible leaden tube, for the purpose of conducting off the hydrogen gas. Within the gun-barrel (Fig. 61.) is introduced a quantity of iron turnings, or refuse card teeth. The glass retort is partly filled with water. A quantity of charcoal within the furnace being ignited, soon heats the gun-barrel to a red, and then to a white heat. In the meantime, a chafing dish of burning coal is placed under the retort; the water soon boils, is changed to steam, which passes through the gun-barrel and parts with its oxygen to the metal, while the hydrogen escapes through the flexible leaden tube, and may be collected.

It has been shown, (308, *Exp.* 1st.) that when water is subjected to the action of the galvanic pile, it will be decomposed, and hydrogen will appear at the negative, and oxygen at the positive pole. Let a glass tube be filled with water, corked at both ends, and the two wires of the galvanic circle, then put through the corks. The water being acted upon by galvanic electricity, its elements separate, hydrogen being attracted to the negative pole, and oxygen to the positive.

315. The composition of water may be proved by analysis.

Exp. Analysis of water by means of an apparatus invented by Dr. Hare. Analysis by galvanic action.



Water.

Hydrogen 1	Oxygen 8
---------------	-------------

Chem. Equiv. 9.

316. The figure represents the comparative bulk of the atoms of hydrogen and oxygen as they exist in water ; the former being twice as large as the latter, as is ascertained by the bulk of the two gases obtained by the decomposition of water. As the weight of the atom of oxygen is found to be 8, while that of the atom of hydrogen is 1, it follows that the specific

gravity of oxygen is sixteen times greater than that of hydrogen ; so that if its ultimate atom had the same bulk as that of hydrogen, its combining number would be sixteen instead of eight.

317. *Natural history.* Water, as obtained from the usual sources, is impure. Rain water collected at a distance from buildings, is less impure than that from springs, or that which has fallen from the eaves of houses, but still contains several gases, the odoriferous matter of plants, with traces of animal and saline matter. The animal and vegetable matter contained in rain water, causes its tendency to putridity. Spring and river water, in addition to the same impurities which exist in rain water, contain several *salts* which they acquire from the soil, and of which sulphate of lime is one of the most frequent. To these salts, water owes the property commonly called *hardness* ; that is, the property of decomposing soap, (or of *curdling* it, as it is usually termed ;) for soap, is in reality, a salt, being composed of acid and alkali ; so that when it meets an earthy salt in solution, a double decomposition ensues ; the soap and the salt exchange acids, and two new salts are formed, one of which floats on the surface of the water. A solution of pearlash, shows the presence of these salts, by producing a white precipitate. The white deposit on the inside of a tea-kettle, in which spring water has been much boiled, is a mixture of carbonate and sulphate of lime.

318. The spring water of some localities is harder than that of others, because some soils contain more of soluble salts than others. The presence of these saline substances, not only communicates a somewhat nauseous taste to water, but injures its solvent powers in some particular instances ;

316. Comparative bulk of the atoms of hydrogen and oxygen. Specific gravity of oxygen compared with hydrogen.

317. Impurities of water. Rain water. Spring and river water. Cause of the hardness of water. Why hard water decomposes soap. Tests of the presence of salt in water. Cause of the white deposit on the inside of a tea-kettle.

318. Why the water of some springs is harder than others. Why soft water is better for making tea than hard water. Effect of boiling or freezing water in relation to its impurities. Distillation of water.

thus, it has been found that of equal portions of rain and spring water, the former will extract from a given portion of tea, a considerable greater quantity of its soluble matter than the latter. The gaseous and other volatile bodies contained in water, may be expelled by boiling it; they also partially escape, when water freezes, so that water in sufficient purity, for many purposes, may be obtained by melting fresh fallen snow. Such water is flat, tasteless and insipid; the liveliness of water, in its ordinary state, being due to the gases it holds in solution. But the only way of obtaining perfectly pure water, is by distillation in silver vessels, in which process, the saline impurities remain in the distilling vessel, while the water is converted into vapor and passes into the condenser.*

319. *Physical Properties.* Pure water is transparent, colorless, tasteless and inodorous: a non-conductor of caloric, an imperfect conductor of electricity, and a powerful refractor of light. It is the unit of specific gravity for solids and liquids, and is 828 times heavier than air. At 212° F., the barometer standing at 30 inches, the water boils; it freezes at 32° , and in congealing, shoots into needle shaped crystals, which cross each other at angles of 60 and 120° .

320. If the aeriform bodies that previously existed in water, be expelled by boiling, it absorbs every gas, but in very different proportions; some gases being dissolved in very minute quantities, while of others, water will take up several hundred times its own bulk. The quantity absorbed may be increased by pressure, and is in direct proportion to it; on removal of the additional pressure the excess of gas escapes with effervescence, as in the instance of common soda water. The gas contained in water under ordinary atmospheric pressure, is expelled by heat, or by removing the pressure with an air pump. Water has a very extensive range of affinities, and is, therefore, an important chemical agent; it is the most general *solvent* we possess.

321. Water enters into two kinds of combination besides solutions, and in these it unites in definite proportions; these combinations exist 1st, in *crystals*; 2nd, in *hydrates*.

1st. Many bodies in crystalizing from their solutions in water, carry with them a portion of water which constitutes an essential part of the crystal, and which cannot be separated without destroying its form and transparency. Water thus combined, is called water of *crystalization*. It is believed to be in a state of greater solidity in this combination than in the form of ice. It may be expelled by heat; and the crystal will then fall into powder.

2nd. Water exists in another class of compounds called *hydrates*. Some of these are liquids; for example, the strongest sulphuric acid of commerce

* A coffee apparatus invented in France, makes the *vapor* of water pass through the ground coffee. The aromatic portion is thus extracted, with less of the bitter principle, than in the usual method. The water being distilled before it comes in contact with the coffee, all the impurities of the former are left in the boiler.

319. Physical properties of water.

320. Absorption of gases by water. Effect of pressure on absorption
Solvent power of water.

321. Compounds where water exists in definite proportions. Water of
crystalization. Liquid, and solid hydrates.

contains an atom of water to an atom of acid, and is therefore a hydrate of sulphuric acid; the strongest nitric acid, that can be produced consists of one equivalent of acid and two of water. Many hydrates, however, are solid; and the water they contain is in the greatest state of condensation in which it is known. Much caloric is consequently evolved during the formation of hydrates; thus, in the slaking of lime, which operation is in fact the conversion of pure lime into a hydrate, the heat evolved, amounts to 800° F. Some hydrates are decomposed by heat; but others retain the combined water at the highest temperatures.

322. *Deutoxide of Hydrogen.* 2 ox. 16, to 1 hyd. 1=17, its equivalent. This is called deutoxide, (or *binoxide*) because 2 atoms of oxygen combine with one of hydrogen; and sometimes the *peroxide*, it being the highest combination known of oxygen with hydrogen. It was discovered by Thenard in 1818.

This substance, cannot be formed by the direct union of the two gases. The only method at present known, is the oxidation of water by means of the *peroxide of barium*. In this process is added to water a portion of hydrochloric acid, and the peroxide of barium; the latter, parting with oxygen, is reduced to a protoxide which unites with the hydrochloric acid, while the liberated oxygen unites with the water, converting it into *deutoxide of hydrogen*. Sulphuric acid is added to precipitate the protoxide of barium.

323. The deutoxide of hydrogen is transparent and colorless, heavier than water, its sp. gr. being 1.452; it is volatile, inodorous, and has a metallic taste. It thickens the saliva, whitens the skin, and is, to a degree, caustic. It bleaches powerfully; its oxygen being considered the active bleaching principle. It is very easily decomposed, either by the contact of other bodies or by heat; and can only be preserved by keeping it at a temperature of about 32° F. If heat be applied to it in its concentrated state, half of its oxygen suddenly escapes with a violent explosion, and the residual product is water. The deutoxide of hydrogen has not been applied to any of the arts, and at present is only interesting to the Chemist, as a peculiar and striking illustration of the doctrine of definite proportions.*

CHAPTER XIII.

HYDRACIDS.

324. A class of substances possessing acid properties are termed *hydracids*, (or *hydro acids*,) because they contain hydrogen as

* See Thenard's *Traité de chimie*, and other elaborate works on this subject.

322. Proportions of the deutoxide of hydrogen. Name. Discovery. Manner in which it may be formed.

323. Properties. Decomposition. Effects of heat upon it. Its action with metals and oxides. Its application to useful purposes.

one of their elements. Acids are the most remarkable products obtained by the union of both oxygen and hydrogen with other bodies. And yet, these two gases, so powerful in their combinations with other bodies, and standing each at the head of two distinct electro-chemical classes, form by their natural combination with each other, the mild, inoffensive compound, water, with no trace of acid properties whatever.

Some of the *oxacids* or oxyacids, we have already noticed, as Chloric, Iodic, Bromic and Fluoric acids; and as we proceed to consider the electro-positive bodies, we shall have occasion to describe other important acids formed by a combination of those bodies with oxygen.

All acids are formed by the union of a substance called the *base* or radical, with an acidifying principle. In chloric acid, *chlorine* is the *radical* and *oxygen* the *acidifier*.

325. Of the radicals of the hydracids, some are simple bodies, and others compound. All the simple radicals are electro-negative, except sulphur; and even that is so while in combination with other electro-positive bodies. The compound radicals are electro-positive in relation to oxygen and other substances of the same class, but go to the positive pole, (and therefore, are electro-negative,) when just separated from combination with hydrogen or a metal. So that as regards the part, they act in composition of a hydracid, they may all, (both simple and compound,) be considered as *electro-negative*. They all have feeble affinities for compound bodies, but powerful ones for the simple electro-positive substances, and when their compounds with the latter are put into water, (provided they be soluble,) that fluid is decomposed, its oxygen unites to the electro-positive elements to form an oxide, and its hydrogen unites to the electro-negative radical to form a hydracid. If the oxide thus formed be a salifiable base, it combines with the hydracid to form a salt; if the compound put into water be insoluble, no action takes place. Thus common salt is *chloride of sodium*; dissolved in water it is *muriate of soda*, hydrochloric acid being formed by the chlorine and the hydrogen of the water, and soda by the sodium and the oxygen of the water; but chloride of silver is quite insoluble in water, and undergoes no change in it. When a salt of a hydracid has been thus formed, the binary compound of the radical and the metal may be again obtained, by evaporating the solution to dryness, and heating the dry mass to expel the water which is re-formed.

326. The compounds of metals with the radicals of hydracids are called *Haloid* bodies, from their resembling salts in their characters and habitudes; the name *haloid* being derived from the Greek *hale*, sea-salt and *oidos*, like.

324. Why are the hydracids so named? Products of the union of oxygen and hydrogen with other bodies, and with each other. The radical and acidifying principle of acids.

325. Radicals of the hydracids. Electrical nature of the simple and compound radicals. Effect of water in decomposing compounds formed between electro-positive and electro-negative bodies. Change which takes place in the chloride of sodium when dissolved in water. How may the chloride of sodium, or binary compound of the radical and metal, be again obtained?

326. Haloid bodies. Five most important radicals of the hydracids. Order of their affinities for hydrogen. Their affinities for oxygen.

Indeed, as had just been stated, they appear to become salts on being dissolved.

The five most important of the simple radicals of the hydracids are,

- | | |
|--------------|--------------|
| 1. Chlorine, | 3. Iodine, |
| 2. Bromine, | 4. Fluorine, |
| 5. Sulphur. | |

Fluorine having never been obtained in a separate state, the comparative energy of its affinity for hydrogen is not ascertained. Neither is it known whether it can combine with oxygen or not. The other four radicals, are placed in the above list according to the order of their affinities for hydrogen; so that chlorine will decompose hydrobromic, hydriodic and hydrosulphuric acids, forming hydrochloric acid and liberating the other radicals; Bromine acts in the same way with hydriodics and hydrosulphuric acids; and iodine with hydrosulphuric acid only. The affinities of these bodies for oxygen, are in the inverse order of their attraction for hydrogen: sulphur having the greatest, and chlorine the least affinity for oxygen.

327. The hydracids may be obtained, by pouring strong sulphuric acid on certain compounds, of their respective radicals with a metal. The water, which even the strongest liquid sulphuric acid contains, furnishes hydrogen to the radical and oxygen to the metal; the metallic oxide thus formed, unites to the sulphuric acid and forms a sulphate, and the hydracid is left free. The hydracids are all, in reality gases; those of chlorine, bromine and iodine contain equal volumes of the two constituents, united without any condensation, so that one volume of the radical and one of hydrogen constitute two volumes of the hydracid. The specific gravity of these three hydracids is therefore half the sum of the specific gravities of their constituents. The gaseous hydracids are generally heavier than air, and have strong attraction for water. Some of them are absorbed by that liquid to the amount of several hundred times its bulk. During the formation of these watery solutions, condensation takes place, heat being evolved, and the liquid resulting is heavier than water. It is in this state of solution that the hydracids are used in chemical operations; heat will expel from the liquid the greater part of the gaseous acid.

328. The hydracid gases are decomposed when electrified with the proper quantity of oxygen gas, water being formed and the radical set at liberty; some of the metals also, decompose them with the aid of heat, uniting with the radical and liberating the hydrogen.

The liquid hydracids, that is the solution of the gaseous acids, act differently on different metallic oxides; with some protoxides, the acid combines to form salts; with others, a mutual decomposition occurs, and water is produced, together with a binary compound of the radical and the metal; but, in such cases, the latter compound is insoluble. Some of the peroxides yield a portion of their oxygen to the hydrogen of the acid, forming water and eliminating the radical; and thus are reduced to the state of protoxides, which combine with the radical acid and form salts. The first process given for obtaining chlorine, (§ 262,) is an example of this decomposition. With some oxides the hydracids do not re-act in any manner.

327. Manner in which the hydracids may be obtained. Nature and constitution of the hydracids. Attraction of the gaseous hydracids for water.

328. Their decomposition. What are liquid hydracids, and how do they affect metallic oxides?

329. *Hydrochloric* or *muriatic acid*. 1 chl. 36, to 1 hyd. 1=37. Sp. gr. 18. 21 hyd.=1, 1.2694 air=1.

This was at first known under the names of *marine acid*, and *spirit of salt*, and was regarded as an oxacid, formed by the union of oxygen with an imaginary base, named *muriatium*; afterwards it was called *muriatic acid* (from *muria*, sea-salt) which name it retained until the importance of shewing the constituents of bodies by their chemical names had become fully established.

Fig. 62.



It is obtained by pouring strong sulphuric acid on *chloride of sodium*, (common salt,) contained in a tubulated glass retort A, (Fig. 62) and applying heat at C. The tube of the retort, B passes under a receiver filled with mercury and inverted over a mercurial trough. The *water* of the sulphuric acid furnishes *oxygen* to the *sodium*, and *hydrogen* to the *chlorine*; the newly formed *oxide of sodium*, unites with the *sulphuric acid* forming *sulphate of soda*, and the *hydrochloric acid* being disengaged, pas-

ses through the tube of the retort into the receiver. The dense white fumes which appear over the mercurial trough, are caused by the escape of some portion of the hydrochloric acid gas, which unites with the aqueous vapor of the atmosphere.

330. *Physical Properties*. Hydrochloric acid is colorless, transparent, and of a peculiar odor. It is irrespirable when pure; but if diluted with air, may pass into the lungs, but, even in that case, it exerts a corrosive action on them. Its affinity for water is great, a volume of that fluid absorbing 480 volumes of the gas, and forming the *liquid muriatic acid*.

331. The process of forming hydrochloric acid, is very conveniently performed, by an apparatus called, from its inventor, Woulfe's apparatus. (Fig. 63.) The retort *a*, contains common salt and sulphuric acid; a gentle heat being applied, the muriatic gas is disengaged and passes into the globe or first bottle, *b*, which, with the other bottles, contains water. The first bottle serves to condense any vapor which may be mingled with the muriatic acid gas, and the liquid in this will then be an impure solution of *muria-*

329. Equiv. and sp. gr. of hydrochloric acid. Synonymes. Mode of obtaining hydrochloric acid. Rationale of the process.

330. Properties.

331. Mode of obtaining hydro-chloric acid by means of Woulfe's apparatus. Why should the bottles be kept cool? Further proof of the affinity of this gas for water.

tic acid. From the globe *b*, the purified gas proceeds through the bent tube to the next bottle, where a portion is absorbed by the water; the excess of gas then passes on, and a portion is, in like manner, absorbed by the liquid. Should some portion of the gas escape absorption, it may by the last tube be conducted under a receiver in the pneumatic cistern. The number of bottles may be increased or diminished. The straight tubes *c, c, c*, are called safety tubes. While they oppose atmospheric pressure to the escape of the gas, they prevent the vacuum which would ensue from a sudden absorption of the gas, and which might draw in the impure acid contained in the globe.

Fig. 63.



During this absorption a great condensation takes place, and heat is consequently evolved; so that the bottles used to contain the liquid must be kept cool by ice, in order that the solution may be saturated. As a further proof of the affinity of this gas for water, if a piece of ice be put into a jar of the gas, it will be melted almost as rapidly as by a hot iron; and the gas is absorbed by the water thus formed.

332. *Chemical properties.* This gas possesses acid properties in a very high degree; combining with salifiable bases, reddening litmus paper, &c.; many of the metallic oxides react on it by the aid of heat, water and *chloride* of the metal being formed; several of the metals also decompose it by means of their affinity for chlorine; in such cases, a chloride of the metal is formed and hydrogen gas set free. It is the only known compound of chlorine with hydrogen, and composed of equal bulks of chlorine and hydrogen gases, united without any condensation.

333. *Nitro-hydrochloric or Nitro-muriatic acid* consists of 1 part of nitric acid with 4 of hydrochloric. It was called by the alchemists *aqua regia*, on account of its remarkable property of dissolving gold and platinum. Soon after the acids are mixed, the liquid grows deeper colored, and, at last, becomes wine colored, and chlorine is evolved. On heating the mixture, chlorine and deutoxide of nitrogen are expelled, after which it no longer dissolves gold; hence it appears that chlorine is the cause of its solvent property with regard to that metal.

334. *Hydrobromic Acid* is composed of equal volumes of vapor of bromine

332. Chemical properties.

333. Nitro-hydrochloric acid.

334. Composition of hydrobromic acid gas in respect to weight and volume. Resemblance to muriatic acid. How obtained?

and of hydrogen. In odor, and in other properties it resembles hydrochloric acid. Thus it forms salts with some oxides, and is decomposed by others; it has a powerful affinity for water. It is obtained by exposing bromine to the action of sulphuretted hydrogen gas, when the former takes the hydrogen, and sulphur is deposited; or, by mixing bromine, phosphorus and water in a small retort and applying heat; in which case, the phosphorus and bromine join in decomposing water, the former taking the oxygen and the latter the hydrogen. It was discovered by M. Balard.

335. *Hydriodic Acid* contains one volume in bulk of iodine vapor, and one of hydrogen gas, combined without alteration of bulk. It is consequently, constituted like hydrochloric and hydrobromic acid gases, which it also resembles in its general properties; being decomposed by the same agents and under the same circumstances. The analogy extends even to its odor and its solubility in water. As the affinity of iodine for hydrogen is less than that of either bromine or chlorine, those substances will each decompose hydriodic acid, forming the corresponding hydracid, and eliminating iodine. Hydriodic acid gas, may be made by bringing iodine into contact with sulphuretted hydrogen gas, when sulphur will be set free, and iodine will take its place; but this process is not commonly to be preferred. The best way of procuring this gas, is to moisten a mixture of iodine and phosphorus, in a very small retort, and apply heat, collecting the gas over mercury. As in the formation of hydrobromic acid gas, the oxygen of the water is taken by the phosphorus; so in this case, the hydrogen combines with iodine. The solution of hydriodic acid gas in water, or *liquid hydriodic acid*, is best obtained by passing hydrosulphuric acid gas into water in which iodine is held suspended; the oxygen of the water disengages the sulphur, and the hydrogen combines with iodine.

336. We have treated of *hydrofluoric acid*, under the head of its radical, fluorine. *Hydrosulphuric acid*, will be considered under the head of *sulphuretted hydrogen*, the name by which it is usually distinguished. *Hydrocyanic acid*, is a hydracid of a very peculiar nature, but cannot be well understood, until after the composition of its radical *cyanogen* shall have been explained.

CHAPTER XIV.

NITROGEN.

$$337. \text{Equiv. } \left\{ \begin{array}{l} \text{by vol. } 100 \\ \text{" weight } 14 \end{array} \right\} \text{ Sp. gr. } \left\{ \begin{array}{l} 0,9722 \\ 14 \end{array} \right. \begin{array}{l} \text{Air}=1 \\ \text{Hyd.}=1 \end{array}$$

Nitrogen is a permanent gas, and constitutes nearly four fifths of the atmosphere in bulk, If a lighted taper be covered

335. Composition of hydriodic acid gas. Its analogies with hydrochloric and hydrobromic acids. May be decomposed by them. Mode of obtaining it. Liquid hydriodic acid.

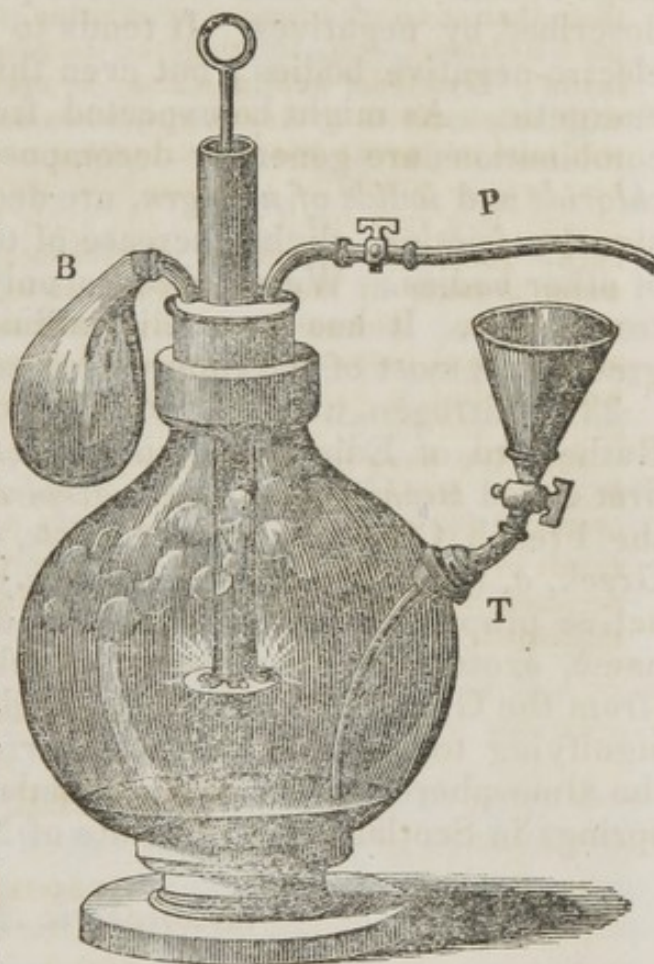
336. What other hydracids are there besides the hydrochloric, hydrobromic, and hydriodic?

337. State in which nitrogen exists. Gas which remains when the oxy-

with a large tumbler, or bell glass, the combustion will soon consume the oxygen of the air, and nitrogen will remain. For experiments, nitrogen may be better obtained by burning phosphorus under a bell glass inverted over water. The phosphorus, combining with the oxygen of the air, forms phosphoric acid, which appears at first in dense white fumes, but soon settles upon the surface of the bell glass, and may be rinsed off in the water. The oxygen being now absorbed from the air, the bulk of the residue will be found, when cooled, to be condensed,* and on testing its properties it will be found to be nitrogen.

Dr. Hare has invented the apparatus here represented (Fig. 64.) for obtaining nitrogen in large quantities. Phosphorus is placed in a cup suspended in a glass vessel. Water is introduced by means of the tunnel T. The bladder, B, gives room for the expansion of the air which takes place when the phosphorus is burning. The nitrogen gas having been obtained by means of consuming the oxygen, it is expelled by pouring more water into the funnel, which taking its place in the lower part of the vessel expels the gas through the tube P, the stop cock being turned so as to admit it to pass. The gas is thus received into vessels for the purpose of experiment. Slight impurities consisting of carbonic acid, and vapor of phosphorus, may be removed by solution of caustic, potassa, or lime. Several other substances, having affinities for oxygen will absorb it slowly from air, among these, are, protosulphate

Fig. 64.



of iron, and the alkaline hydrosulphurets. Carbon and sulphur, do not consume the oxygen of the air so completely as phosphorus does, and the products of their combination are sulphurous and carbonic acids, which being both gaseous, would, therefore, remain mixed with the nitrogen, and require

* The fact of this diminution of bulk is known by the water over which the bell glass is inverted rising higher in the glass than before the burning of the phosphorus.

gen in an inclosed portion of atmospheric air is burned. Obtained for experiments. Objections to the use of carbon and sulphur. Obtained from animal matter. Explain fig. 64.

a separate process for removing them. Nitrogen is a constituent of animal matter, and may be obtained by its digestion in diluted nitric acid.

338. *Physical and Chemical properties.* Nitrogen is colorless, transparent, tasteless, inodorous, permanently elastic, and lighter than common air. It does not support the combustion of burning bodies, neither will an animal live in it; but in neither of these cases, is it supposed to exert any positive action; the effects being due merely to the absence of oxygen; as the innoxious substance, water, will extinguish flame or destroy animal life by excluding the air, and consequently the oxygen which is necessary to support combustion and respiration. Indeed, nitrogen seems to possess no active properties, and can only be described by negatives. It tends to combine mostly with the electro-negative bodies; but even these affinities are not very energetic. As might be expected from its weak affinities, its combinations are generally decomposed with great facility; the *chloride* and *iodide of nitrogen*, are decomposed with loud explosion by friction, slight increase of temperature, or the contact of other bodies. Water absorbs only a minute portion of nitrogen gas. It has a peculiar affinity for caloric, and is an ingredient in most of the fulminating compounds.

339. Nitrogen was discovered about the year 1770, by Dr. Rutherford of Edinburgh, and Scheele of Sweden. It was at first called *mephitic gas*, or *non-respirable air*, and afterwards by the French Chemists, named *azote*, or *life destroyer*, (from the Greek, *a*, to deprive of, and *zoe*, life.) The latter name implies active properties, such as this gas does not possess. For the name, *azote*, has been generally substituted that of *nitrogen*, (from the Greek word *gennao* to produce, combined with *nitro*,) signifying to produce *nitro*, or *nitric acid*. It constitutes $\frac{4}{5}$ of the atmosphere, exists in all animals and some plants, and in springs in Scotland and the state of New-York.

Atmospheric Air.

340. The atmosphere is a mass of gaseous matter, surrounding the earth and accompanying it in its revolutions. It possesses *weight*, upon which property depends the action of the *sucking pump*, the *barometer*, and the *support of water or mercury in an inverted bell glass*, above the level of the exterior liquid.

On weighing a glass flask full of dry air, exhausting it carefully, and

338. Its physical properties. Is not a supporter of combustion. Its affinities not energetic. Why its compounds are easily decomposed.

339. Discovery and name.

340. Nature of the atmosphere. Its weight.

weighing again, it will be found to lose weight by the exhaustion in the proportion of $30\frac{1}{2}$ grains for every 100 cubic inches of air withdrawn;—this being when the barometer stands at 30 inches, and the thermometer at 60° Fahrenheit. Air is, therefore, 831 times as light as water, and about 11260 times as light as mercury. It is taken as the unit of specific gravity for aeriform bodies.

341. From the observations of Dr. Wollaston and others, it seems to be established that the atmosphere is limited; and its extent is estimated at about 45 miles. As the air is more and more rare, as the distance from the earth increases, and as its expansive force decreases in the same ratio as its density, it follows, that there must be a point at which its elastic force is just counteracted by the earth's attraction. If the atmosphere were to expand without limit into space, the sun and the other planets would attract a portion of it to themselves, and would have atmospheres of the same kind as ours; a circumstance which is quite inconsistent with astronomical observation. Dr. Wollaston, from a series of observations, considers that this extreme rarefaction might take place, but for the fact that the atmosphere consists of indivisible ultimate atoms, that can be no farther rarefied.

342. The atmosphere is highly elastic and compressible. When the pressure upon a confined portion of it is doubled, it will be reduced to half its original bulk; or, if half the original pressure be removed, it will expand to double its former bulk; in other words, its *density is directly as the pressure*, and its bulk in the *inverse ratio* to that pressure. This law is good also, for all aeriform bodies, so long as they continue in the aeriform state.

343. The temperature of the air is lower as we ascend, for as it must absorb caloric in order to expand, and this can be derived from no external source, it must render latent its own sensible heat; for radiant caloric passes through gaseous and aeriform media, without affecting them; so that the higher strata of air, though nearer the sun, derive no heat from it. The decrease of temperature is estimated at about one degree for every 300 feet; so that there is, in every latitude, some point in the atmosphere at which ice never melts. This point at the equator, is about 15207 feet from the earth's surface; and the distance decreases gradually toward the poles, where it is at the earth's surface.

344. The atmosphere is essentially composed of nitrogen and oxygen gases. Many other bodies are found in it, such as carbonic acid, watery vapor, the odoriferous matters of plants, &c. &c.; of these, the first two are the most constant, and in the greatest quantity; but even they vary in their proportions, which are never so large, compared to the whole mass, as to allow us to consider these bodies otherwise, than as accidental impurities. The carbonic acid is never more than 6.2 parts in 10.000 of air.

341. Limited extent of the atmosphere. Dr. Wollaston's argument drawn from the limited extent of the atmosphere respecting ultimate atoms,

342. Elasticity and compressibility of the atmosphere. Temperature,

343. Gradual decrease of temperature,

344. Composition of the atmosphere,

Eudiometry.

345. After the discovery of oxygen, it was for some time believed, that the proportion in which it was contained in the atmosphere, varied at different times and places; and that the salubrity of a place, depended on the quantity of oxygen in the air around it. Hence the analysis of air was called "Eudiometry," or the "measurement of quantity," and this name has been retained, though the supposition from which it arose, has been shown to be false.

Many *eudiometers* have been invented. They consist, in general, of tubes adapted to an apparatus for absorbing, or consuming the oxygen of a given quantity of air, and for measuring the residuum. The purity of the air is estimated by the quantity of oxygen which it is found to contain. Various substances which will absorb, or disengage the oxygen from a confined portion of air, and neither mix with, nor affect the volume of nitrogen, have been used in eudiometry. But the only analysis of air susceptible of perfect accuracy, is founded on the constancy of the proportion in which oxygen and hydrogen unite when burned together.

346. If we put into a strong tube inverted over mercury, 5 measures of dry air, and add to this, 2 measures of pure and dry hydrogen gas, and then explode the mixture by the electric spark, or otherwise, we shall find after the tube has cooled, that just three measures have disappeared, and that the mercury has risen to fill their places. Now of these *three* measures, *two* we know to be hydrogen; and we also know that two measures of hydrogen, by explosion, condense *one* measure of oxygen. If we add more hydrogen to the residual four measures of gas, we can no longer produce an

Fig. 65. explosion; whereas, if we had not originally added enough hydrogen, there would still have remained an excess of oxygen after the experiment.



347. Five measures of air, then, contain exactly one measure of oxygen; and the remaining four measures, on examination, will prove to be nitrogen. This is the composition of atmospheric air; and the same unvarying result has been obtained at whatever season, height, or latitude the air may have been collected for experiment. So that it may be considered established that the atmosphere throughout, its whole mass, consists of nitrogen and oxygen gases in the proportion of 80 per cent. of the former, and 20 per cent. of the latter. The apparatus for performing the analysis, has been made in various forms. It is always, essentially, however, a strong glass tube *a*, (Fig. 65.) open at one end; and perforated near the closed end, by two metallic wires *b b*, of which the points are opposite and within one tenth of an inch of each other. These wires serve for passing an electric spark into the mixture of gases.

345. Origin of the term eudiometry. Construction and use of eudiometers.

346. Manner in which the constitution of the air may be demonstrated. Proportions of oxygen and nitrogen contained in it. These proportions do not vary.

347. Apparatus for analyzing the air.

348. The atmosphere is generally regarded as a *mechanical mixture* of the two component gases. Some, however, prefer the supposition, that it is a *chemical compound*. The reasons for the latter opinion are, briefly,

1st. That the proportions of nitrogen and oxygen are everywhere the same; whereas, if air were a mere mixture, the heavier gas would be found most abundantly, in the lower strata. 2nd. The proportions are definite, and accord with the numbers established as the atomic weights of oxygen and nitrogen; agreeably to which, the atmosphere consists of two atoms of the latter to one of the former.

But the investigations of Mr. Dalton, and especially of Dr. I. K. Mitchell of Philadelphia, have proved, that gases have a strong tendency to diffuse themselves through each other, contrary to gravity, and in spite even of the interposition of a bladder or thin sheet of india rubber; and this, too, when no chemical affinity can be supposed to exist between them. If we fill a phial with hydrogen gas, and another with carbonic acid gas, connect them only by a capillary tube, and place them so that each gas shall be in its natural position, viz., the light hydrogen above, and the heavy carbonic acid below; it will be found after some time, that the carbonic acid has ascended, and the hydrogen descended, contrary to gravity in each case; and that the gases are equally mixed in both phials. In this case, no chemical affinity has been supposed to exist between the gases operated on. Furthermore, the facility with which bodies possessing affinities for oxygen, attract it from the atmosphere, is too great to admit the belief that it is chemically combined there. Again, the specific gravity and refracting power of the air, are arithmetical means between those of nitrogen and oxygen; whereas, in cases of chemical combination, these two properties seldom escape alteration. And lastly, by merely mixing the two gases in the proper proportions, we can imitate the atmospheric air perfectly; whereas, it is only with great difficulty that we can make them combine, so as to produce one of the undoubted compounds of nitrogen and oxygen. It seems, therefore, highly probable that the atmosphere is a mere mixture of its components.

349. The oxygen of the air is the active constituent; to it are owing the agencies of air in supporting combustions and respirations, and in most of the chemical changes in which it is concerned. The use of the nitrogen is not fully ascertained. It is generally held to be a mere diluent, by means of which, the oxygen is prevented from stimulating the system too highly. There is, however, little doubt that some nitrogen is absorbed in the process of respiration. It might be supposed that the immense consumption of oxygen in combustions, respiration, spontaneous decompositions, and other operations, which are incessantly going on, would ultimately alter the proportions of the constituents of the atmosphere, to an extent that would render it unfit to perform its office. Doubtless this would be the case without some compensating circumstance. Only one such circumstance is known, and that is *vegetation*. It is ascertained that plants in the day-time, absorb carbonic acid, of which they appropriate the carbon, and restore the oxygen to the atmosphere. In the night, the contrary process goes on; the vegetables absorb oxygen and evolve carbonic acid. But it appears that the quan-

348. Objections to the theory that air is a chemical compound of the gases and not a mere mechanical mixture. Answer to these objections and arguments in favor of the theory.

349. Agencies of oxygen and nitrogen in the atmosphere. In what manner is it known, that air is replenished with oxygen, to make up that which it loses by combustion, respiration, &c. Do the other compounds of nitrogen and oxygen resemble atmospheric air?

tity of oxygen absorbed in the night, is less than that given out during the day; so that vegetation *tends* to preserve to the atmosphere its due portion of oxygen. Whether this cause is alone sufficient, or whether oxygen is furnished by other sources is a question yet to be decided.

On account of the doubt which exists, whether air is a mechanical mixture or chemical compound of nitrogen and oxygen, we have treated of it under a separate head. All the *certain* chemical combinations of these two gases, are widely different in their properties, from this mild and inoffensive agent.

Chemical Compounds of Nitrogen and Oxygen.

350. There are *five* compounds of nitrogen and oxygen, all of which conform strictly to the law of multiple proportions. The three highest in oxidation are acids; at the ordinary temperature, their natural form is that of liquids, exceedingly volatile, and uniting in all proportions with water. The remaining two are gases, neither acid nor alkaline, and with little affinity for water.

Definite compounds of oxygen and nitrogen.

Protoxide of nitrogen,	Nitrogen 14	added to oxygen 8
Deutoxide of nitrogen,	" 14	" " 16
Hypo-nitrous acid,	" 14	" " 24
Nitrous acid,	" 14	" " 32
Nitric acid,	" 14	" " 40

351. *Protoxide of Nitrogen* is the well known *exhilarating gas*, often called *nitrous oxide*. It is prepared, by heating nitrate of ammonia in a small glass retort, and may be collected over water, which should be warm, in order to prevent, as much as possible, the absorption of the gas. Care must be taken that the temperature does not rise above 500° F.; the melted salt should be kept in a state of uniform and moderate effervescence, till the whole disappears or enough gas has been collected.

The rationale is as follows. *Nitric acid* and *ammonia* constitute the salt called *nitrate of ammonia*. Nitric acid consists of *nitrogen*, 1 equivalent, and *oxygen*, 5 equivalents. Ammonia contains *nitrogen*, 1 equivalent, and *hydrogen*, 3 equivalents. The 3 equivalents of *hydrogen* with 3 of *oxygen* form 3 of *water*; and the remaining 2 equivalents of *oxygen* with the 2 of *nitrogen*, constitute 2 equivalents of *nitrous oxide*.

352. *Physical and chemical properties.* Nitrous oxide gas is colorless, has an agreeable but faint odor, and a sweetish taste, and dissolves in about its bulk of water at 60°. Its specific

350. How many chemical compounds of nitrogen and oxygen are there? Names and constitution of these compounds.

351. How is the protoxide of nitrogen prepared? Rationale.

352. Properties. Why do bodies burn in this with more brilliancy than in common air?

gravity is about 1.5. In mixture with an equal bulk of hydrogen, it explodes violently, on the application of flame, or the electric spark. As a given bulk of this gas contains $2\frac{1}{2}$ times as much oxygen as an equal bulk of air, bodies burn in it with proportionate brilliancy. Thus, a recently extinguished candle, of which the wick is still red hot is relighted, on being plunged into it, and burns with great splendor. Sulphur and phosphorus, previously ignited, burn very rapidly and brightly, when immersed in this gas. The combustibles, in these cases, unite with the oxygen of the gas, and set the nitrogen free.

353. *Respiration.* Exhilarating gas was shown by Davy to support respiration for three or four minutes, but no longer. It produces strong excitement, usually of an agreeable kind, with a rapid flow of ideas, and an irresistible propensity to some kind of *muscular action*. It has been supposed that by this test the real character of an individual was developed; but the grave sometimes become suddenly gay, the coward bold, the meek quarrelsome; and it might as justly be said, that insanity exhibits the real disposition. Some instances have occurred in which instant and alarming insensibility, and mental derangement have resulted from its respiration.*

354. *Deutoxide of nitrogen*, called also *binoxide*, *nitrous gas*, and *nitric oxide*. Most of the metals, and many other oxidable bodies take a portion of the oxygen from nitric acid when brought into contact with it. In all such instances, the nitric acid is reduced to some of the lower compounds of nitrogen and oxygen; and, in a few cases it is entirely deprived of oxygen, so that pure nitrogen only remains. The degree of reduction depends on the comparative affinity of the metal for oxygen. In most cases, nitric oxide is one of the products, and in some, the only one. It is evolved when copper is acted on by nitric acid moderately diluted. If the operation be performed in the open air, the *deutoxide of nitrogen* which is evolved instantly combines with *oxygen* and produces *nitrous acid*, which appears in dense red fumes; but if it be performed in close vessels, and in a retort the beak of which is plunged under water, the production of red fumes only lasts till the oxygen of the air in the vessel is

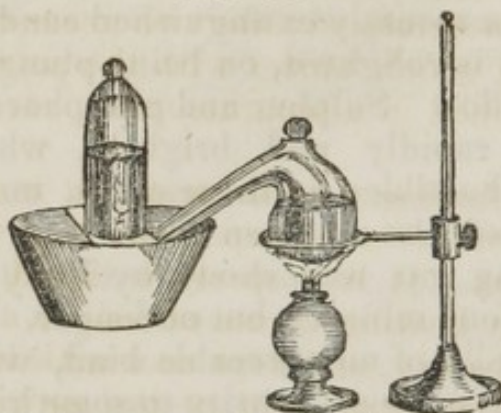
* We have witnessed several cases of fainting and spasms in young persons after inhaling the exhilarating gas, and would never advise any one to venture upon this dangerous experiment, but under the direction of a practical and experienced chemist; and we might add also with a physician near at hand.

353. Its power of supporting respiration. Effects on the human system.

354. Synonymes. How produced from nitric acid?

consumed; after which, the *nitric oxide* comes over very rapidly, and may be collected under an inverted bell glass filled with water.

Fig. 66.



355. Let some copper filings be put into a retort, (Fig. 66,) and nitric acid be poured in at the tubulure; place a lamp under the retort, the beak of the latter being immersed in water below the perforated shelf which supports the inverted bell-glass. A violent action takes place between the copper and nitric acid, and the red fumes of *nitrous acid*, fill the retort and pass over into the pneumatic tub where they are absorbed by the water; after this, the oxygen in the re-

tort being consumed, a colorless gas appears, which does not unite with water, but ascends into the bell-glass taking the place of the water with which it had been filled. This is the deutoxide of nitrogen, or nitric oxide.

356. *Physical and chemical properties.* It is colorless; its specific gravity is 1.04, and it is sparingly absorbed by water. When oxygen, either alone, or in mixture with other gases, is admitted to a jar containing nitric oxide, brownish-red fumes of *nitrous acid vapor* appear; these are immediately absorbed by water. Nitric oxide forms feeble combinations with alkalies and alkaline earths; but as it has no action on blue test paper, it cannot be considered an acid. It supports the combustion of charcoal and phosphorus, which burn brilliantly in it; extinguishes a candle and burning sulphur. Hydrogen does not explode with it, but the mixture burns with a brilliant flame, of a greenish white color. In all cases of combustion in this gas, the combustible becomes oxidized, and nitrogen gas is liberated from the deutoxide. It is irrespirable on account of its causing a spasmodic closing of the glottis. It is partially decomposed by a red heat, or by a succession of electric sparks. Iron filings attract part of its oxygen and convert it into the protoxide. Potassium, when heated in it, takes all its oxygen and liberates its nitrogen, and therefore affords an accurate mode of analyzing this gas.

357. As red fumes of nitrous acid, which are absorbed by water, are always produced when nitric oxide is mixed with atmospheric air, this property of nitric oxide is made use of in *eudiometry*, or the analysis of air, in order to ascertain the proportion of oxygen. As in *two volumes of nitric oxide*, a volume of nitrogen is combined with one volume of oxygen, (occupying the same bulk as if merely mingled,)—to convert this nitrous oxide into ni-

355. Mode of obtaining deutoxide of nitrogen.

356. Physical and chemical properties.

357. Eudiometry by means of action of the protosulphate of iron with nitric oxide.

trous acid, one volume of oxygen must be added. Of course, if nitrous acid be the product, one third of the deficit produced, would be the quantity of atmospheric oxygen present.*

358. *Hyponitrous Acid*. When a mixture of nitric oxide and oxygen is confined over mercury, with strong solution of potassa, the alkali is gradually neutralized; the two gases combining to form hyponitrous acid which unites with the potassa. This acid has not yet been obtained in a separate state. It was discovered by Gay Lussac.

359. *Nitrous Acid*, called *fuming nitrous acid*. It is very volatile, is usually seen in the form of a red vapor, and has, until recently, been described as a gas. It is properly a liquid, and may be obtained in that form, by heating nitrate of lead to a dull red heat. The receivers must be dry, and kept cool with ice or snow. The heat decomposes the nitric acid of the nitrate of lead, and resolves it into oxygen and nitrous acid. Nitrous acid is powerfully corrosive, of an orange color, pungent odor, and sour taste. It reddens litmus paper, and when added to solutions of the alkalies, seems to be converted into nitric acid, for the resulting salt is a nitrate, and not a nitrite. It boils at 82° Fahrenheit, and evaporates with very great rapidity, when exposed to air. When once mixed with air or other gases, it cannot be again liquefied without great pressure or intense cold.

Nitrous acid can be obtained in the *form of vapor*, by mixing two measures of deutoxide of nitrogen, with one of oxygen, in a glass vessel which has been dried and exhausted of air. The vapor cannot be kept over mercury, for it parts with oxygen to the metal; nor over water, for the liquid absorbs it. It unites with water in all proportions. A very weak solution is pale blue; as more of the acid is gradually added, the solution passes through several shades of green and at last becomes orange colored, like the dry acid. It is supposed that water at first decomposes nitrous acid, resolving it into nitric and hyponitrous acids, and that the blue tint is due to the latter. After the water becomes saturated to a certain point, this decomposition ceases, and the nitrous acid begins to dissolve unchanged. At this period, the red color of the nitrous, with the blue of the hyponitrous acid, produces the green. At last, the quantity of nitrous acid is such, that its color predominates over, and hides the other color entirely.

360. Nitrous acid parts, rapidly, with its oxygen to combustible bodies, metals, &c., oxidizing some with such rapidity as to set them on fire. It is commonly reduced to deutoxide of nitrogen; but in some cases of violent action, it is totally deprived

* For a description of Dr. Hare's apparatus for analyzing atmospheric air by means of nitric oxide, see *Chemistry for Beginners*, page 99.

358. Hyponitrous acid.

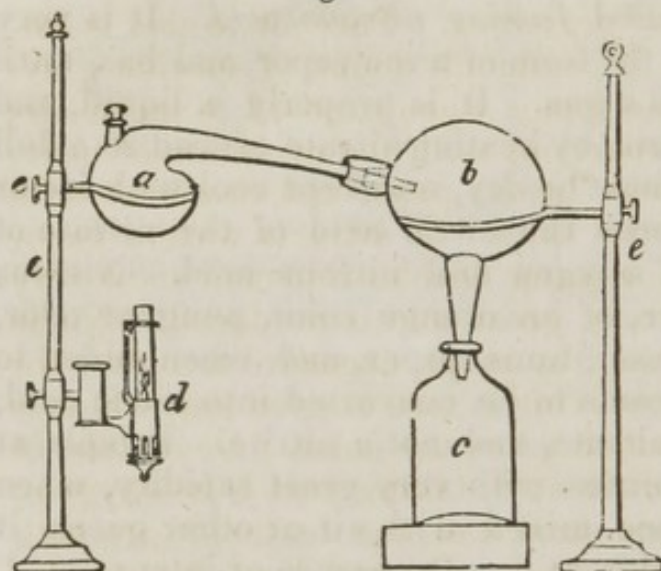
359. Nitrous acid. How obtained in the liquid form. Properties. Obtained in the form of vapor. Union of this acid with water. Changes of color in its solution.

360. Inflammable nature of nitrous acid, and decomposition.

of oxygen; and in others, it is reduced to protoxide of nitrogen. It is totally decomposed by a red heat.

361. *Nitric acid* is known in commerce under the name of *aqua fortis*. There are two kinds, the *single*, and *double*; the latter being twice as strong as the former. This acid is procured by mixing nitrate of potassa, or nitre, commonly called salt-petre with strong sulphuric acid, and distilling the mixture. The proportions differ in different manufactories, and the qualities of the acid obtained, vary accordingly. The least quantity of sulphuric acid used, is half the weight of the nitric; the largest, is an equal weight.

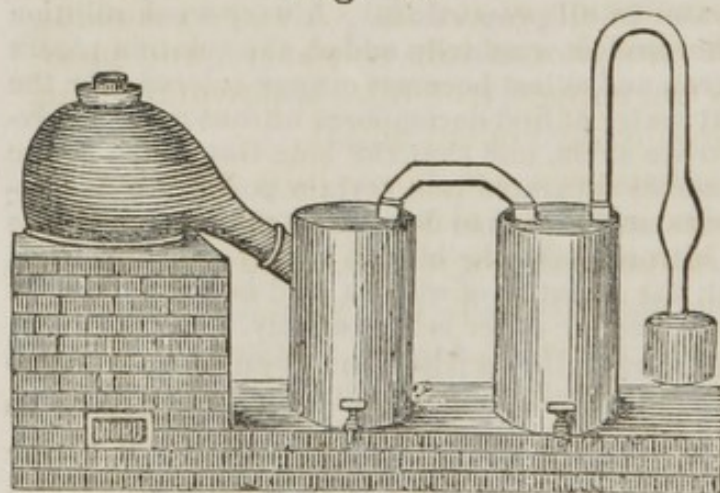
Fig. 67.



Experiment. Nitric acid on a small scale, may be procured with the apparatus here represented; *a* is a retort (Fig. 67.) containing pounded salt-petre and sulphuric acid; *b*, is a receiver communicating with the vessel *c*. The lamp, *d*, serves for heating the retort; the stands, with sliding rings, *e e*, support the retort, lamp, and receiver.

Rationale. Sulphuric acid decomposes salt-petre (nitrate of potassa,) by uniting with potassa; the nitric acid being liberated passes from the retort into the receiver *b*, and from thence into the bottle, *c*, and is absorbed by water, of which the bottle contains a small portion. On examining this water it will be found to be weak nitric acid.

Fig. 68.



Those who manufacture nitric acid for purposes of commerce, make use of large iron retorts set in brick work (Fig. 68) and communicating with receivers made of earthen ware, furnished with stop cocks, the last of which has a safety tube communicating with a vessel of water.

362. The theory of the operation in the manufactory of nitric acid, is obvious. Nitre is a compound of *nitric acid* and *potassa*, the *sulphuric acid* being added, combines with the *potassa*, and forms *sulphate of potassa*, excluding the nitric acid, which being vaporized by heat, is condensed in cool receivers.

361. Common name of nitric acid. How procured. Exp. Rationale. Manufacture of nitric acid for commerce.

362. Theory of the operation in the manufacture of nitric acid.

363. Nitric acid may be formed directly, for the purpose of demonstrating its composition *synthetically*, by passing electric sparks through a mixture of oxygen and nitrogen gases confined over a solution of potassa. It is believed that a portion of the native nitrates owe their origin to the formation of nitric acid from the elements of air, by the electric discharge during thunder storms; this acid being carried to the earth by the rain, acts on the oxides and carbonates with which it comes in contact.

364. *Physical and chemical properties.* Pure nitric acid is colorless and transparent. It is commonly found of specific gravity 1.42. It gives off white fumes when exposed to moist air; unites with water in all proportions with the evolution of heat; is sour to the taste, reddens litmus paper and combines with salifiable bases to form neutral salts. It attracts watery vapor from the air. Its affinity for water enables it to melt snow very rapidly, by which liquefaction, great cold is produced. Nitric acid becomes red and fuming, by much exposure to light; for that agent decomposes it, resolving it into oxygen gas, which is evolved, and nitrous acid which gives the color. Deutoxide of nitrogen also decomposes nitric acid, taking part of its oxygen; by which process the nitric acid and the deutoxide are both brought to the state of nitrous acid. By red heat it is totally decomposed into oxygen and nitrogen gases. It also readily parts with oxygen to most bodies which have an affinity for it, and is, therefore, a very powerful oxydizing agent. For this reason it increases the combustion of red hot charcoal; and also converts sulphur and phosphorus into sulphuric, and phosphoric acids. It oxidizes tin, copper, iron filings, powdered zinc and some other metals, producing violent action.

Animal and vegetable substances are powerfully attacked by this acid, and some of them, such as volatile oils, are set on fire by the rapid oxidation. It stains the skin yellow, destroying the cuticle, and causing deep ulceration if not speedily removed. The caustic power of *nitrate of silver*, (*lunar caustic*,) is due to the acid which enters into its composition; and the acid is occasionally substituted for the salt, as a caustic. In all these cases, the nitric acid is deprived of a part of its oxygen, and is reduced either to nitrogen, or one of its oxides.

365. The salts of nitric acid, called *nitrates*, possess the

363. Nitric acid formed by electricity. Supposed origin of some of the native nitrates.

364. Physical and chemical properties of nitric acid. Decomposition by light. By deutoxide of nitrogen. By heat. Why a powerful oxidizing agent. Its effect on animal and vegetable substances.

365. Salts of nitric acid.

power of imparting oxygen to other bodies by the aid of heat, and are therefore known as *deflagrating* salts.

We shall consider them more fully under the head of salts.

366. The most delicate of all tests for nitric acid is indigo, the blue color of which is destroyed by it, and converted into a yellow. The mode of applying the test is to dissolve some indigo in cold, dilute sulphuric acid, and add enough of the solution to produce a distinct blue color in the separated liquor; then drop in a little more sulphuric acid to take away the base with which the nitric acid is combined; the nitric acid, being thus set free, acts on the indigo.

367. *History.* Nitric acid was discovered by Raymond Lully an alchemist in distilling a mixture of *nitrate of Bologna* and clay. Basil Valentine, in the 15th century described it as the *water of nitre*. In 1785 Mr. Cavendish of England discovered it to be composed of oxygen and nitrogen.

CHAPTER XV.

NITROGEN AND ITS COMPOUNDS.

Nitrogen and Hydrogen, or Ammonia.

368. *Ammonia.* 1 nit.=14 to 3 hyd.=3. *Equiv.* 17. This is a permanent gas, colorless, and transparent, of an irritating and pungent odor, and a burning and caustic taste. It is not respirable except diluted with air. If inhaled through the nostrils, it irritates them, and produces a flow of tears. It is used medicinally to neutralize acidity in the stomach, and is a powerful tonic and stimulant.

Ammonia combines with all the acids, neutralizing them and producing a distinct class of salts, most of which are crystallizable and soluble. When ammoniacal gas is mixed with any gaseous acid, as the muriatic, carbonic, &c., dense white fumes appear, and the acid and ammonia combine to form a salt, which is deposited on the vessels as a white powder. Ammonia extinguishes burning bodies which are plunged in it. It will not burn in atmospheric air; but a small jet of it burns in pure oxygen. When a lighted candle is put into it, the flame becomes yellow, and enlarged for an instant before it is extinguished, owing to a momentary combustion of ammonia.

Ammonia may be detonated by the electric spark when in mixture with oxygen. The products of the detonation are water and nitrogen, with a

366. Indigo a test for nitric acid.

367. History.

368. Composition and equivalent of ammonia. Physical Properties. Its combinations. White fumes of ammonia, how caused? Effect of ammonia on burning bodies. Detonation. Decomposition by electricity and heat.

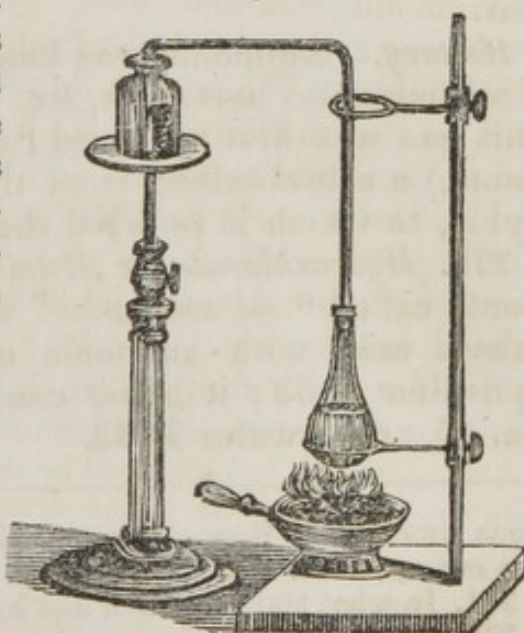
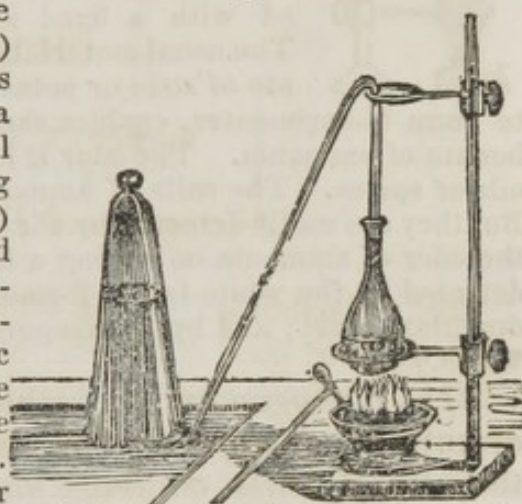
little nitric acid. It is resolved into nitrogen and hydrogen gases by a succession of electric sparks, or by passing it through red hot tubes; and the two gases occupy twice the bulk of the ammonia. By adding oxygen to the mixed gases and exploding by the electric spark, it is found to be composed of one and a half volume of hydrogen to half a volume of nitrogen, condensed to one volume; or by weight, of 3 equivalents of hydrogen and 1 of nitrogen. Ammoniacal gas is brought to the liquid state by a pressure of $6\frac{1}{2}$ atmospheres, or about 97 pounds to the square inch.

369. The alkaline properties of ammonia are well marked. It turns the yellow color of turmeric paper brown; but as the ammonia soon evaporates, the yellow color is restored. Although it is a strong alkali, its elasticity favors the decomposition of its salts; so that they are decomposed by any of the fixed alkalies, or by the alkaline earths. This fact furnishes means of procuring *ammoniacal gas*. Fig. 69.

370. The materials commonly used are *hydrochlorate of ammonia*, (sal ammoniac) and *slaked lime*. The odor of ammonia is perceived as soon as they are mixed in a mortar. The proportions used are equal weights of the two articles. On heating this mixture in a glass retort (Fig. 69.) the gas comes over abundantly mingled with watery vapor. To separate the latter, there should be an intermediate receiver containing fragments of caustic potassa, or chloride of calcium. If the latter is used, some of the gas will be absorbed as well as the watery vapor. The dried gas should be collected over mercury. *Rationale*. The lime combines with *hydrochloric acid*, and the ammonia passes off in gas. Fig. 70.

The gas of ammonia has a powerful affinity for water. Its solution is "*aqua ammonia*," and "*spirits of hartshorn*." It is the form under which ammonia is used in the operations of a laboratory. *Aqua ammonia* is obtained by passing a stream of the gas into distilled water.

Exp. The retort, (Fig. 70) containing hydro-chlorate of ammonia and lime is subjected to heat; ammoniacal gas rises, and is received in a vessel containing cold water, by which it is rapidly absorbed.

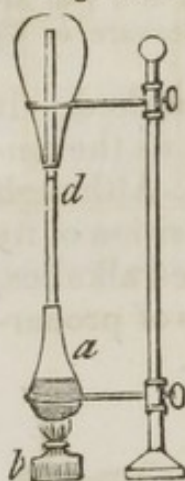


369. Its alkaline properties. Liquefaction of ammonia. Decomposition of its salts.

370. *Exp.* Mode of obtaining ammonia. Proof of its affinity for water.

The solution is transparent and colorless. It is lighter than water. If exposed to the air, it absorbs carbonic acid, and is converted into *bi-carbonate* of ammonia. A very common and convenient method of obtaining the gas is by heating the solution in a retort.

Fig. 71.



Exp. The retort *a*, (Fig. 71,) contains liquid ammonia which being heated by the lamp *b*, ammoniacal gas evolves, and as it is lighter than air, it rises and takes its place in the upper vessel.

The affinity of ammoniacal gas for water may be further shown by letting a small quantity of it escape into moist air, where on account of its union with aqueous vapor it will cause a cloudy appearance. If a piece of ice be passed into a jar of this gas, it is liquefied by it immediately; and the gas disappears, being absorbed in the water produced by the melted ice.

Smelling bottles are filled with some salt of ammonia mixed with a fixed alkali, to develop the ammoniacal gas. The usual materials are carbonate of ammonia, and carbonate of soda or potassa; for the tendency of the fixed alkalies, to form *bi-carbonates*, enables their neutral carbonates to decompose carbonate of ammonia. The odor is improved by the addition of some fragrant oils or spices. The salts of ammonia are inodorous, except the carbonate. But they are easily detected by the action of heat, and by the development of the odor of ammonia on adding a fixed alkali. Free ammonia may be also detected by the white fumes formed on the approach of a rod dipped in hydrochloric acid; and by its temporary action on moist turmeric paper. (See ¶ 369.)

371. Nitrogen and hydrogen gases cannot be made to combine directly; but in their nascent state, or at the instant in which they leave other combinations, they then unite, and form ammonia; this is always one of the products when animal matter undergoes decomposition, either spontaneously or by means of heat.

History. Ammonia was long known as *volatile alkali*, *spirit of sal ammoniac*, hartshorn, &c. Dr. Priestly called it *alkaline air*. This gas was first procured from *sal ammoniac* (or salt of ammonia,) a salt obtained from the temple of Jupiter Ammon, in Lybia, to which is referred the origin of the name.

372. *Hydrochlorate*, or *Muriate of Ammonia*. This salt, commonly called "*sal ammoniac*" is obtained by saturating hydrochloric acid with ammonia or its carbonate. Its chemical equivalent is 63; it being constituted of 1 mu. acid 37 add 1 am. 17, add 1 water 9=63.

Aqua ammonia. How obtained? Properties of this solution. Effect of this gas upon ice. Smelling bottles. Tests for the salts of ammonia.

371. In what state nitrogen and hydrogen unite. History.

372. Hydrochlorate of ammonia.

373. *Exp. 1st.* Into one retort *a*, (Fig. 72.) put a small quantity of *hydrochloric acid*, and into another *a*, *liquid ammonia*: from each liquid gases will be evolved, and passing into the cylinder unite and form dense white fumes, which at length settle in solid concretions on the inner surface of the glass cylinder; this precipitate is *hydrochlorate of ammonia*.

It may be formed directly by mixing equal measures of ammoniacal and hydrochloric gases.

Exp. 2d. Let A and B, (Fig. 73.) be two flasks with bent tubes containing the gases which meeting in the bottle C, are condensed, and form hydrochlorate of ammonia.

374. *Nitrate of Ammonia* is composed of 1 atom of nit. 1 of am. and 1 of water. It is readily formed by saturating nitric acid with carbonate of ammonia. The solution affords crystals by evaporation.

If evaporated at 100° Fahrenheit, the crystals are large, striated prisms. If at 212° Fahrenheit, the crystals are fibrous. And at 300°, no regular crystallization takes place. This salt in any form, is deliquescent. It dissolves in water so rapidly as to produce great cold, which is increased if ice or snow be substituted for water. Heat decomposes this salt at about 400° Fahrenheit. Water and protoxide of nitrogen are the products. Suddenly heated to 600°, it explodes violently, forming water, nitrous acid, deutoxide of nitrogen, and nitrogen. The tendency which the elements of the acid and alkali have to form other compounds, and the volatile nature of those compounds, will account for the explosion.

375, *Chloride of Nitrogen.* 4 Chl. 144 added to 1 Nit. 14 = 158; this substance from its composition may properly be called *quadro-chloride*, having four measures of chlorine. Chlorine does not combine with nitrogen, when both are in the gaseous state; but if one of these gases is in the *nascent* state, it will unite with the other, if present. Chloride of nitrogen is the most explosive compound known, and is exceedingly dangerous. It is exploded by a gentle heat, by slight friction, by agitation, and by the con-

Fig. 72.

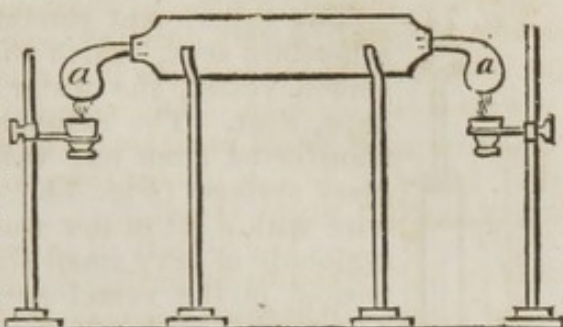
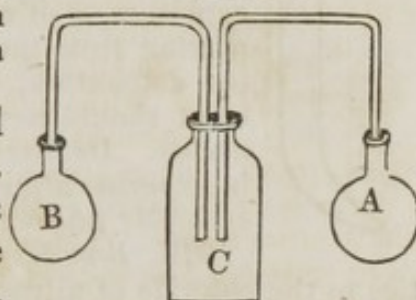


Fig. 73.



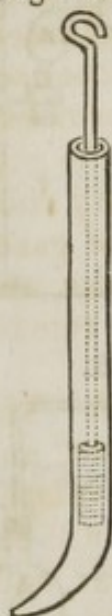
373. *Exp 1st.* *Exp. 2d.*

374. Composition of nitrate of ammonia. How formed. Crystals. Its deliquescence. Action of heat. Cause of explosion by heat.

375. Composition and equivalent of chloride of nitrogen. In what state chlorine combines with nitrogen. Explosive nature of chloride of nitrogen. Manner of transferring it. Cause of its ready decomposition. Violent explosion, and products of the detonation.

tact of many combustible substances ; as a rod dipped in olive oil produces detonation the instant of contact.

Fig. 74. The experiment should be made on a globule no larger than a mustard seed, which should be placed at the bottom of a deep leaden vessel, the water will be dispersed, and the vessel, perhaps, rent. The manner in which this yellow oil-like fluid is transferred from one vessel to another, is by drawing it into a glass syringe (Fig. 74.) having a pointed orifice, and a copper wire with a bit of tow wound closely round it for a piston ; thus a globule of very small size may be drawn into the tube, and deposited in the vessel prepared for the detonating experiment. The facility with which the decomposition takes place, is due to the small affinity of chlorine and nitrogen, and their strong tendency to resume the gaseous form ; and the great violence of the explosion, is of course, the result of their immense expansion in passing from the liquid to the aeriform state. The products of the detonation, are chlorine and nitrogen gases. This experiment should never be made without strong gloves and glass masks. Its discoverer, Mr. Dulong, received a severe wound, in experimenting with it ; and Sir Humphrey Davy had his eyes seriously injured in the same manner.



376. *Bromide of Nitrogen.* This substance has similar properties to the chloride of nitrogen, and may be formed in a similar manner.

377. *Iodide of Nitrogen.* This is a black powder, obtained by pouring a solution of ammonia on iodine. It is very explosive ; but as one of the constituents is naturally a solid, the explosion is not quite so readily produced, nor so violent, as that of the chloride. It is resolved by the detonation, into nitrogen gas and vapor of iodine. The iodide of nitrogen is supposed to consist of 3 equivalents of iodine=372 added to 1 nitrogen 14=386 ; and may properly be termed, a *Teriodide of nitrogen*.

CHAPTER XVI.

CARBON.

378. *Equiv.* $\left\{ \begin{array}{l} \text{by vol. } 100. \\ \text{" weight } 6. \end{array} \right\} \text{ Sp. gr. } \left\{ \begin{array}{l} 3.05 \text{ Water}=1 \\ 6.12 \text{ Hyd. } =1 \end{array} \right.$

Vegetable and animal bodies consist, essentially, of *carbon, oxygen, hydrogen*, and sometimes *nitrogen*. Many of them contain, also, several *alkaline* and *earthy salts*, and *siliceous mat-*

376. Bromide of nitrogen analogous to the chloride.

377. Properties and constitution of iodide of nitrogen.

378. Essential constituents of vegetable and animal bodies. Accidental components. Mineral substances most abundant in the bark of vegetables. Products of the combustion of organic bodies when burnt in the open air. Different products when air is excluded. Volatile products of destructive distillation. Charcoal.

ter, which are considered as accidental rather than necessary components. Growing vegetables derive their mineral substances from the soil in which they grow, and these are found more abundant in the bark where the circulating vessels are situated, than in the wood. When organic bodies are heated *in the open air*, the atmospheric oxygen combines with carbon, to form carbonic acid; and with hydrogen to produce water; and the products of the combustion, being essentially gaseous, or very volatile, are dissipated, forming that very complex mixture of gases and vapors, called *smoke*. The alkaline and earthy salts, and siliceous matter not being either combustible or volatile, remain on the *hearth*, constituting *ashes*.

But the results are quite different, when *air is excluded*. The organic matter is then decomposed by the agency of heat, and most of its elements re-combine in various forms. The volatile products of this process, (called *destructive distillation*,) are exceedingly complicated. Among them, are impure vinegar, called *pyroligneous acid*; and acid and fetid oil, to which the name *emphyreumatic oil* has been given; *carburetted hydrogen* or illuminating gas; *carbonic acid*, *ammonia*, and *watery vapor*. The oxygen contained in these products, is that which belonged to the composition of the organic matter; and as this is never sufficient for the complete oxidation of the carbon and hydrogen, a large proportion of the former remains after the experiment. This, together with the ashes, constitutes *charcoal*.

379. There are several varieties of charcoal, of very different degrees of purity, but all deriving their common characteristics from the combustible element, carbon.

Lamp-black is one of the purest of the common varieties. It is obtained by burning refuse oils and resinous matters in chambers hung with coarse matting. The smoke deposits free carbon upon the matting, whence it is swept off and collected.

Ivory-black, is an animal charcoal, and is obtained by heating bones excluded from air. It contains more earthy matter than vegetable charcoal, and is therefore more impure; but is best for some purposes. The ashes it contains, are principally phosphate and carbonate of lime, which constituted the hardening matter of the bone. The ivory-black obtained in this manner, is that usually met with in commerce. The *real ivory-black* is obtained from ivory.

All the varieties of *pit coal*, or mineral coal, are carbon, more or less impure; and are supposed to be derived from the spontaneous decomposition of vegetable matter. Some of them burn with flame, on account of their containing bituminous matter. Sulphur is a very frequent ingredient; and the matter of ashes abounds in them. The ashes of mineral coal, however,

379. Varieties of charcoal. Lamp-black. Ivory-black. Mineral coal. Its origin. Why some kinds burn with flame. Difference in the ashes of mineral and vegetable charcoal. Anthracite. Plumbago. Coke.

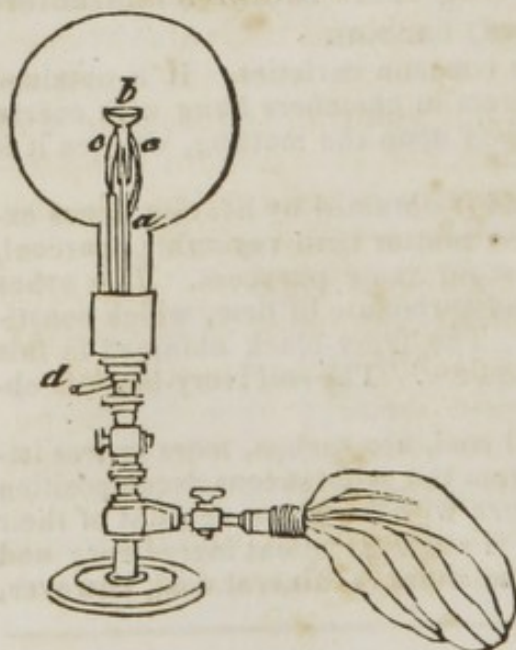
differ from those of vegetable charcoal. The greater difficulty of igniting them, is chiefly owing to their greater compactness and density.

One of the densest and purest varieties of mineral coal, is *Anthracite*, which contains more than 90 per cent. of carbon. *Plumbago*, or black lead, is carbon combined with a very small proportion of metallic iron. Its composition is variable. *Coke*, is a very dense and impure variety of carbon, obtained by the distillation of bituminous coal. The leading object of the distillation, is the furnishing of gas for illumination, which is evolved in large quantity. Coke is the residual product. It is exceedingly difficult of combustion, but when burning in a blast furnace, gives an intense heat. Mixed with wood charcoal, it is largely used in smelting iron ores, and other metallurgic operations; and its importance is such that coal is frequently distilled for the sake of the coke, though the gas be wasted.

380. Carbon in its purest form, as obtained artificially, may be made by passing the vapors of alcohol, ether, and the volatile oils, through porcelain tubes, heated red hot.

The purest native variety of carbon, is the *diamond*, which is chrystallized carbon. Many attempts have been made to make diamonds, by fusing and by crystallizing carbon, but without success. It resists fusion, even in the intense heat of a powerful galvanic apparatus, and no menstruum has been found to deposit it in crystals. The *diamond* is the hardest body known. It is generally colorless, but sometimes tinted. It has a highly crystalline structure, its primitive form is an octahedron. It is a most powerful refractor of light, to which, with the angular forms into which it is cut, it gives its brilliant play of colors, called its *water*. Newton conjectured the combustible nature of the diamond, on account of its great refractory power, before

Fig. 75.



any proof of this property had been obtained. It may be consumed by an intense heat in the open air, or by heating it strongly with nitre. But the most brilliant mode of burning diamonds, is in an enclosed portion of oxygen gas, acted upon by a jet of hydrogen.

Exp. The figure (Fig. 75,) represents a glass globe, having fitted to its neck, a copper cap, with an apparatus into which a stop cock is screwed, and from which a jet-pipe, *a*, passes up into the globe. Above this pipe, are two wires, *c c*, one of which is attached to the jet-pipe, the other passes through an insulating glass

380. How may carbon be obtained nearly pure? Crystallized carbon. Properties of the diamond. Exp. showing the combustion of a diamond in oxygen gas. Product of the combustion of diamond in oxygen gas. Size and value of diamonds.

tube, to the outside of the apparatus, where it terminates at *a*. At the end of the jet-pipe, is a small platinum grate. On this, the diamond is placed, in such a situation, that the stream of hydrogen which issues from the jet, plays upon it, and not on the platinum. The lower part of the apparatus, has in its side, an aperture, to which is affixed a tube with a stop-cock; and with this is connected a bladder filled with hydrogen gas. When the apparatus is used, the glass globe is removed from its stand, placed on an air pump, exhausted of air, and then filled with oxygen gas; after which it is again screwed to the stand. The wire *d*, is then connected with the conductor of an electrical machine by means of a chain wire; a discharge of electrical sparks is then to pass between the wires *c c*. A stop cock being now opened, hydrogen gas being pressed from the bladder, issues through the jet-pipe *a*, and the diamond is heated to a white heat; after which, it takes fire and consumes.

The product of the combustion of the diamond in oxygen gas, is *carbonic acid*, which is the same as that arising from the combustion of pure charcoal. The most splendid diamonds have been found in the East Indies, and in Brazil. They are esteemed the most valuable of all gems. Some few have been found as large as a pigeon's egg; these are considered as of immense value.

381. There are three modes of making wood charcoal. 1st. The most complete process is that used by manufacturers of gun powder, who require very pure charcoal. The process consists in distilling the wood in cylindrical retorts of cast iron. 2d. The ordinary wood charcoal for fuel, is prepared by covering a pile of wood with earth, so as nearly to exclude air, and then set it on fire at the bottom. The combustion is slow, as but little air is admitted; but in time the volatile parts are driven off and carbon remains. 3d. For chemical experiments, charcoal should be prepared by charring wood under sand or melted lead to exclude all the air.

382. Carbon, or charcoal in its purest form, is black, brittle, pulverulent, unaltered by the action of air and moisture at common temperatures, and not affected by heat, even the most intense, when air is excluded. It is not volatile, is infusible and insoluble; is not attacked by alkalies, nor, at common temperatures, by any acid. Its specific gravity is said to be greater than that of diamond; wood charcoal, on account of its porosity, floats awhile on water, but sinks as soon as its pores are filled with the fluid. Charcoal is an excellent conductor of electricity, but a very bad conductor of heat, especially when powdered.

Charcoal has a remarkable antiseptic power, preventing the putrefaction of meat and vegetables when covered with it in a state of powder. On account of its indestructibility it is customary to char the end of posts that are to be set in the earth, and the inside of the water casks of ships. Grains of wheat, charred by the vol-

381. Modes of preparing wood charcoal.

382. Properties of carbon. Antiseptic property. Valuable as a dentrifice. Effect in the decolorization of liquids.

canic eruption which buried Herculaneum in A. D. 79, were found perfect, eighteen centuries afterwards ; and knife handles recently made in England and sold as *antiques*, at a high price, were manufactured from *charred stakes* driven into the bed of the Thames to prevent the passage of the Roman army, under Julius Cæsar. Finely powdered charcoal is an excellent dentrifice, especially as the extreme hardness of its particles gives it a great polishing power ; It removes coloring matter from liquids of vegetable origin ; thus dark colored wines and other liquors are filtered through it. The decoloring power is greater in animal, than in vegetable charcoal, on account of the greater quantity of earthy salts contained in the former.

383. Charcoal absorbs gases and vapors. This is a mechanical effect, depending on the porosity of the charcoal. Of the different gases, it absorbs different quantities, dependent on the relative elasticity of the gases ; the least elastic, and therefore most easily condensable gases, are absorbed in the greatest quantities. Vapors are, therefore, more absorbable by charcoal, than gases, and liquids, still more than vapors. The gases will be given off by heating the charcoal.

Fresh charcoal from box-wood, according to Sassure's experiments, absorbed in 24 or 36 hours,—

of Ammoniacal gas,	90 times its bulk.
of Sulphurous acid gas,	65 “
of Carbonic acid gas,	35 “
of Oxygen gas,	9.42 “
of Nitrogen gas,	7.05 “
of Hydrogen gas,	1.75 “

An application of the absorbing property of charcoal is made by using it in a powdered state for removing putrescence from meat which has been kept too long, also for cleansing docks, vessels &c. Bad water by being filtered through it may be made pure.

384. Charcoal is *highly combustible* in air, or oxygen gas ; in the former, the combustion is slow, in the latter, brilliant, with emission of sparks. In either case, and in all other examples of the direct oxidation of carbon, the product is carbonic acid gas. If pure, the charcoal is consumed without residue. Charcoal is also oxidized by being heated with nitric acid ; but the nitrates, chlorates, and some other salts, yield their oxygen to it, very

383. Absorbing property. On what the absorbing power depends. What gases most readily absorbed ? Degrees of absorption of different gases by charcoal. Application of the absorbing property.

384. Combustion of charcoal. Product of the combustion. Action of charcoal when heated with nitric acid, or with deflagrating salts. Reduction of metallic oxides by charcoal aided by heat.

rapidly, at a red heat, causing the violent combustion, called *deflagration*. Metallic oxides, also, by the aid of heat, are reduced by charcoal to the metallic state, upon which property are founded most of the processes for obtaining metals from their ores. There are many other processes, both in Chemistry and in the arts, in which charcoal is employed as a powerful deoxidizing agent.

COMPOUNDS OF CARBON AND OXYGEN.

385. *Carbonic Acid Gas*. 1 Car. 6 to 2 ox. 16=22.

This gas is constantly found in the atmosphere, being generated by combustion, respiration, and many other processes. It is contained also in many solid mineral bodies; thus chalk, marble, Iceland spar, and limestone, all consist of the same compound of carbonic acid and lime, in different degrees of purity. This is the first gas that was distinguished from common air; its discovery opened a new field of investigation, that of the elastic fluids, which has changed the aspect of *pneumatic chemistry*.

The first steps towards its discovery, may be traced to the Alchemist Van Helmont, who observed that calcareous stones sometimes yielded an *air*, to which he gave the name of gas. Hales afterwards asserted, that this sort of air was an essential part of these stones; and he attempted to ascertain in what proportion it existed in them. Dr. Black, in 1775, discovered that this air was capable of being absorbed by lime and the alkalies, of neutralizing them, and causing them to effervesce with acids. Priestly studied its properties with much care, and the English Chemists usually ascribe to him the honor of its discovery. But the French assert that their countryman Lavoisier first determined the proportion of its constituent parts, and understood its nature. It appears that both Priestly and Lavoisier were at the same time engaged in studying and experimenting upon carbonic acid gas, and publishing in their respective countries the results of their investigations.

386. Carbonic acid gas was at first named *fixed air*, on account of its remaining in a fixed state in stones and rocks; it has been called *aerial acid*, *chalkly acid* and *gaseous oxide of carbon*. It received its present name on the reformation of the chemical nomenclature.

387. It may be obtained by burning pure charcoal in oxygen gas, or by exposing almost any of its numerous and abundant combinations with the metallic oxides, to a strong red heat, in an iron retort.

Exp. 1st. The easiest method of obtaining it is to pour one of the

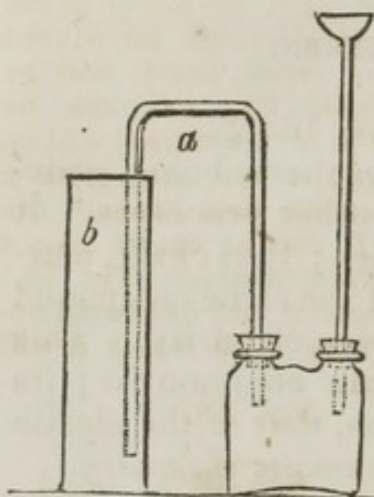
385. Composition of carbonic acid gas. Where found? Importance of its discovery. History.

386. Synonimes.

387. Modes of obtaining carbonic acid gas. *Exp. 1st.* *Exp. 2nd.*

stronger acids, (as the hydrochloric) in a dilute state, upon small fragments of marble or other carbonate, in a flask or stopped glass retort. The hydrochloric acid unites with the lime of the marble, forming hydrochlorate of lime. The liberated carbonic acid gas may be collected over mercury, or over water in the usual manner; or, as it is much heavier than air, it may be received in a dry glass bottle or jar, standing with its mouth upwards; in this case, the tube proceeding from the flask must be bent twice at right angles, and reach quite to the bottom of the receiving vessel.

Fig. 76.



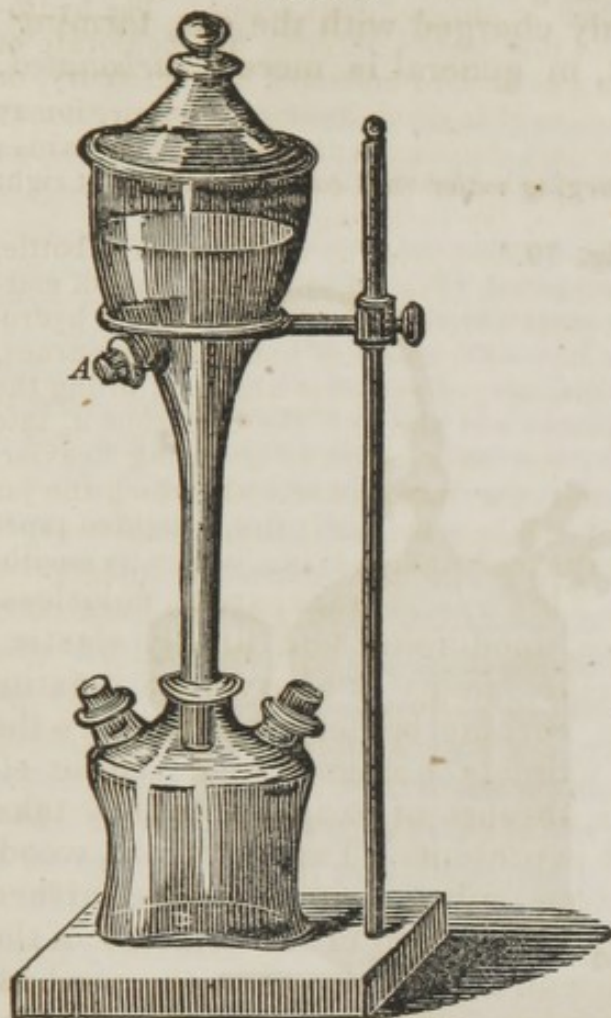
Exp. 2d. Thus, into the double necked bottle, here represented, (Fig. 76,) put fragments of marble, and pour through the funnel diluted hydrochloric acid; effervescence immediately ensues, and the disengaged carbonic acid gas, filling the bottle, passes out through the bent tube *a*, into the jar *b*; and on account of its being heavier, crowds out the atmospheric air which the jar contained. When the jar is full, a lighted taper will be extinguished, if held just within its mouth.

388. This gas is transparent, colorless, tasteless, inodorous, and highly elastic; Its specific gravity is above 1.5; it extinguishes burning bodies, and destroys the life of animals immersed in it; these effects are not due to the mere absence of oxygen, for they take place even when some oxygen is present. Thus charcoal, wood, candles, and other carbonaceous substances, are extinguished before the oxygen is consumed, by reason of the mixture of the latter with the carbonic acid, which is produced in the combustion. And hence persons are often suffocated by pans of burning charcoal in apartments not sufficiently ventilated. The unwholesome effect of crowded assemblies, is partly due to the carbonic acid produced by respiration. This gas acts on the system as a narcotic poison.

It is often found in wells, pits, and caverns, being generated there by the spontaneous decomposition of organic matter, or of earthy carbonates. Before descending into such places, it is proper to *let down a burning candle*. If it be extinguished, the air is unfit to support respiration. Another test is *clear lime water*, which becomes covered with a pellicle of carbonate of lime when exposed to an atmosphere of this gas. It may be removed in such cases, by letting down buckets containing a mixture of lime and water, as the lime unites with the carbonic acid gas to form carbonate of lime; or it may be drawn up in buckets, and poured out like water.

388. Properties of carbonic acid gas. Its effects on combustion and animal life. Pans of burning charcoal in close rooms. Air of crowded assemblies. Air of wells, pits, &c. Tests by which the presence of carbonic acid gas may be known. How may the gas be removed?

Fig. 77.



389. Put into a three necked bottle (Fig. 77,) two ounces of the carbonate of ammonia, and one ounce of orange colored nitrous acid, carbonic acid gas will be evolved and be visible as it rises in a cylindrical jar, fitted to the bottle. When full, it will press out beneath the cover at the top of the jar. Let the cover be removed, and a candle introduced within the vessel, and it will be extinguished. The gas can be drawn off at *A*; its current will be visible, and it will extinguish a burning candle held beneath the orifice. It can be drawn like a liquid, into a tumbler, (Fig. 78,) from whence it may be poured upon a burning lamp which it will extinguish.

Fig. 78.



390. As water absorbs carbonic acid gas, another mode of removing it from wells, &c., is to pour down a quantity of water. Animation, when suspended by the effect of this gas, has been restored, in some cases, by dashing cold water over the patient. Water absorbs its own bulk of carbonic acid gas, at the ordinary temperature and pressure of the atmosphere; under a greater pressure, a larger quantity is absorbed. Thus a pressure of two atmospheres causes water to absorb twice its bulk of the gas; three atmospheres, three times its volume, and so on. By a pressure equal to thirty six atmospheres, carbonic acid itself becomes condensed into a liquid.

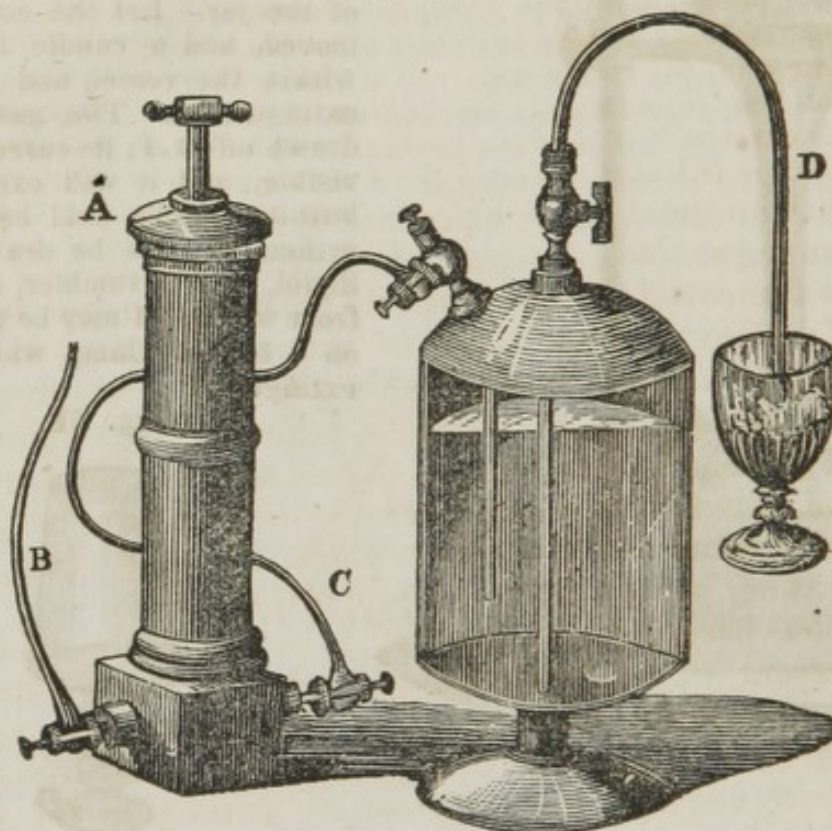
389. Experiment to shew that carbonic acid gas is heavier than atmospheric air.

390. Absorption of carbonic acid gas by water. Effect of pressure on this absorption. Soda or carbonated water. Describe Dr. Hare's apparatus for carbonating water. What takes place when the water is relieved from pressure?

By compressing carbonic acid gas over water with a forcing pump, the water becomes highly charged with the gas, forming what is sold, as *soda water*, but, in general is merely *carbonated water*.

Dr. Hare's apparatus for charging water with carbonic acid.

Fig. 79.



A, (Fig. 79,) is a condenser fastened into a block of brass furnished with a conical brass screw, by means of which, it is easily attached to the floor. In this block are two valves, one opening inwardly from the pipe B, the other outwardly towards the pipe C. The pipe B, communicates with a reservoir of gas which the condenser draws in, and forces through the other pipe, into a strong copper vessel containing the water. The carbonated water is drawn out by means of a syphon D. When the pressure on the water is relieved, the greater part of the gas escapes with effervescence leaving only what the water is capable of holding in solution, at ordinary atmospheric pressure. The remainder may be expelled by boiling the water or by placing it under the receiver of an air pump, and exhausting the air.

391. Water which contains carbonic acid gas, has a lively, brisk taste, sparkles when poured from one vessel to another and changes to red the blue color of litmus paper; but the latter effect is only temporary, for the acid soon evaporates and th

391. Properties of carbonated water. Tests of carbonic acid in water. Cause of the crust which is deposited when spring water is boiled.

blue is restored. The insipid taste of boiled water is owing to its having lost the carbonic acid which spring waters always contain. The presence of this gas in water, may be detected by mixing it with clear lime, or baryta water; it becomes milky, on account of the formation of an insoluble carbonate of lime or baryta.

Care should be taken to have the alkaline water in excess; for if the carbonated water predominate, the precipitate is not formed, or is re-dissolved, those carbonates being soluble in excess of carbonic acid. On account of the latter property, the spring waters of a limestone district, often contain carbonate of lime in solution. On boiling, the excess of carbonic acid is expelled, the carbonate of lime is deposited, and by frequent repetition, the vessel in which it is boiled, becomes lined with a white calcareous crust.

392. Carbonic acid gas is a product of fermentation. If cider, beer, champagne, &c., be put into bottles, and tightly corked before the fermentation has entirely ceased, the gas which is generated during the remainder of the fermentation, is forced into the liquids under a considerable pressure, and gives them the effervescent quality or liveliness, which renders them agreeable. An overcharge of the gas, expels the cork or bursts the bottle; and this will happen when the liquors are bottled too soon. This occurrence often takes place in bottled yeast, which, in fermentation, gives off a large proportion of gas.

393. It has been remarked, (§349,) that carbonic acid gas is always present in the atmosphere, and that the vegetation of plants has an agency in decomposing it and restoring oxygen to the air. A small proportion of carbonic acid in the atmosphere is favorable to vegetation, by furnishing carbon to the plants; but in too large proportion it destroys vegetable life. It has been found that plants are benefitted by being watered with a solution of this gas. Carbonic acid combines with the alkalies, earths, and most of the salifiable metallic oxides, forming a class of salts called *carbonates*, many of which occur abundantly as minerals, as carbonate of lime in its various forms of limestone, chalk, marble, Iceland spar, stalactite, &c. The carbonic is a very weak acid, and does not completely neutralize the alkalies; therefore all the carbonates are decomposed by hydro-chloric, nitric and most other acids, carbonic acid escaping with effervescence. All the carbonates, except those of ammonia, potassa, soda and lithia are decomposed by heat.

394. Carbonic acid is the highest known oxide of carbon. It contains in bulk one volume of carbonic vapor and one volume of oxygen, condensed into one volume.

392. Cause of the effervescence and other peculiar properties of fermented liquors. Bursting of the bottles containing such liquors.

393. Decomposition of carbonic acid gas by plants. Carbonates. Why easily decomposed?

394. Composition of this gas. How proved.

Its composition is proved by passing the vapor of phosphorus over a red hot carbonate, in which case phosphoric acid is formed and carbon set free ; or by passing a succession of electric sparks through the gas, by which means it is resolved into oxygen and carbonic oxide ; or by electrifying a mixture of hydrogen and carbonic acid when water and carbonic oxide will be formed. It is also decomposed by being brought in contact with iron filings or charcoal at a red heat ; the iron or charcoal takes half its oxygen, converting it into a carbonic oxide. Potassium takes the whole of its oxygen ; forming potassa and liberating carbon.

395. Carbonic acid gas has been liquefied by very powerful compression aided by exposure to cold. Mr. Faraday obtained it in this state by disengaging it from carbonate of ammonia by means of sulphuric acid, in a glass tube hermetically sealed, one end being immersed in a freezing mixture. The liquid acid was colorless, and floated upon the sulphuric acid and water, contained in the tube. The pressure under which this fluid was formed was estimated to be equal to that of thirty six atmospheres. A French Chemist* who had previously succeeded in liquefying this gas, announces that he has also obtained it in a *solid state*. Its solidification requires a cold equal to 100th degree of the centigrade below the freezing point ; and, though the liquefied gas evaporates almost instantaneously, and with a violent explosion, the solid continues some minutes exposed in the open air, and insensibly disappears by a slow evaporation. The first instance of a *gas becoming solid* and concrete is so much the more remarkable as it relates to a gas, to liquefy which requires the most powerful mechanical action, and which resumes with great rapidity its gaseous state when the compression is removed. In the liquid state its elastic force is equal to that of gunpowder, while in the solid state the spring appears completely broken, the new body disappearing by slow evaporation.

396. *Carbonic Oxide*. Its constituents are, 1 atom of carbon with 1 of oxygen=14 its chemical equiv. It is never formed by the direct oxidation of carbon, carbonic acid being always the result of that process. Most of the processes for obtaining carbonic oxide depend on depriving carbonic acid of half its oxygen ; this is easily effected at a red heat, by charcoal and by several of the metals. Thus when a mixture of chalk and iron filings is heated to a red heat, carbonic acid is driven from the chalk ; the hot iron immediately takes a part of the oxygen from the carbonic acid and reduces it to carbonic oxide. When charcoal is used for this purpose, it is itself converted into carbonic oxide. The gas thus evolved may be collected over water.

Other more easy and elegant processes are founded on the decomposition of oxalic acid and its salts by sulphuric acid. *Oxalic acid* is a crystalizable, poisonous, vegetable acid, which like nitric acid is incapable of existing in an uncombined state ; so that when not united to a salifiable base it always

* M. Thilorier. See Silliman's Journal, Oct. 1836 ; and also the same Journal for Jan. 1837. Translations from *Annales de Chimie*.

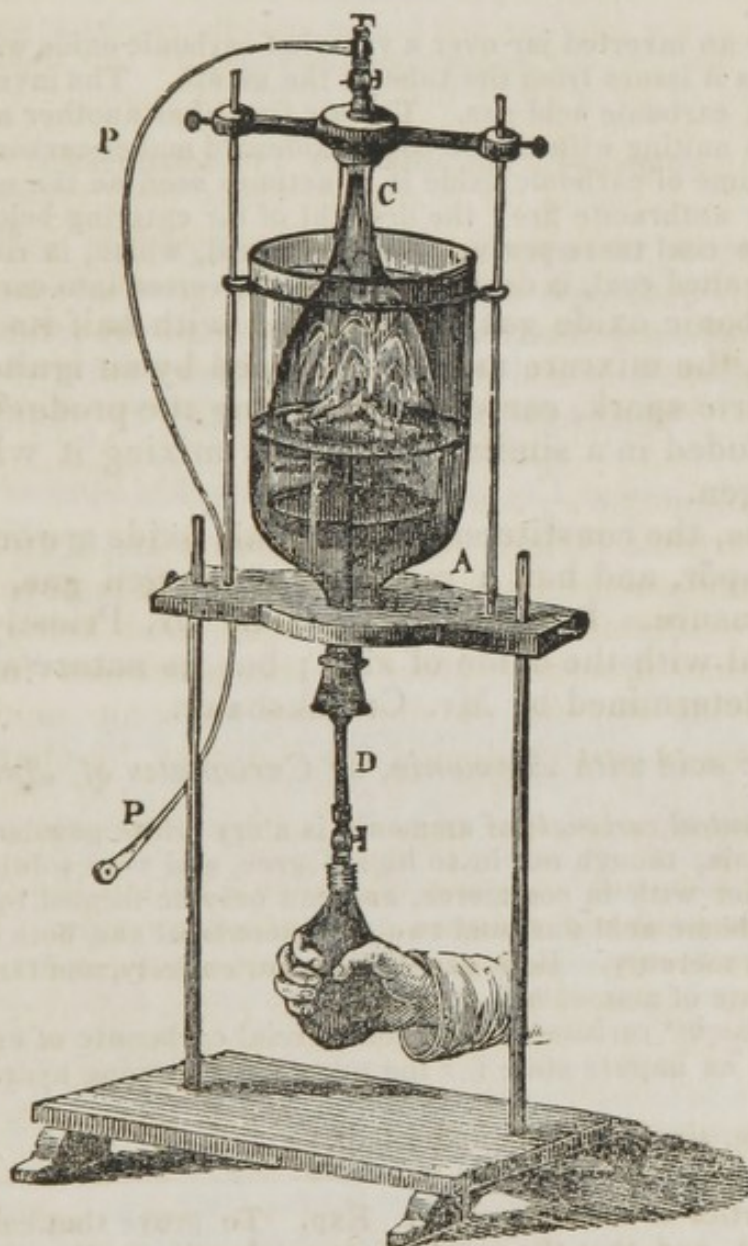
395. Pressure under which it was formed. Solidification of carbonic acid.

396. Composition of carbonic acid gas. How formed. How obtained by heating chalk with iron filings ? How obtained by means of oxalic and sulphuric acid. Dr. Hare's apparatus for separating carbonic acid gas from carbonic oxide.

contains water. Besides this water necessary to its existence, the crystallized acid consists of 3 atoms of oxygen and two of carbon. On heating this acid or its salts in a glass retort, with an excess of sulphuric acid, the latter takes both water and alkaline base; the oxalic acid, thus set free, resolves itself into the two gaseous compounds of carbon and oxygen. These mixed gases being collected over mercury, the carbonic acid will be speedily absorbed by a little milk of lime or solution of potassa, and the carbonic acid remain pure.

Dr. Hare's apparatus for purifying carbonic oxide by lime water.

Fig. 80.



The gases being obtained in the manner directed above, they are conveyed by means of the pipe, P, (Fig. 80,) which is supposed to communicate with a reservoir of the mixed gases, to the bell glass C, containing lime water. The lime water sinks into the lower bell glass, A, as the gases are introduced by turning the stop cock communicating with the pipe P. The lower pipe D, communicating with the bell glass A, has affixed to it an In-

dia rubber bag; by pressing this with the hand, jets of lime water are thrown into the gas in the bell glass C, until all the carbonic acid having united with the lime, the carbonic oxide is left pure, and may now be transferred to any receiver by turning the stop cock of the pipe P.

397. Carbonic oxide is transparent, colorless and inodorous; it is very sparingly absorbed by water; its specific gravity is 0.972. It has neither acid nor alkaline properties, and has no effect on lime water. It extinguishes burning bodies, and is irrespirable, being like carbonic acid, a narcotic poison. It is inflammable, burning in contact with oxygen with a pale flame. In this, and all cases of its direct oxidation, *carbonic acid is the sole product.*

Exp. Place an inverted jar over a vessel of carbonic oxide which is burning in a jet, as it issues from the tube at the mouth. The inverted jar will be filled with carbonic acid gas. The air furnishes another atom of oxygen=8, which uniting with the carbonic oxide=14 makes carbonic acid=22.

The blue flame of carbonic oxide is sometimes seen on the upper part of a charcoal or anthracite fire; the draught of air entering below, the combustion of the coal there produces carbonic acid, which, in rising through the mass of ignited coal, is decomposed and converted into carbonic oxide.

398. Carbonic oxide gas being mixed with half its volume of oxygen gas, the mixture may be exploded by an ignited body or by the electric spark, carbonic acid being the product. It may also be exploded in a similar manner by mixing it with protoxide of nitrogen.

By volume, the constituents of carbonic oxide are one measure of carbon vapour, and half a measure of oxygen gas, condensed into one measure. It was discovered by Dr. Priestly in distilling charcoal with the oxide of zinc; but its nature and composition was determined by Mr. Cruickshank.

Carbonic acid with Ammonia, or Carbonates of Ammonia.

399. The *neutral carbonate* of ammonia is a dry white powder, having the odor of ammonia, though not in so high degree, and very soluble in water. It is never met with in commerce, and can only be formed by mixing one volume of carbonic acid gas, and two of ammoniacal gas, both in a *perfectly dry state*, over mercury. Both gases disappear entirely, and the white powder of carbonate of ammonia is deposited.

400. The *Sesqui* carbonate* is the commercial carbonate of ammonia. It is procured in an impure state for the purpose of forming hydrochlorate of

* Latin term, signifying one and a half.

397. Properties of carbonic oxide. *Exp.* To prove that carbonic oxide is combustible, and that the result of its combustion in the air is carbonic acid gas. Blue flame of carbonic oxide seen in coal fires.

398. Explosive mixtures with carbonic oxide. Constitution by volume. History.

399. Neutral carbonate of ammonia.

400. Sesqui carbonate of ammonia. How prepared. Its properties. How is the bi-carbonate of ammonia formed?

ammonia, by heating bones and other animal matter in close vessels. Animal matter being composed of carbon, oxygen, hydrogen, and nitrogen, the elements are separated by the agency of heat and recombined in other forms, one of which is the salt in question. The sesqui-carbonate of the shops, is procured by sublimation from a mixture of hydrochlorate of ammonia with carbonate of lime. On exposure to the air this salt becomes opaque and pulverulent, loses its odor and decreases in weight. It is then found to have become bi-carbonate of ammonia. *Bi-carbonate of ammonia* is formed as above, by exposing the sesqui-carbonate to the air. It is also obtained by passing a current of carbonic acid gas through a solution of the common carbonate. On evaporating the solution, the salt crystalizes.

CHAPTER XVII.

Compounds of Carbon with Hydrogen

401. Carbon and hydrogen possess opposite properties in respect to their tendency to assume the gaseous form. They have a strong affinity for each other, and their compounds are remarkable for their inflammable nature. Carbon and Hydrogen form, with each other, at least, six definite compounds ?

1. Light carburetted hydrogen gas, consisting of 1 equivalent add to 2. eq.				
2. Olefiant gas,	"	2	"	2. "
3. Faraday's bicar. hyd.	"	6	"	3. "
4. " Quadrocarburet,	"	4	"	4. "
5. Naphtha,	"	6	"	6. "
6. Naphthaline,	"	3	"	2. "

Of these, the first two are permanent *gases*. The fourth is a *vapor* at common temperatures, but a liquid at 0° F; the third and fifth are *volatile liquids*; and the last is a *volatile solid*.

402. It is to be observed that several of these compounds present a remarkable exception to the laws of combination. The second, fourth and fifth consist of carbon and hydrogen in precisely the same *ratio*, that is, one equivalent of each element; yet they are totally distinct in all their physical, and most of their chemical properties; nor have we any right to suppose that a compound consisting of one proportional of hydrogen and one of carbon would resemble either of them. The constitution of these bodies seems to indicate that, for the formation of any specified compound, not only must certain *proportions* be observed in the quantities of the constituents, but also, that the concurrence of a particular number of atoms is necessary. Thus, if we could compel three atoms of olefiant gas to cohere, we should probably obtain an atom of Naphtha; and if two atoms of the

401. Affinity of carbon and hydrogen for each other. Different forms under which they combine. Names and composition of these compounds. States in which they exist.

402. Exception of some of these compounds to the laws of combination.

same gas were to coalesce, they might form an atom of quadrocarburet. The analysis of some organic bodies proves that slight variations in composition, or different modes of combination may produce great differences in properties : there is but one other case, that of hydrophosphoric acid, in which the laws of combination appear so inexplicable as in the present. Until more light is thrown upon the subject, we must be content to attribute the difference of properties, among bodies containing the *same elements in the same proportions*, to the influence of the *mode of combination*.*

403. *Light Carburetted Hydrogen.* The gas is also called *sub-carburetted hydrogen gas*, and *bi-hydroguret* of carbon. It was formerly known as *inflammable air*, and *the air of marshes*. It can only be obtained, in a separate state, by stirring the mud of stagnant pools, and collecting the bubbles of gas as they rise in an inverted receiver filled with water. It is formed in such situations during the spontaneous decomposition of vegetable matter.

There is a rivulet running through the village of Fredonia, and another which passes by Portland Harbor, both in Chautauque County in the State of New York, from the waters of which bubbles of light carburetted hydrogen gas are constantly rising. The supply of gas at Fredonia is sufficient for lighting the houses of the village, and a gasometer has been constructed for collecting it. The light house on Lake Erie at Portland harbor is completely supplied with gas obtained from the rivulet above mentioned. The origin of the gas in these cases has not been traced.

404. This gas is colorless, transparent, tasteless, inodorous, sparingly absorbed by water, and of specific gravity 0.5555. It burns with a yellow flame ; and if mixed with air or oxygen in proper proportions, it explodes violently, when touched with flame or the electric spark. Whether exploded, or burnt silently, the sole products are carbonic acid and water.

405. *Blowers and Fire-damp.* Light carburetted hydrogen is often generated in large quantities in coal. Sometimes it is

* Since these anomalies in the laws of chemical combinations began to attract the attention of men of science, they have been arranged under different heads : as *Isomerism*, from the Greek *isos* equal, and *meros* a part ; *polymerism* from *polus* many and *meros* ; and *metamerism*, according to, and *meros*. *Isomeric* bodies are those which contain the same absolute and relative number of atoms of the same elements, and have, therefore, the *same atomic weight* ; *Polymeric* bodies are those which contain the same relative, but not the same absolute number of atoms of the same elements, and whose *atomic weights* are consequently *unlike*. *Metameric* bodies are those which, while they contain the same absolute, and the same relative number of atoms of the same elements, yet constitute substances belonging to an entirely different class of bodies, or a different order of chemical compounds. The carburets are therefore polymeric bodies.

(Rep. of the British Association for 1835, pp. 435, 436.)

403. Synonymes of light carburetted hydrogen. How formed, and obtained ? Natural reservoirs of this gas.

404. Properties. Products of its combustion.

pent up in cavities where it was formed, and, being under great pressure, rushes out with much force, when a cavity is broken into; a reservoir of this description, is called by the miners, "*a blower*." At other times, it issues silently from between the layers of coal. In either case, it mixes with the air of the mine, constituting the *fire-damp* of the miners, which, if set on fire, explodes with terrible violence, producing a shock which has been felt at a distance of several miles. By the explosion of the *fire-damp*, carbonic acid and water are produced; so that if it were possible for a miner to escape the effect of concussion, he would perish by suffocation in the mephitic gas, which the miners call *choke-damp*. Such explosions were frequent, in the British coal mines, till a few years ago; and the annual loss of life occasioned by them, was truly deplorable. It was reserved for the genius of Sir H. Davy to discover means for preventing such dreadful accidents, and "the fear of them." Davy descended with the miners into the region of the *fire-damp* to obtain specimens of the gas. He found by experiments that the most explosive mixture was 1 part of gas to about 7 of air; that 5 volumes of air would explode but feebly, and that over 14 volumes of air to 1 of gas would not explode at all. He also found that the most explosive mixture can not be kindled without the heat of flame; that iron at a red heat and even at a white heat will not explode it. By means of a little instrument, called the *safety lamp*, whose simplicity is scarcely less admirable than its utility, the miner now fearlessly descends into dark caverns filled with combustible gases, and lamp in hand safely pursues his daily avocations, undisturbed by the terror of destructive explosions.

In the course of his experiments, Sir H. Davy assisted by previous discoveries of Dr. Wollaston, developed some facts respecting the nature of flame, a subject which had not previously been well understood, and which, as connected with our present subject we shall here introduce.

Flame is found to be gaseous matter in a state of incandescence, and its temperature far higher than any to which solid bodies can be brought. This being the case, in order to extinguish flame it is only necessary to cool it; this may be effected by bringing it into contact with a sufficient quantity of solid matter which may convey away the heat by means of its conducting power. It would follow from this, that the greater the conducting power, the less the mass of solid matter necessary to effect the object, and *vice versa*; and consequently that metals would produce the effect more readily than any other bodies, the masses being the same. Some of these facts may be readily proved by simple experiments. If the point of a knife, or the end of a metallic wire be held very near to the flame of a candle, a

405. *Blowers* of mines. Fire-damp, its properties, &c. Choke-damp. Observations on the nature of the fire-damp which led to Davy's invention. Different temperatures of different flames. Gases kindled by solid bodies at different temperatures. Explosive mixture of light carburetted hydrogen and oxygen.

dark spot will appear on the blaze opposite to the metallic point; the gas in that part being cooled below incandescence by the conducting body. If a very small flame be made with a cotton thread, passed through a cork shaving, and floating on oil, it will be extinguished by holding over it, and in contact with it, an exceedingly small ring of fine iron wire; a ring of glass of the same size, will diminish the flame, and a larger glass ring will put it out, the sufficiency of conducting power being compensated by the greater quantity of matter.

Wollaston had observed, that "*an explosive mixture cannot be kindled through a glass tube so narrow as 1-7 of an inch in diameter,*" and also that the mixture could not be exploded through fine wire gauze, which acts on the same principle as longer tubes. Now if a fine wire gauze be held upon a common flame, the flame will not pass through the gauze, but will appear as if cut off, (See Fig. 81.) On applying a lighted taper above the wire gauze, a flame will be produced on the upper surface, which is a continuation of the flame below, (See Fig. 82.) The gas of which the flame consists, actually passes through the gauze, but is extinguished in its passage, by the cooling power of the wire.

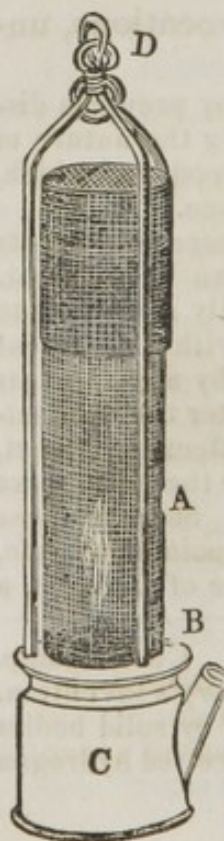
Fig. 81.



Fig. 82.



Fig. 83.



Davy's Safety Lamp. (Fig. 83.) A is a cylinder or case of wire gauze, having no less than 625 apertures to the square inch, with a double top securely fastened to the brass rim B, which screws on to the lamp C. The whole is protected and rendered convenient for use, by the frame and ring D. With this lamp the miner would not be exposed to suffocation for want of oxygen, since he would be admonished by its becoming extinguished that an atmosphere which could not support the combustion of the oil, would not support respiration.

In gas manufactories, spirit ware-houses, and in all places where inflammable vapors or gases are likely to be generated, as in the examination of foul sewers and drains, where artificial light is required, it is obvious that these lamps have very important uses, as well as in the lighting of mines. As different flames have different temperatures, it will obviously be necessary to vary the texture of the gauze, according to the nature of the gas to be extinguished. Moreover it is necessary to observe, that some gases, as carbonic oxide, are kindled by a solid body at a dull red heat; others require a bright red, or a white heat, to set them on fire; while some are not ignited without the direct application of flame. It happens, that light carburetted hydrogen requires a higher temperature for ignition than any other gas; this is fortunate, because the wire gauze must, necessarily become heated, which would cause the

ignition of explosive mixtures, containing other inflammable gases and vapor.

406. Explosive mixtures, may be made to undergo a sort of slow combustion at a temperature below that of flame, and consequently without explosion. This fact may be demonstrated by immersing a small slip of platinum foil or wire, heated red hot, into a mixture of light carburetted hydrogen and air. The temperature of the heated metal will cause the oxygen to combine with carbon and hydrogen, enough heat being evolved by the chemical action, to keep the wire ignited, but not enough to set the gaseous mixture on fire. Upon this fact has been founded the *flameless lamp*, (Fig. 84.) A spiral coil of fine platinum wire is placed vertically, so as to surround the cotton wick and rise a quarter of an inch above it. Some alcohol being put into the lamp, the wick burns and ignites the platinum wire. In this condition, if placed in an explosive mixture, and the wick be extinguished, the wire will continue to glow, giving light enough to guide the steps of the miner to a place of safety.

Fig. 84.



407. It appears that an explosive mixture of any combustible gas with oxygen, is necessary to the production of flame, and that an ordinary flame is a mere shell, the interior of which is filled up with gas, which is not ignited. This fact may be demonstrated by a few simple experiments.

Exp. 1st. Hold a thin glass tube, *b*, (Fig. 85,) about the diameter of a small quill, and three or four inches long, so that its lower extremity shall be immersed in the flame *a*, of a large candle, the tube making an angle of about 45° with the axis of the flame; a portion of the gas *b*, from the interior of the flame, will pass along the tube, and may be set on fire at its extremity.

Fig. 85.



Exp. 2nd. With a fine pointed glass syringe, gas may be drawn from the interior of a common lamp flame, and on being gently pressed out, in contact with a spirit lamp will burn.

Exp. 3d. On cutting off the flame with wire gauze, and looking down upon it, it will be seen that the section is a luminous ring, of which the central part is quite dark.

Fig. 86.

Exp. 4th. Place a wooden hoop (Fig. 86,) of 6 or 8 inches diameter, and 2 or 3 inches broad, upon the water of the pneumatic tub. Within this hoop, pour some sulphuric ether, and set it on fire. A large flame will be obtained, and it may be shown that combustion is not going on in its interior, by passing the hand through the water under the hoop, and up into the center of the flame, taking care not to touch its sides. Considerable heat will be felt, but it may be endured for a second or two without much inconvenience.



406. Slow combustion of explosive mixtures without flame. Heated platinum immersed in a mixture of light carburetted hydrogen and air.

407. Experiments showing that flame is a shell, the interior of which contains gas not ignited.

408. But though the space within the flame be not in a state of ignition, there is oxygen contained in it, the motion of the inflammable vapor through the air being sufficient to cause the two to mingle to some extent. That oxygen is contained there may be proved by putting in some combustible requiring less oxygen than that which constitutes the basis of the flame.

Fig. 87. Thus if a piece of phosphorus be put in a small wire cage at the extremity of a wire bent at right angles, (Fig. 87,) it may be passed up under the hoop into the flame; the water will drain off through the cage, the phosphorus will soon melt and at last take fire, and be consumed. Thus the inner part of the flame is not in a state of ignition, not because oxygen is not present, but because it is insufficient to form an explosive mixture with the inflammable gas.



409. The luminousness of flames depends in general, on the presence of solid matter diffused through them in an incandescent state, and not to their heat. Indeed the colorless flames, such as those of hydrogen and strong alcohol, are often hotter than the luminous ones; for the solid matter which makes a flame luminous, exerts a cooling influence proportionate to its conducting power. Pure hydrogen and oxygen, if set on fire in a strong glass globe, will give a strong light, because of the great compression. Of all flames, the white, containing a due proportion of all the rays of the spectrum, is most luminous; the colors of the rest are owing to the deficiency of some of the rays, and the consequent preponderance of others; of the colored flames, the yellow is the most luminous.

410. The flames of common fires, candles, lamps, &c., consist of some of the compounds of carbon and hydrogen; generally, of several mixed together. These gases arise from the decomposition which wood, oil, and the other organic matters undergo by the action of heat. The carburets of hydrogen, all undergo decomposition at some degree of heat, the higher carburets being more easily decomposed than light carburetted hydrogen; the carbon and hydrogen burn separately; and the particles of ignited carbon diffused through the flame of hydrogen, give it its luminous property. If the quantity of carbon is out of proportion to the supply of oxygen, a portion of it escapes unburnt, and is seen in the form of black smoke, which soon settles of itself, on cold surfaces; instances of this, are seen in the combustion of naphtha, oil of turpentine, and bituminous matters. But if the quantity of carbon be duly proportioned to the supply of oxygen, it is all consumed, and there is no smoke, as in the burning of strong alcohol.

408. Is the flame not ignited because there is no oxygen present? How may it be proved that there is some oxygen within the interior of the flame.

409. Why the least luminous flames are, in general, the hottest. Different colored flames.

410. Flames of fires, candles, &c. Cause of black smoke. Why there is no smoke in the burning of alcohol.

Olefiant Gas.

411. This gas was so called from its oily appearance, when combined with chlorine. It is sometimes called *hydruret of carbon* or *percarburetted hydrogen*, and is obtained by gently heating, in a glass retort, a mixture of one measure of alcohol and three of strong sulphuric acid. The gas is freely evolved and is to be collected over water. If it be cloudy at first, it must stand some time over the water or be agitated with water before use. Olefiant gas is colorless, tasteless, nearly inodorous and of specific gravity 0.97. It is very little absorbed by water, extinguishes flame, and does not support respiration. It burns in the air with a white flame of greater splendor than any other gas; and when previously mixed with oxygen gas and set on fire, it detonates with exceeding violence. It is resolved into its elements by a succession of electric discharges, and it is more or less completely decomposed by passing through heated tubes, according to the degree of heat employed; a low heat only reducing it to light carburetted hydrogen, while an intense heat entirely separates its elements.

412. Olefiant gas derived its name from its property of forming an oil-like fluid by combination with chlorine. This combination takes place when the two gases are mixed, and the presence of light is not necessary to the re-action. The compound so formed is properly called *hydro-carburet of chlorine*, but from its volatility and ethereal taste and odor is often denominated *chloric ether*. It has a sweet and aromatic taste, boils at 150° F. distills unchanged, and is decomposed in passing through red hot tubes. It produces a kind of intoxication, more resembling that of protoxide of nitrogen than that of ardent spirits, and has been recommended as a stimulant in medicine. It dissolves freely in alcohol, but not in water; yet the alcoholic solution may be diluted to any extent. The solution of chloric ether in alcohol may be obtained by distilling a mixture of alcohol and chloride of lime; and it is also formed when chlorine gas is passed into alcohol. If hydro-carburet of chlorine or chloric ether be confined under a bell glass filled with chlorine, and exposed to the sun, it is decomposed: the free chloric combining with its hydrogen, and leaving the carbon and chlorine of the compound in combination, constituting perchloride of carbon.

Bromine and iodine likewise may be brought by indirect methods, into combination with olefiant gas, forming the hydro-carburets of bromine and of iodine; compounds bearing a close analogy to the hydro-carburet of chlorine.

413. *Bi-carburet of Hydrogen.* This according to Faraday is a transparent liquid, of an oily appearance having the odor of

411. Composition of olefiant gas. Synonymes. How obtained. Properties. Products of its combustion. Decomposition.

412. Derivation of the name. Hydro-carburet of chlorine. Combinations of olefiant gas with bromine and iodine.

413. Composition and properties of bi-carburet of hydrogen. Decomposition.

oil gas and a specific gravity of 0.85. It boils at 186° and freezes at 30° . It does not mix with water, but dissolves in alcohol, ether and oils. It burns with a yellow flame giving out much soot; and its vapor explodes with oxygen gas or air. It is decomposed by chlorine in the sunshine, and by being passed through red hot tubes; carbon being deposited in each case.

414. *Quadro-Carburet of Hydrogen* is a liquid at zero, but boils a little above that point; so that, at common temperatures it is a gas. In the fluid state it is lighter than any other liquid, having a specific gravity of 0.627. The density of its vapor is nearly twice that of air. It is combustible, giving a bright light, and much smoke; and the vapor explodes with oxygen, producing carbonic acid and water. Chlorine gas combines with it producing an oily liquid, which in taste, odor, and volatility bear a strong resemblance to the hydrocarburet of chlorine, but different from that substance in not yielding a chloride of carbon. It is largely absorbed by sulphuric acid, and forms with it a compound, the nature of which is not fully understood. Like the other carburets of hydrogen, it may be analyzed by detonating its vapor with oxygen gas, or by passing it over red hot peroxide of copper.

415. *Naphtha* appears on the shores of the Caspian Sea, and also in some parts of Italy. It is also separated from petroleum by distillation. A substance which appears to be identical with it, is obtained by distilling the tar formed in the process of manufacturing coal gas. It is a colorless liquid when pure; but generally has a yellow tinge. It is very volatile, has a strong odor, and burns with a bright flame and much smoke. It dissolves in alcohol, ether, oils, and petroleum, but not in water. It is used to preserve potassium, sodium, &c. from contact with air.

416. *Naphthaline* is also obtained from coal tar, by sublimation after the naphtha has been distilled off. It is a white crystalline solid, heavier than water, of a peculiar odor and pungent aromatic taste. In the open air it slowly evaporates like camphor. It scarcely dissolves in water, but does so in naphtha, in some of the oils, and especially in alcohol and ether. It does not burn readily, but when inflamed burns rapidly with much smoke. Acetic, oxalic and sulphuric acids dissolve naphthaline forming solutions which have some shade of red. The solution in sulphuric acid is a distinct acid called *sulpho-naphthalic acid*. This acid has some curious properties, but has not been applied to any use in the arts. Its salts are all soluble and combustible.

417. *Coal and Oil Gas*. As organic substances consist of carbon, oxygen, hydrogen and sometimes nitrogen, among the

414. Composition and properties of quadro-carburet of hydrogen. Its combination with chlorine. With sulphuric acid. How analyzed?

415. Where is naphtha found? Its properties and use.

416. How is naphthaline obtained? Properties. Its solutions in acids. Sulpho-naphthalic acid.

417. Proportion of carburetted hydrogen in the products of destructive distillation. Bodies which afford large quantities of inflammable gas.

numerous products of their destructive distillation, a portion of carburetted hydrogen is usually found. The proportion which it bears to the other products will, other things being equal, depend upon the relative quantities of oxygen and hydrogen contained in the substance distilled; large doses of oxygen leading to the formation of more carbonic acid and water. Resinous, bituminous and oleaginous substances are found to contain more hydrogen, relatively to the oxygen, than other bodies of organic origin; and therefore afford, by destructive distillation, large quantities of inflammable gas. Hence the preference is due to this set of compounds, in the preparation of carburetted gases for illumination. Coal furnishes carburetted hydrogen by being distilled at a red heat, in large iron retorts; but as the bitumen contained in the coal is the source of the gas, the different varieties of coal vary greatly in their fitness for this purpose. The best of all is the coal of Lancashire, England; but the Richmond, Va. coal yields a large quantity of gas; while the anthracite, such as Lehigh, Lackawana, &c. affords little or none. Of different specimens, that is best for producing carburetted hydrogen, which contains the most bitumen and least sulphur.

418. The combustion of a common lamp, or candle, is an example of the simultaneous production and consumption of oil gas. When flame is applied to the wick of a candle, the heat causes a portion of the wax or tallow to melt; by means of capillary attraction the melted portion rises in the wick, and is decomposed by the heat applied, which at the same time sets the resulting gas on fire. The combustion thus commenced, will continue so long as there is matter to feed it; the heat of the flame constantly melting and decomposing fresh portions of the candle. In this operation, the wick is to be regarded only as a bundle of capillary tubes, serving to convey the fluid oil to the point where it is to be decomposed; a glass capillary tube, will answer the same purpose. The wick being surrounded by inflammable gas, and thus out of contact of the air, cannot burn, and contributes nothing to the flame. The gradual consumption of an ordinary cotton wick, is owing to the heat of the surrounding flame, by which it undergoes destructive distillation; and the crust of carbon which results, clogs the wick, in the case of a lamp, and prevents the free ascent of oil to supply the combustion. Part of this crust of carbon, or *snuff* as it is called, perhaps is derived from carburetted hydrogen which is decom-

418. Oil gas generated and consumed in a common lamp. Why a candle burns brighter for being snuffed, or a lamp for being trimmed. Why a candle recently extinguished may be re-lighted without the actual contact of flame.

posed by the heat in the interior of the flame. As soon as the exposed part of the wick of a candle becomes long enough to project beyond the flame into the air, it undergoes combustion and disappears. A very simple experiment will show the resolution of oil into inflammable gas by heat. Let a common tallow candle, with a thick wick, burn until the uncovered part of the wick is nearly an inch in length, and then extinguish it suddenly. So long as the wick continues red hot, a stream of smoke will ascend from it. This column of smoke, contains carburetted hydrogen gas, produced from the tallow which the red hot wick continues to decompose; and if a piece of burning paper be applied to it at the distance of two or three inches above the wick, it will take fire, and the flame running down, will re-light the candle.

419. *Bi-chloride of carbon* discovered by M. Julin, consists of soft and white fibres, of an odor resembling spermaceti; it burns with a red flame. *Proto-chloride of carbon* is a limpid, colorless liquid. *Chloride of carbon*, called the new chloride of Liebig, is a limpid, colorless liquid. *Per-chloride of carbon*, of Faraday, is a transparent solid, of an aromatic odor. *Chloro-carbonic acid*, affords a singular instance where two acidifying principles unite with one base to form an acid. It was discovered by Dr. John Davy who called it phosgene gas. It is formed by exposing equal volumes of chlorine and carbonic oxide to the solar rays, when rapid combustion takes place, and they contract to one half their volume. *Chloral* a compound of carbon, oxygen and chlorine was discovered by Liebig by the mutual action of alcohol and chlorine. It is an oily transparent liquid. *Periodide* and the *protiodide* of carbon, have been obtained. *Bromide of carbon* is formed by means of the *periodide of carbon* and *bromine*.

CHAPTER XVIII.

COMPOUND OF CARBON AND NITROGEN.

CYANOGEN.

420. *Bi-carburet of nitrogen or cyanogen*. 1 nit. 14 to 2 carbon 12=26. This compound in many respects seems to act the part of a simple element. It was discovered by Gay Lussac. It is obtained by the action of heat on cyanuret of mercury contained in a retort. It is conducted over mercury. The cyanuret, (formerly *prussiate*.) of mercury is simply resolved by heat into cyanogen gas and mercury, its components. The vapor of mercury is condensed in the pneumatic trough, and the gas passes over.

This gas is colorless, has a pungent odor, is condensible into

419. Compounds of carbon with *chlorine, iodine and bromine*.

420. Composition and discovery of cyanogen. How obtained? Properties. Product of its combustion. Its solutions.

a liquid by a pressure of $3\frac{1}{2}$ atmospheres; its sp. gr. is 1.8. It extinguishes burning bodies, but burns when set on fire in the air, producing carbonic acid, and liberating nitrogen gas; it may also be exploded when mixed with oxygen gas. It is very soluble in water, and still more so in alcohol; and its solutions have acid properties; these, however, do not belong to cyanogen, but are due to acids which are generated by the reaction of the elements.

421. Cyanogen, though a compound body, is strongly analogous to the simple electro-negatives: tending to combine with metals and other electro-positive simple bodies, and forming with them compounds which resemble the chlorides, iodides, &c., these compounds are called *cyanurets* or *cyanides*. It also forms acids by uniting with oxygen and hydrogen, respectively.

The name *cyanogen*, (from the Greek *kuanos*, blue, added to *gennao*,) implies *generator of blue color*; and was given it by its discoverer Gay Lussac, from its being contained in *Prussian blue*, to the composition of which it is essential. The latter substance will be considered in treating of iron, which is its base.

Compounds of Cyanogen and Oxygen.

422. *Cyanous Acid*. There are two isomeric compounds, or consisting of the same proportions of cyanogen and oxygen, viz. *one equivalent of each*; yet notwithstanding this identity of composition, their properties are entirely distinct.* One of them, called *cyanous acid* of Liebig, forms salts possessing the property of detonating by friction or percussion; and is frequently called *fulminic acid*. One of its salts is called *fulminate of mercury*. This compound, now much used for priming fire arms, under the name of *percussion powder*, is formed by dissolving mercury in nitric acid, and, after the solution has become cool, adding alcohol. In the violent action which ensues, nitrous and ethereal fumes are given off, and a white precipitate subsides, which is the fulminating mercury. By substituting silver for mercury, a *fulminate of silver* may be obtained, which explodes rather more readily than that of mercury.

423. *Cyanous Acid of Wohler* is formed when cyanogen gas is passed into a hot aqueous solution of an alkali, where water is decomposed and the cyanite and hydro-cyanate of the alkali are formed, as the chlorate and hydrochlorate are, in similar circumstances. The cyanite of potassa is best obtained by applying a low red heat to a mixture of equal parts of ferro-cyanate, (triple prussiate,) of potassa and peroxide of manganese. The cyanogen of the ferrocyanic acid takes oxygen from the oxide of manganese, and the

* See *Isomerism*, note to § 402.

421. Resemblance to simple electro-negatives. Origin of the name.

422. Two compounds of cyanogen and oxygen. Cyanous acid of Liebig. Fulminates.

423. Cyanous acid of Wohler. Anhydrous cyanous acid.

cyanous acid, so formed, unites with the potassa. The cyanite of potassa is then dissolved by boiling alcohol, and deposits as the solution cools. By dissolving this salt in cold water, and adding it to a solution of nitrate of silver, a cyanite of silver is precipitated; which, may be decomposed by a current of sulphuretted hydrogen gas. The sulphuret of silver is precipitated, and the cyanous acid remains in solution. It is decomposed in a few hours, being acted on by the water so as to form carbonate of ammonia. The same resolution of cyanous acid and ammonia is effected by boiling the cyanite of potassa in water, when carbonate of potassa remains and ammonia escapes; and if a dilute acid stronger than the cyanic be added to solution of cyanite of potassa, carbonic acid escapes, while the stronger acid forms salts with the potassa and ammonia. If an undiluted acid be used, the cyanous acid remains undecomposed a short time, and gives an odor like vinegar.

Anhydrous cyanous acid was obtained by M. Wohler, by distilling anhydrous cyanic acid, and collecting the products in cool vessels. Cyanous acid thus obtained is a colorless liquid, very volatile, which forms a soluble salt with baryta, and an insoluble one with oxide of silver and some other metallic oxides; the latter being totally soluble in nitric acid.

424. *Cyanic Acid*, consists of 1 Cyan. 26 added to 2 ox. 16=42.

This compound is formed by boiling bichloride of cyanogen with water. Water is decomposed, its hydrogen combining with the chlorine and its oxygen with the cyanogen. By the evaporation most of the hydro-chloric acid is expelled, and on cooling the cyanic acid crystalizes. The crystals are colorless and at first, transparent; but they become opaque if exposed to air, and give off water by gentle heat. This acid is nearly tasteless and volatile; but if subjected to strong heat a portion of it is resolved into pure cyanous acid and oxygen. It is decomposed by potassium forming with its oxygen, both potassa and cyanuret of potassium.

Compounds of Cyanogen and Hydrogen.

425. *Hydro-cyanic or Prussic Acid*, consists of 1 Cyan. 26 added to 1 Hyd. 1=27. This acid by its combination with the oxide of iron produces Prussian blue. It was discovered by Scheele in 1780, but he only obtained it in solution with a large proportion of water. Gay Lussac first obtained it pure. It has never been found uncombined in nature; though it is said to exist in the leaves, flowers, and kernels of the peach, and almond, and in the bark of certain plants. Thenard however, speaks doubtfully of the existence of this acid in those vegetable substances. Most writers are silent on the subject; but Professor Silliman says, that if peach, laurel, or almond water be combined with lime or an alkali, it will precipitate Prussian blue from a solution of iron. It is produced during many chemical operations; it results in some degree whenever any substance

424. Composition of cyanic acid. How formed. Its crystals. Solubility in water and acids. Properties. Decomposition.

425. Compounds formed by hydro-cyanic acid with oxide of iron. Discovery of this acid. Where found. How produced.

vegetable or animal which contains nitrogen is distilled and from the action of nitric acid on vegetable and animal substances, and of ammoniacal gas upon burning charcoal.

426. Hydro-cyanic acid is liquid, colorless, and corrosive. Its odor is strong, resembling that of peach blossoms. It reddens litmus feebly. It is very volatile; boils at 79° F. and freezes at zero. The voltaic pile decomposes it, the hydrogen going to the negative, and the cyanogen to the positive pole. Its vapor is inflammable and detonates with oxygen gas. This acid consists of 1 volume of vapor of carbon, $\frac{1}{2}$ a volume of hydrogen, and $\frac{1}{2}$ a volume of nitrogen condensed into one volume. Its action on the animal system is very destructive, as has been proved by the experiments of Orfila, Magendie and others. The end of a small tube having been touched to a drop of this acid was put into the mouth of a dog; the animal made two or three rapid inspirations and fell dead. One drop of the acid was applied to the eye of a dog, and the effects were scarcely less sudden than in the other case. Prussic acid, says Thenard, is without doubt, the most active and mortal of all known poisons, and a knowledge of its effects, renders less extraordinary those sudden deaths by poison so common in the annals of Italy. It acts upon the system by destroying the sensibility and the power of voluntary contraction of the muscles.

427. When introduced with some iron under a bell glass with mercury, and adding water to the mixture, it gradually disengages hydrogen gas, and prussian blue is produced. The production of this color furnishes a method of detecting the poison when used criminally. Portions of the stomach of a person supposed to be destroyed by prussic acid, are cut up and introduced into a retort with water slightly impregnated with sulphuric acid. If, on testing them with a prepared solution of the protoxide of iron, prussian blue is formed, there must have been present, hydro-cyanic acid. The sulphate of copper, furnishes a still more satisfactory test.

Hydro-cyanic or prussic acid unites with most alkaline bases, forming salts which are called *prussiates* or *hydro-cyanites*. These salts are poisonous. Prussic acid is used as a medical agent with some success but it is of too dangerous a nature, to be employed without great caution.*

* The melancholy and mysterious end of the admired poetess L. E. Landon, afterwards Mrs. McLean, who was discovered dead with a phial of this poison in her hand, was the subject of much remark a few years since. In one of her novels, she made a prominent character terminate a wretched existence by using a *liquid* which she had prepared from "*almond blossoms*," to be kept ready for use in case of emergency. Who can estimate or control the power of a morbid imagination?

426. Properties of hydro-cyanic acid. Decomposition by the voltaic pile, &c. Action on the animal system.

427. Tests of the presence of hydro-cyanic acid. Union with alkaline bases. Use in medicine.

428. *Chloride of Cyanogen*, sometimes called *cyanuret of chlorine*, and *cyanide of chlorine*, was discovered by Berthollet; he named it *oxyprussic acid*, on the supposition that it was composed of prussic acid and oxygen. Gay Lussac, who afterwards studied its nature, called it *chlorocyanic acid*.

It was not obtained in purity, until about the year 1827, when it was procured by exposing powdered cyanuret, (prussiate of mercury) moistened with water, to the action of chlorine gas contained in a closely stopped bottle. After a few hours, the color of the chlorine disappeared, the cyanuret of mercury was converted into the solid bi-chloride of mercury, (corrosive sublimate,) and a gaseous *chloride of cyanogen* filled the bottle. This acid is a limpid, colorless liquid at 10° ; and above this, at the common pressure, it is a gas. When enclosed in sealed tubes, it is liquid at 68° Fahrenheit, being then under the pressure of 4 atmospheres created by its own vapor. It is poisonous to the animal system; the vapor is offensive and injurious to the eyes; its taste is caustic. It is very soluble in water, and alcohol; it is absorbed by alkalies, and if an acid be then added, an effervescence takes place, carbonic acid is evolved, and ammonia, hydrochloric acid, and probably hydrocyanic acid are formed. It precipitates green, the solutions of the protoxide of iron; this precipitate becomes a beautiful blue by the addition of sulphuric acid, or sulphate of iron; but if potassa be mixed with the chloride of cyanogen before adding the salt of iron, this precipitate is not formed.

429. *Perchloride (or bichloride) of Cyanogen*. We have, in this compound, twice as much chlorine, as in the chloride of cyanogen; that is, 2 atoms of chlorine to 1 of cyanogen. It was discovered by M. Serullas, and is prepared by adding anhydrous prussic acid, to dry chlorine. It is solid at common temperatures. Its vapor is acrid and poisonous. It is rapidly decomposed by hot water, forming hydrochloric and cyanic acids.

430. *Bromide of Cyanogen* resembles prussic acid in its noxious qualities. On account of the danger, attending its preparation, and the difficulty of obtaining a sufficient supply of bromine, it has hitherto been little studied.

Iodide of Cyanogen is obtained by heating a mixture of 1 part of *iodine*, and 2 of the *cyanuret of mercury*. The violet vapors of iodines which first appear, are succeeded by white fumes, arising from the decomposition of the cyanuret; these, when condensed in a receiver, settle upon its sides resembling flocks of cotton. The iodide of cyanogen is composed of 1 equivalent of cyanogen, 26, with 1 of iodine 124, its chemical equiv. is, therefore, 150.

431. *Boron*. Equiv. 8. The discovery of this simple element is, by English Chemists, ascribed to Sir Humphrey Davy, who, in 1807 obtained it by exposing boracic acid to the action of 500 pairs of galvanic plates. The French Chemists assert that it was discovered in 1809 by Gay Lussac and Thenard. It appears that, though Davy discovered the existence of such an element, he did not obtain it in sufficient quantity to determine its properties.

428. Synonymes of chloride of cyanogen. How first obtained pure. Properties. Its precipitates with protoxide of iron.

429. Composition of the perchloride of cyanogen. Discovery, preparation and properties.

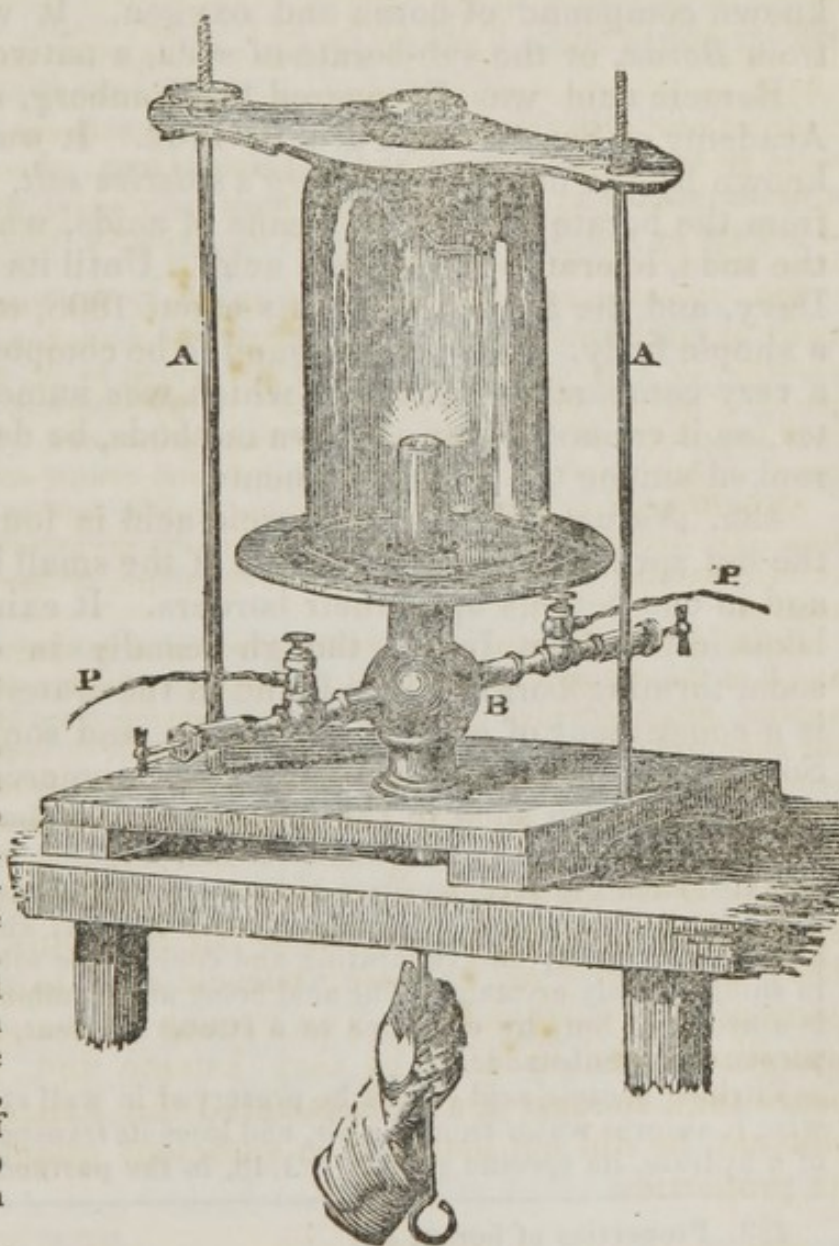
430. Bromide of cyanogen. Iodide of cyanogen.

431. Discovery of boron. Manner in which it was obtained by Davy. By Gay Lussac and Thenard.

Thenard says, "According to Davy, when boracic acid is brought in contact with the two poles of a very powerful battery, there appears at the negative pole, a small brown spot, which he attributes to the presence of boron, while the oxygen of the acid appears at the positive pole. But it is not possible, by this means to obtain an appreciable quantity of boron."* It was obtained by Gay Lussac, and Thenard, by heating equal parts of boracic acid, and potassium, in a porcelain or copper tube hermetically sealed at one end. The tube is heated to redness, one part of the acid is decomposed, giving off oxygen to the potassium; a portion of the oxygen of the undecomposed acid combines with the newly formed oxide of potassium; and the result of the operation, is the sub-borate of potassa, and boron. This salt is then dissolved into water, and the boron precipitated.† Berzelius recommends as the easiest and most economical mode of preparing it, to decompose the fluo-
borate of potassa, by heating with potassium.

Fig. 88.

432. By Dr. Hare's method boracic acid is put with the potassium into a copper cup (Fig. 88.) supported by a cylinder of copper C; —A A are rods which support a large receiver. One of the pipes, P, communicates with an air pump. The air being exhausted from the receiver, an iron rod heated to redness, is introduced through the cylinder B, until it touches the bottom of the cup. The cup is soon heated and a deep red flame appears to cover the whole mass. On cooling, it is found that the potassium has taken from the acid its oxygen, forming the oxide of potassium, (potash,) while pure boron remains.



* Thenard *Traité de Chimie*, Tome I. p. 212.

† *Traité de Chimie*, Tome II. p. 137.

433. Boron appears at ordinary temperatures, as an olive green powder. It is insipid to the taste, inodorous, and insoluble, not only in water, but in ether, alcohol, or oils. It is a non-conductor of electricity; absorbs oxygen at a high temperature, giving off light, and it burns spontaneously in chlorine gas. It decomposes nitric acid, taking a portion of its oxygen, and thus forming boracic acid, while nitric oxide is liberated.

Compounds of Boron and Oxygen.

434. *Boracic Acid.* 1 bor. 8 + 2 ox. 16=24. It is the only known compound of boron and oxygen. It was first obtained from *Borax*, or the sub-borate of soda, a native alkaline salt.

Boracic acid was discovered by Homberg, a Chemist of the Academy of Sciences of Paris in 1702. It was for many years known by the name of *Homberg's sedative salt*, and was obtained from the borate of soda by means of acids, which, uniting with the soda, liberated the boracic acid. Until its decomposition by Davy, and the French Chemists about 1808, it was regarded as a simple body. It was then found to be composed of oxygen and a very combustible substance which was named boron; the latter, as it cannot, by any known methods, be decomposed, is now ranked among the simple elements.

435. *Natural History.* Boracic acid is found in solution, in the hot springs of Lipari, in many of the small lakes of Tuscany, and in concretions upon their borders. It exists extensively in lakes in the East Indies, though usually in combination with soda, forming borax. It is found in the craters of volcanos, and is a constituent of boracic *tourmaline*, and some other minerals. So common has this acid become in commerce, that it is sometimes used with soda in the manufacture of borax.

For chemical experiments, and medicinal purposes, boracic acid is usually obtained from the decomposition of borax, or the borate of soda by sulphuric acid, and boiling water, sulphate of soda is formed, and boracic acid is liberated; the latter, on evaporating and cooling the solution, is precipitated in shining, scaly crystals. The acid being now combined with some water; is a hydrate; but, by exposure to a strong red heat, it melts into a transparent glassy substance.

Vitrified boracic acid should be preserved in well stopped bottles, otherwise it absorbs water from the air, and loses its transparency. In the state of a hydrate, its specific gravity is 1.48, in the purified or vitreous state, it

433. Properties of boron, &c.

434. Composition of boracic acid. From what first obtained? Discovery. Synonymes, &c. How obtained from the borate of soda? When discovered to be compound?

435. Natural history. How obtained for chemical experiments and medicinal purposes? Properties. Crystals of boracic acid.

is 1.80. It is inodorous, and has a bitter, rather than an acid taste. It effervesces with the alkaline carbonates, though when applied to turmeric paper, it acts like an alkali, giving it a brown color; it reddens vegetable colors. In solution with alcohol, it burns with a beautiful pale green flame.

The form of crystals of boracic acid are hexahedral, they have a pearly whiteness, and feel smooth and oily like spermaceti. They contain,

Boracic acid	24,	or one equivalent.
Water	18,	“ do.

Equiv. of boracic acid 42.

436. Boracic acid, like hydrochloric and hydrofluoric acids, was long ranked among undecomposed bodies; but like them, it is now found, both by analysis and synthesis, to consist of an inflammable basis, uniting to a supporter of combustion; but while the base of boron combines with oxygen to form boracic acid, we have found the hydro-chloric acid having inflammable hydrogen for its base united to a supporter of combustion, chlorine. The hydrofluoric may still be regarded as of a doubtful nature, though at present, it is usually ranked among the hydracids.

437. *Chloride of Boron* is formed by the combustion of boron in chlorine gas. As one equivalent of boron 8, unites with 2 equivalents of chlorine, 72, the representative number of this chloride is 80; and it is usually called, on account of its composition the *bi-chloride* of boron.

Sir Humphrey Davy first observed, that boron takes fire spontaneously in an atmosphere of chlorine, and burns with a vivid light. Berzelius afterwards commenced a series of experiments, to ascertain the nature of the compound formed by this combustion. He found it to be a gas which is rapidly absorbed by water, when double decomposition takes place, and hydro-chloric and boracic acids are produced. M. Dumas and M. Despretz have found that the bi-chloride of boron may be generated by the action of dry chlorine on a mixture of boracic acid and charcoal, heated to redness in a porcelain tube.

438. *Fluoride of boron* is generally known among Chemists, by the name of *fluoboric acid gas*; but its nature and composition, remain doubtful. If fluorine could be obtained in an uncombined state, and then united with the inflammable boron, the result would be an undoubted fluoride of boron; but, as fluoric acid has not yet been decomposed, its combinations are still regarded as of an uncertain character. “The chief difficulty in determining the nature of hydro-fluoric acid,” says Turner, “arises from the water of the sulphuric acid which is employed in its preparation. To avoid this source of uncertainty, Gay Lussac and Thenard made a mixture of vitrified boracic acid, and fluor spar, and exposed it, in a leaden retort, to heat, under the expectation that as no water was present, anhydrous fluoric acid would be obtained. In this, however, they were disappointed; but a new gas came over, to which they applied the term of fluo-boric gas.” The gas may be formed by the action of hydro-fluoric acid on a solution of boracic acid. Some suppose, that in the decomposition of fluor spar, (fluoride of

436. Acids which were formerly ranked among undecomposed bodies.

437. Chloride of boron.

438. Fluoride of boron. Synonyme. Its doubtful nature. Experiment of Gay Lussac and Thenard. Explanations. Fluo-borates. Properties of fluoride of boron.

calcium,) the two substances interchange elements, the calcium and oxygen uniting to form lime, and a portion of free boracic acid forming with the lime, while borate of lime, boron, and fluorine, enter into a direct combination. The discoverers of this gas regarded it as a compound of fluoric and boracic acids, and therefore named it fluo-boracic acid, and the salts which it forms with alkalies, *fluoborates*.

While fluoric acid has a powerful action upon glass, the fluo-boric acid, (or fluoride of boron,) has no effect upon it, its affinity for silex being neutralized by the presence of boron. It carbonizes animal and vegetable substances, extinguishes flame, and is irrespirable. When absorbed by water, for which it has great affinity, it forms a dense, fuming, and corrosive liquid, somewhat resembling sulphuric acid, equally powerful in its effects on vegetable blues.

CHAPTER XIX.

SILICON.—PHOSPHORUS.

439. *Silicon*, Equiv. 8. We should, reasoning *a priori*, expect that the simple, or undecomposable elements might be more easily understood than compounds; but this is not generally the case. Indeed, most of these elements, except some of the metals, are found in nature only in combination, from which, science alone has taught us how to disengage them. Thus, though silicon, in combination with oxygen, forms silex, one of the most abundant substances in nature, it has remained hidden from our observation, till within a few years; and it is only by difficult and complicated processes, that it has been obtained in quantities sufficient to render observations and experiments upon it, of a definite and satisfactory nature.

440. Sir Humphrey Davy by experiments with silex, or siliceous earth and heated potassium, discovered that the former is a compound of oxygen and a peculiar base, to which, on the supposition of its being a metal, he gave the name of *silicium*, corresponding to calcium and potassium, the metallic bases of lime and potash. This substance has continued to be classed among the metals, until Berzelius has proved that it is infusible, devoid of metallic lustre, a non-conductor of electricity, and in short is destitute of all the distinguishing characteristics of metals. On account of its resemblance to boron and carbon in being combustible, it is by late Chemists, ranked among the

439. Why simple bodies are less readily understood than compound. Obscure nature of silicon.

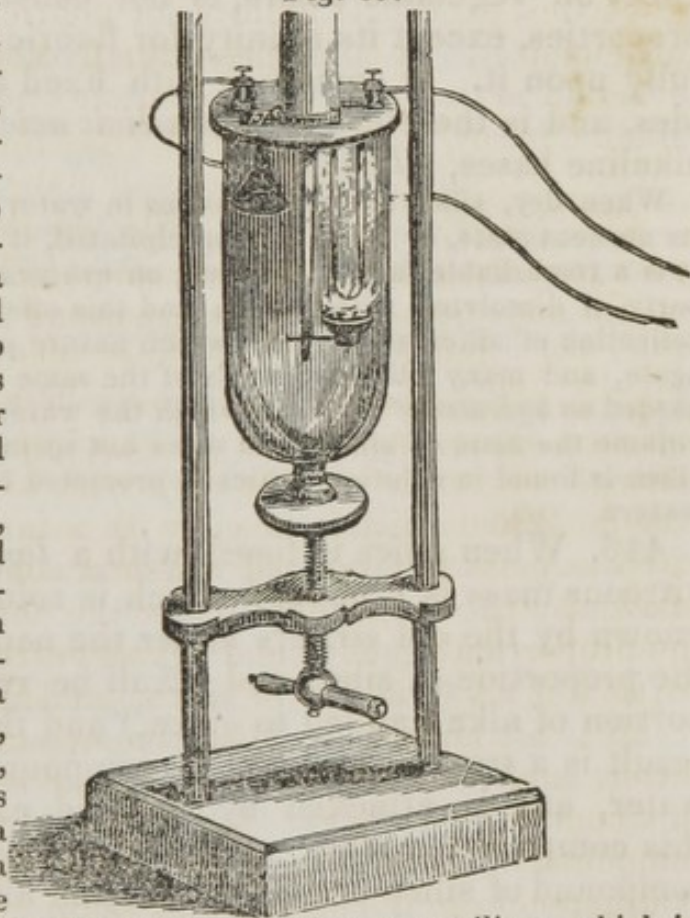
440. Discovery of the compound nature of silex. Change of the name *silicium* to *silicon*.

non-metallic combustibles, and in corresponding terminology called *silicon*.

441. Berzelius states,* that pure silicon is of a dark brown color, exhibiting no metallic lustre even by rubbing, and like earthy bodies, opposes resistance to the body against which it is rubbed. It leaves a stain upon glass vessels, adhering strongly to them when dry. It is destitute of taste or odor, and has no action upon vegetable colors. It is a bad conductor of heat and electricity, burns neither in the air nor in oxygen, and remains unaffected by the flame of the blow pipe. It decomposes water, and becomes converted into silex by its union with oxygen.

442. Silicon was first obtained pure by Berzelius in 1824, by the action of potassium on fluo-silicic acid gas. Dr. Hare has invented a convenient apparatus for this purpose. A bell glass (Fig. 89.) is so fixed that it may be connected with an air pump; a platinum wire is suspended within the bell glass, and a cup containing potassium hangs just below the wire. The air being exhausted from the bell glass, fluosilicic acid, (or fluoride of silicon,) is admitted, and the platinum wire ignited by an electric spark. The potassium is inflamed, and in burning, decomposes the fluo-silicic acid, giving rise to a peculiar deep red flame, and chocolate colored fumes, which condense into flakes forming, (except in color,) a miniature representation of a snow storm. On washing the precipitate which is collected after this combustion, pure *silicon*, which is insoluble, is obtained, the residue being chiefly *fluoride of potassium*.

Fig. 89.



Compound of Silicon and Oxygen.

443. *Silicic acid.* 1 silicon 8+1 of oxy. 8=16. It was cal-

* See *Memoire de Berzelius, Annals de Chimie*, Tome xxvii. p. 341. Those who have not access to the original memoir may find an abridged translation in the author's *Dictionary of Chemistry*, pp. 414—416.

441. Properties of silicon.

442. Dr. Hare's method of obtaining silicon from fluo-silicic acid.

led *silicic acid*, from its analogy with boracic and fluoric acids, and because, like acids, it saturates the alkalies. It is often called *silex*; in the laboratory *silica*. It has long been known in the arts, and was called by ancient Chemists, *vitriifiable earth*, because it entered into the composition of glass. It is extremely diffused in nature, being the principal constituent of most mineral substances. It is found nearly pure in flint, white sand, quartz crystals, calcedony, and various other minerals.

444. It may be prepared by heating to a red heat flint, or quartz crystals, and throwing them into water.

445. *Physical and Chemical properties.* Silica is a light, white powder, insipid, tasteless, and harsh to the touch. It has no effect on vegetable colors, is not caustic, and has no alkaline properties, except its affinity for fluoric acid, which acts powerfully upon it. It combines with fixed alkalies and metallic oxides, and is therefore termed *silicic acid*, and its compounds with alkaline bases, *silicates*.

When dry, silica neither dissolves in water nor is absorbed by it, but in its nascent state, or when just precipitated, it dissolves freely in this liquid. It is a remarkable fact, that silica, on evaporation, should thus lose its property of dissolving with water; and this offers an explanation of the vast collection of silicious crystals which nature presents in cavities of quartz, agate, and many other minerals of the same class; and which may be regarded as *hydrates of silica*, in which the water of crystalization exceeds in volume the mass of silica. In some hot springs as the geysers of Iceland, silica is found in solution, which is promoted by the soda contained in their waters.

446. When silica is fused with a *large* portion of potassa, a vitreous mass is produced which is soluble in water. This was known by the old writers under the name of *liquor of flints*. If the proportion of silica and alkali be reversed, (that is, a *small* portion of alkali added to silica,) and the mixture be fused, the result is a transparent, brittle compound which is insoluble in water, and is attacked by no acid except the hydro-fluoric; this compound is *glass*. "Every kind of glass is a *silicate*, or a compound of silica and an alkali, and all its varieties are owing to differences in the proportions of the constituents, to the nature of the alkali, or the presence of foreign matter. Thus, green bottle glass is made of impure materials, such as river sand, which contains iron, and the most common kind of kelp or pearlshes. Crown glass for windows is made of purer alkali.

443. Composition of silicic acid. Its synonymes. Its existence in nature.

444. Mode of obtaining it.

445. Properties. Silicates. Its action with water. Crystals.

446. Liquor of flints. Glass. Cause of varieties of glass

and sand which is free from iron. Plate glass for looking glasses is composed of sand and alkali in their purest state, and in the formation of flint glass besides these pure ingredients, a quantity of red lead or litharge is employed.* Black oxide of manganese improves the transparency of glass, by oxidizing any carbonaceous substances in the materials used; and boracic acid or borax are employed in making imitations of gems. Silica is also used in the composition of porcelain; as pure clay without any silicious earth would shrink too much for this purpose.

Compounds of Silica with Chlorine, Sulphur and Fluorine.

447. *Chloride of Silicon* is formed by the combustion of silicon in chlorine gas. It is liquid, limpid, and volatile, evaporating in open vessels, in the form of a white vapor. Its odor resembles that of cyanogen. Water changes it into muriatic acid and silica.

448. *Sulphuret of Silicon*. Silicon when heated with the vapor of sulphur, unites with it, forming a white earthy looking substance. Water converts it into sulphuretted hydrogen and silica. The former escapes with effervescence, the latter dissolves.

449. *Fluoride of Silicium, or Fluo-silicic Acid Gas* is composed of 1 Silicon 8 added to Fluor 10=18.

In treating of hydro-fluoric acid, especially its action upon glass we found that in decomposing that substance a peculiar gas was generated. This is the *fluo-silicic acid*. It is a colorless gas, of a strong odor and caustic taste. It extinguishes combustion, is irritating to the lungs, and is not decomposed by heat. Its specific gravity is 3.57. Water acts upon it, precipitating silica in a gelatinous state. It forms white fumes with the atmosphere by combining with aqueous vapor. When distilled in a receiver containing water, it becomes covered with a silicious crust which at length covers the water, and it is necessary to shake the vessel and break this crust that the condensation may not thus be prevented. Moist substances exposed to this gas, become encrusted with it, so as to resemble petrifications; thus insects, reptiles, and vegetable substances, by being moistened and placed in an atmosphere of this gas may be made to appear like natural fossils.

It may be prepared for experiments by heating in a retort three parts of fluor spar and two of silica, with an equal weight of sulphuric acid; it must be collected over mercury. When dissolved in water, it becomes the *silico-hydro fluoric* or *silicated fluoric acid*; the hydrogen of the water combining with the fluorine, and the oxygen with the silicon.

PHOSPHORUS. EQUIV. 12.

450. Phosphorus combines so readily with oxygen and other

* Turner.

447. Formation and properties of chloride of silicon.

448. Formation of sulphuret of silicon.

449. Composition of fluo-silicic acid. When produced. Properties. Action with water. How prepared for experiments? Change when dissolved in water.

substances that it is not found pure in nature. It is solid, but so soft and flexible that it may be bent with the fingers like wax. It may be cut with a knife. Its color when pure is white, but on exposure to air and moisture it assumes a brownish hue. When excluded from contact with the air, light gives it a red color. Its specific gravity is 1.77. Its odor is feeble, somewhat resembling that of hydrogen gas. It is always luminous in the dark, hence its name—the light-bearer, from the Greek *phos*, light, *phero*, to bear.

451. *History.* Phosphorus was discovered in 1669, by Brandt, an alchemist of Hamburgh, in his search for the *philosopher's stone*, or the art of converting the common metals into gold and silver. The preparation of phosphorus, however, remained a secret until 1737, when a stranger in Paris, communicated it to a committee of the French Academy of sciences. But the method then used was tedious and imperfect. In 1769, Gahn of Sweden, in connection with Scheele, published a newly discovered process for obtaining phosphorus by distillation of bones. This is the one now generally followed. Phosphorus being thus easily obtained, chemists were able to study its properties. Much is due to the labors of M. Pelletier, who first combined it with sulphur and many of the metals; to Lavoisier, who investigated its combination with oxygen; to Dulong and Davy, who studied its different acids, and to Berzelius, who has examined the combinations of these acids, with different bases.

452. The solid parts of the bones of animals consist, principally, of the phosphate of lime, a salt formed by the union of phosphoric acid and lime. A man of common stature is said to have about one pound of phosphorus in his bones. Phosphoric acid is a compound of phosphorus and oxygen. From the decomposition of the phosphate of lime, in bones, phosphorus is obtained.

The usual process is, to digest in sulphuric acid a quantity of calcined bones, (that is, bones burnt in an open fire,) reduced to powder. The phosphate of lime is decomposed by the sulphuric acid, which, uniting with the lime forms sulphate of lime; the disengaged phosphoric acid being now mixed with powdered charcoal, and strongly heated in an earthen retort, parts with its oxygen to the charcoal, forming carbonic acid, while phosphorus passes over in the form of vapor, and may be collected by placing the beak of the retort under a receiver filled with water. When first obtained it is of a red color, owing to the presence of the phosphuret of carbon, from which it may be purified by another distillation.

450. Why is phosphorus not found pure in nature? Its physical properties. Derivation of the name.

451. History.

452. Where does phosphorus exist? Mode of obtaining it.

453. Phosphorus is highly inflammable, and gives off a garlic odor when burning. When exposed to the air at common temperatures it undergoes slow combustion, appearing in the light as a white smoke and in the dark as a beautiful blue luminous cloud. It should be kept in water, as a slight degree of heat, in the open air readily kindles it to a flame. It melts at 99° F. takes fire at 108° ; and volatilizes at 219° .

454. Perhaps no substance affords such a variety of brilliant experiments, especially for an evening's exhibition, as phosphorus.

Exp. 1st. Words or figures drawn on the wall of a dark and warm room with a stick of phosphorus will leave traces, which in the night will appear like fire.

Exp. 2nd. A few grains of phosphorus in the bottom of a wine glass will burn with brilliancy, and a succession of detonations, by pouring on water and sulphuric acid.

Exp. 3d. Oil, in which phosphorus has been dissolved, when rubbed on the face and hands, exhibits the appearance of a lambent flame, playing over the features, accompanied with luminous clouds and flashes. Unless the phosphorus is entirely dissolved, this may prove a dangerous experiment; severe burns have been thus caused.

Fig. 90.



Exp. 4th. The combustion of phosphorus in oxygen gas, (Fig. 90,) or even an enclosed portion of atmospheric air, is attended with a splendor too great for the eye to endure. During combustion dense white vapors like flakes of snow will fill the jar. These vapors are phosphoric acid, consisting of phosphorus and oxygen.

Exp. 5th. Eudiometry may be performed by consuming the oxygen of the air with phosphorus. If a cylinder of phosphorus be supported upon a wire within a glass matrass (Fig. 91,) inverted in a jar of water, the included air is gradually absorbed. In order to determine the quantity of oxygen in the air, we have only to ascertain the ratio between the quantity absorbed, and the quantity included.

Fig. 91.



455. Phosphorus does not, at the ordinary pressure, burn in oxygen gas at a temperature below 80° ; but if the pressure is diminished, it becomes luminous in the dark, and burns. Nitrogen, by rarefying the oxygen of the atmosphere, acts like the diminution of pressure, and singularly favors the combustion. Phosphorus forms combinations with most other combustible bodies. With oxygen it enters into the composition of many minerals, and forms a large portion of the animal frame. It is employed in the arts for the construction of phosphoric matches, and in Chemistry for the analysis of air and the preparation of phosphoric acid. It is a violent poison, though it is sometimes used in medicine in very small doses.

Combinations of Phosphorus and Oxygen.

456. There is an uncertainty with respect to the number of combinations of these two elements. Dr. Turner remarks that "under the term phosphoric acid, Chemists have hitherto included two distinct acids, *phosphoric*, and *pyro-phosphoric*, compounds which afford an instance of a fact of much importance to the atomic theory: viz. That two substances may consist of the *same ingredients*, in the *same proportion*, and yet differ essentially in their chemical properties." These are *isomeric bodies*.*

457. There are three known acid combinations of phosphorus and oxygen, which contain different proportions of their constituent elements.

- | | |
|-----------------------------------|-------------------------|
| 1. <i>Phosphoric acid</i> , | 1 Phos. 12+2 Ox. 16=28. |
| 2. <i>Phosphorous acid</i> , | 1 Phos. 12+1 Ox. 8=23. |
| 3. <i>Hypo-phosphorous acid</i> , | 2 Phos. 24+1 Ox. 8=82. |

458. *Phosphoric acid* may be obtained by the combustion of phosphorus in oxygen gas, (see ¶ 454, exp. 4th.) It may also be obtained by burning phosphorus in an enclosed portion of atmospheric air, occasionally raising the receiver, in order to let in fresh supplies of air, until all the phosphorus is consumed. 1 grain of phosphorus requires about 15 cubic inches of common air, and of course about 4 cubic inches of oxygen for its saturation.

459. This acid is white, solid, inodorous, and soluble in water,

* See ¶ 402. with the note.

455. Circumstances under which phosphorus burns in oxygen gas, &c. Combinations of phosphorus. Uses.

456. Dr. Turner's remark respecting phosphoric and pyro-phosphoric acids.

457. Names and composition of acid compounds of phosphorus and oxygen.

458. How may phosphoric acid be obtained?

459. Properties, &c.

dissolving with a hissing noise, and forming if concentrated, a dense, oily liquid. Though decided in respect to its sour taste, its action on vegetable blue colors, and its effect in neutralizing alkalies, it does not decompose animal matter, like nitric and sulphuric acids.

Fig. 92.



460. Phosphoric acid may be decomposed by heating with charcoal in a retort *a*, (Fig. 92,) placed over a furnace, *b*, the beak of the retort being immersed in the basin of the water, *c*. The phosphoric acid loses oxygen, which, uniting with the vapor of carbon from the charcoal, forms carbonic acid gas: the phosphorus passes over, being volatilized when the retort is at a red heat, and appears in the basin, in the form of a reddish wax.

461. *Pyro-phosphoric acid*. Mr. Clark of Glasgow remarked that common phosphoric acid is, by heat, converted into a substance, which, though unchanged in its constituents or in their combining proportions, exhibits properties of an essentially different kind; this new acid he called *Pyro-phosphoric* acid*.

Phosphoric acid produces with the oxide of silver a *yellow salt*, and renders a solution of albumen turbid. Pyro-phosphoric acid produces with the same oxide a *white salt*, and does not destroy the transparency of albumen. Pyro-phosphoric is less energetic, it has less saturating power, and is separated from its combinations by phosphoric acid. And yet the only *visible* effect of heat on phosphoric acid is to expel water, which, we should infer, would render the acid more powerful, rather than diminish its energies.

462. *Phosphorous acid*. It was ascertained by Lavoisier, that the *slow* and *rapid* combustion of phosphorus produced two distinct acids, the *phosphorous* and the *phosphoric*. At a high temperature, phosphorus, whether burning in common air or in oxygen gas, unites with its highest proportion of oxygen (two equivalents=16,) and produces phosphoric acid; at a common temperature it unites with but one equivalent of oxygen (=8) and forms phosphorous acid.

463. Sir Humphrey Davy first obtained pure phosphorous acid, by subliming phosphorus through the perchloride of mercury, (corrosive sublimate.) The corrosive sublimate is put into a glass tube, connected at one end with a small receiver, (which is to be kept cool,) and at the other with a small tube containing phosphorus; as heat is applied to the phosphorus, it rises in vapor, comes in contact with the corrosive sublimate, which it decomposes by combining with its chlorine, and passes into the receiver in the

* From the Greek *pur* fire, added to phosphoric.

460. Decomposition of phosphoric acid.

461. Discovery of pyro-phosphoric acid. Difference in the properties of phosphoric and pyro-phosphoric acids.

462. Different products of the slow and rapid combustion of phosphorus.

463. Mode of procuring phosphorous acid.

form of a limpid fluid, which is the *chloride of phosphorus*. This, on being mixed with water, decomposes it; the chlorine unites with the hydrogen of the water, forming hydrochloric acid; while the phosphorus attaches itself to the oxygen, producing phosphorous acid. The solution being next evaporated to the consistence of syrup, hydrochloric acid is expelled, and the residue, which is a *hydrate of phosphorous acid*, becomes solid and crystalline in cooling.

464. From its tendency to unite with an additional quantity of oxygen, phosphorous acid is a powerful deoxidizing agent, and precipitates mercury, silver, and gold from their saline combination in the metallic form. On exposure to the air, or in contact with the nitric acid, it absorbs oxygen, and is converted into phosphoric acid. Phosphorous acid combines with salifiable bases, forming salts called *phosphites*; it is acid to the taste, and reddens vegetable blue colors. Its odor resembles that of garlic.

465. *Hypo-phosphoric acid*. Is so named on the supposition that it contains a smaller proportion of oxygen than the phosphorous acid. It combines with salifiable bases forming neutral salts, called *hypo-phosphites*, which are all remarkably soluble in water. Silliman suggests that this acid may be a triple compound of oxygen, hydrogen, and phosphorous, or a *hydracid*, in which case its proper name would be *hydro-phosphoric acid*.*

466. *Oxide of Phosphorus*. Phosphorus is usually made into small sticks of a few inches in length. As it must be preserved in water, it is usually kept in vials of this liquid. After being for some time exposed to the action of water, it becomes encrusted with a whitish substance, which is called the *white oxide of phosphorus*. The red colored residue which appears after the combustion of phosphorus, is called the *red oxide of phosphorus*. Thenard considers these two oxides identical, except that the white oxide is in the *hydrated state*.

Phosphorus and Chlorine.

467. There are two definite compounds of phosphorus with chlorine. One discovered by Davy, called the *perchloride*, the other discovered by Gay Lussac and Thenard, and called *proto-chloride*. Their component parts and chemical equivalents are as follows.

* Silliman's Elements, Vol. 1. p. 429.

464. Properties, salts, &c.

465. Hypo-phosphoric acid. Its salts. Silliman's suggestion respecting its composition.

466. Formation of the white oxide of phosphorus. Red oxide.

467. Discovery and composition of the proto-chloride and per-chloride of phosphorus.

Protochloride of Phos. 1 Phos. 12+1 Chlo. 36=48.

Perchloride of Phos. 1 Phos. 12+2 Chlo. 72=84.

468. The *Protochloride* of phosphorus may be obtained by passing the vapor of phosphorus over perchloride of mercury, (corrosive sublimate,) in a heated glass tube; the perchloride of mercury yields one proportion of chlorine to the phosphorus and becomes calomel, or the protochloride of mercury. The phosphorus has become a volatile transparent liquid, very caustic, and heavier than water. It decomposes rapidly in water in which case a solution of hydrochloric, and phosphorous acids is the result. Its vapor is combustible.

469. The *Perchloride of phosphorus*, sometimes called the *bichloride* and *deutochloride* is formed when dry phosphorus is burned in chlorine gas.

Fig. 93.



(Figure 93) represents a tubulated glass bottle containing chlorine gas, into which some phosphorus being introduced, it burns spontaneously, throwing off brilliant jets of fire, and giving a pale white light. The bladder fastened to the tubulure is to give space for the expansion of the gas by heat, which, as the bottle is air tight, might otherwise, cause it to break. The white, solid, pulverulent substance which collects on the inside of the bottle is the per-chloride of phosphorus. It crystalizes in transparent prisms; is volatile at a heat less than 212° ; decomposes water rapidly, forming with its elements, hydro-chloric and phosphoric acids. Some chemists regard the chlorides of phosphorus as acids, to which they give the name of *chloro-phosphorous* for the proto-chloride, and *chloro-phosphoric* for the per-

chloride. When the per-chloride of phosphorus is heated with about one seventh of phosphorus, it passes to the state of proto-chloride.

470. *Phosphorus* with *bromine* and *iodine* forms compounds termed *bromides* and *iodides of phosphorus*, but they are little understood.

Phosphorus and Hydrogen.

471. There are two compounds of phosphorus and hydrogen, viz.

Proto phosphuretted Hydrogen, and *Per-phosphuretted Hydrogen*

468. Proto-chloride of phosphorus.

469. Per-chloride.

470. Bromides and iodides of phosphorus.

471. Composition of two compounds of phosphorus and hydrogen. The terminations in *ide*, *uret*, &c.

As in the chemical nomenclature, *binary** compounds of substances of the *electro-negative* class, which are not acid, are designated by the termination *ide*, as *oxide*, *chloride*, *bromide*, &c., so *binary* combinations of the *electro-positive* class, which are not of a metallic nature, are distinguished by the termination *uret*, as *phosphuret*, *carburet*, *sulphuret*, &c. When the compound is *gaseous*, the termination *uretted* is used, as *carburetted hydrogen*, *sulphuretted hydrogen*, &c.

472. *Proto-phosphuretted Hydrogen* is sometimes called the *bi-hydruret of phosphorus*, and *hydro-phosphoric gas*. It was discovered by Sir Humphrey Davy in 1812.

It may be obtained when the solid hydrated phosphorus acid is heated in a close vessel. It is a colorless gas, with a disagreeable odor. It does not take fire spontaneously in the atmosphere, as phosphuretted hydrogen does; but when mixed with atmospheric air, or pure oxygen, it detonates violently with the electric spark, or when heated to 300° F., it inflames spontaneously in chlorine gas.

473. *Per-phosphuretted Hydrogen*, (called also the *Hydruret of Phosphorus*,) may be obtained by boiling phosphorus in a small retort (Fig. 94,) with a hot solution of potash, which should entirely fill the vessel, and the beak of the retort should be made to dip into a vessel filled with the same solution. The gas, as it

Fig. 94.



is extricated, gradually expels the liquid from the neck, and inflames, when allowed to escape into the air; or it may be collected under a bell glass, also filled with the same alkaline solution. One peculiar property of this gas is, that of spontane-

ously inflaming on mixture with common air or oxygen gas. This combustion is accompanied with a beautiful appearance. After the explosion, circular, horizontal rings, or coronas, of dense white smoke rise in the air, which increase in diameter, and become fainter as they ascend,† it is decomposed by heat, electricity, and the vapor of sulphur. Lights may sometimes be

* A *binary* compound is one which consists of no more than two elements.

† Some care is necessary in conducting this experiment, that as small a portion of air as possible shall be included in the retort, since the first bubbles of phosphuretted hydrogen gas that are formed, will take fire as soon

472. *Proto-phosphuretted hydrogen*. Discovery. Mode of obtaining it and its properties.

473. *Per-phosphuretted hydrogen*, &c. Cause of lights seen at night in certain situations, &c.

seen at night around burying grounds, and swamps where animal and vegetable substances are undergoing decomposition, "Travelling once," says Silliman, "through a deep valley, in a dark night, between Wallingford and Durham, Conn., I was surrounded by multitudes of pale, lambent lights; these were every moment changing their position, and some of them were within reach of my whip; they were yellowish, but not intense."

Thus does science explain to us the mysterious "Jack o' the Lantern" and "Will o' the Wisp," as being mere exhalations of gases which, on rising into the atmosphere, spontaneously in flame.

475. *Phosphuret of Carbon.* The combination of phosphorus with carbon was first effected by M. Proust, in 1799; it is a soft, yellowish powder, destitute of smell or taste. It slowly imbibes moisture from the air, and then has an acid taste.

CHAPTER XX.

SULPHUR.—EQUIV. 16.

476. *Natural History.* Sulphur is found, as a mineral, in various parts of the world, especially in the vicinity of volcanoes. It is obtained in large quantities from the craters of volcanoes. It is generally massive, sometimes in a state of powder, or crystalline form. Much of the sulphur of commerce, is obtained by applying heat in close vessels to the natural compounds of the metals and sulphur, especially to iron pyrites. The volcanic sulphur is probably the result of similar decompositions.

Properties. Sulphur is a brittle solid, of a citron or greenish yellow color, inodorous, except when heated by friction on fire, and nearly tasteless. It is about twice as heavy as water. It is a very bad conductor of heat and electricity, and becomes negatively electrified when rubbed.

477. Sulphur fuses at about 216° Fahrenheit; it is fluid between 230° and 280° Fahrenheit, and when cast into moulds, forms the common roll sulphur, or brimstone. As the temperature rises, it thickens and becomes darker colored, till at between 425° and 480°, it is so tenacious that the vessel may be inverted without spilling it. At 428°, if poured into water, it becomes a plastic mass, and is used for taking impressions of medals, &c.

as they come in contact with air in the retort, which will be in danger of being broken in the percussion.

475. Phosphuret of carbon.

476. Sulphur found in a natural state. Sulphur of commerce, how obtained? Properties.

477. Affected by heat. Flowers of sulphur. Crystalized sulphur.

Above 480° , it liquefies again, but not so perfectly as at 248° . At 550° , or 600° , it sublimes rapidly; indeed, a slow evaporation commences below the freezing point. The vapor condenses on cold surfaces in the form of a crystalline powder, called *flowers of sulphur*. Sulphur may be crystalized by fusing several pounds of it in a large crucible, and allowing it to cool slowly. When a crust has formed upon the upper surface, it is to be perforated in two places by a hot iron rod, and the sulphur which remains melted, is to be poured out. If a sufficient quantity of sulphur has been used and the cooling very slow, octahedral crystals of sulphur will be found lining the crucible; otherwise the crystalization will be irregular and confused.

478. Sulphur is soluble in *alcohol*, provided the two bodies be brought together in the state of vapor; from this solution, water throws down the sulphur as a white hydrate called "*milk of sulphur*." This is the only combination of sulphur with water, the former being quite insoluble in the latter.

479. Sulphur takes fire on being heated above 300° in the open air; it burns with a blue flame, and if the air be quite dry, produces *sulphurous acid gas*; if moisture be present, some sulphuric acid is formed also. In pure oxygen gas, the combination is far more rapid and brilliant; but the product is sulphurous acid in this case also. Sulphur has numerous and important uses in medicine. Mixed with charcoal and salt-petre, it forms gun-powder, the explosive property of which is owing to the sudden change of solids into gases. It is used for fire matches, for copying medals, and furnishes beautiful crystals for ornamental purpose. With iron filings, it is used as a cement.

Fig. 95.



Ex. If a gun-barrel, (Fig. 95,) heated to a red heat, have a piece of sulphur placed in one end of it, the jet of ignited sulphurous vapor will burn iron wire, as if ignited in oxygen gas; and the iron will fall in the form of fused globules; these are the proto-sulphurets of iron. Hydrate of potassa exposed to the jet, fuses into a sulphuret

of fine red color. Combined with oxygen in the form of sulphurous and sulphuric acids, sulphur is used in the arts of bleaching and dyeing.

480. *Compounds of sulphur and oxygen.* Of these there are four, all of them being acids.

1. <i>Hyposulphurous acid</i> ,	1 Sulp. 16	added to 1 ox.	$8=24$.
2. <i>Sulphurous acid</i> ,	1 Sulp. 16	" 2 ox.	32.
3. <i>Hyposulphuric acid</i> ,	2 Sulp. 32	" 5 ox.	72.
4. <i>Sulphuric acid</i> ,	1 Sulp. 16	" 3 ox.	40.

478. Sulphur with alcohol. Hydrate of sulphur.

479. Product of the combustion of sulphur. Uses. Exp.

480. Names and composition of the compounds of sulphur and oxygen.

481. *Hyposulphurous acid.* This acid is only known in combination with bases, forming salts called *hyposulphites*. On adding a stronger acid, to liberate the hyposulphurous acid, the latter is immediately resolved into sulphurous acid and sulphur. The hyposulphites are of no use in the arts; their most interesting property, is, that their solutions dissolve large quantities of chloride of silver, giving intensely sweet compounds.

482. *Sulphurous Acid Gas.* This is always the *principal* product of the combustion of sulphur in air, or oxygen gas, and is the *sole* product when moisture is not present. But the best mode of obtaining this gas, is by depriving sulphuric acid of a portion of its oxygen. Most of the metals decompose sulphuric acid, becoming oxidized at its expense.

Put 2 parts of mercury, and 3 of sulphuric acid, into a glass retort, and apply the heat of a lamp. The peroxide of mercury is formed, and unites with some of the undecomposed acid, forming persulphate of mercury, which remains in the retort; while the sulphurous acid gas escapes with effervescence, and is to be collected over mercury in the receiver.

484. *Properties.* Sulphurous acid gas is transparent and colorless. Its specific gravity is 2.22, (double that of oxygen,) it is less elastic than any other gas; being condensed into a liquid by intense cold, or by a pressure of one additional atmosphere. Its pungent and suffocating odor, distinguishes it from all other gases. When pure, it is irrespirable, causing a spasmodic contraction of the glottis. If inhaled with air, it excites coughing and is injurious to the lungs; it is fatal to animals confined in it. Thus some naturalists make use of it to destroy the lives of butterflies and insects which they wish to preserve in the cabinet. It is incombustible, and extinguishes burning bodies. It has a great affinity for water, which, will absorb 33 times its bulk. The solution thus formed, has the odor and other properties of the gas itself, and may be substituted for it in many operations. It must, however, be kept in closely stopped bottles; for, on exposure to the air, it rapidly absorbs oxygen, and is converted into sulphuric acid. Its strong *affinity for oxygen* renders it a powerful deoxidizing agent.

485. This gas and its solution in water, possess the property of bleaching, and are used for that purpose to some extent; thus straw bonnets are bleached by the fumes of burning sulphur; and a red rose, or dahlia held in the same fumes, or dipped in aqueous sulphurous acid, will become white, except where portions have been protected by folds in the leaves. But the bleaching is not permanent, the coloring principle being only combined

481. Hyposulphurous acid.

482. How is sulphurous acid gas obtained? Reduction of sulphuric acid, to sulphurous acid, by heating it with mercury.

484. Properties of sulphurous acid gas. Its affinity for water and oxygen.

485. Bleaching property. Effect of cold or pressure upon this acid. Decomposition. Compounds.

with sulphurous acid,—not destroyed. Consequently, the color returns, when, by exposure to the air, the gaseous acid has been dissipated, the stronger acids, also, will restore the color, and the alkalies, by neutralizing the sulphurous acid, produce the same effect. Sulphurous acid liquefied by cold or pressure, is exceedingly volatile, and, by its evaporation, produces cold enough to freeze mercury, and to liquefy some other gases. This gas is not decomposed by heat alone; but is deprived of oxygen, by being brought in contact with hydrogen, and some other oxidable substances, at a red heat. It combines with the salifiable bases forming salts, called *sulphites*.

486. *Hyposulphuric Acid* is formed when sulphurous acid is passed into water, in which peroxide of manganese is suspended. *Theory*. The latter parts with 1 equivalent of its oxygen which uniting with the *sulphurous acid* forms the *hyposulphuric*.

This acid is of no use in the arts, nor in the laboratory. Its salts are generally soluble, even those of the bases with which sulphuric acid would form insoluble salts.

487. *Sulphuric Acid* is commonly known as *oil of vitriol*, having been at first, obtained by the distillation of *green vitriol*. Several of the salts of this acid have obtained the name of *vitriol*, from their *glassy* appearance; as *green vitriol*, which is a sulphate of protoxide of copper; *white vitriol*, sulphate of the oxide of zinc.

488. *Physical and chemical properties*. Pure sulphuric acid is transparent and colorless and of an oily consistency; its taste is intensely sour, and its specific gravity, when most concentrated 1.85. It is one of the strongest acids known, combining with all the salifiable bodies, and even taking them away from almost all other acids, by its superior affinity. It oxidizes many of the metals, and then combines with the oxides; in some cases the acid must be strong, the metal being oxidized at its expense, as in the preparation of sulphurous acid gas, in other cases, the acid must be dilute, the water furnishing oxygen to the metal, and hydrogen gas being evolved.

It has a very great affinity for water, uniting with it in every proportion. This combination is attended with condensation, on which account great heat is evolved; the increase of temperature sometimes exceeds 212° . Snow is melted by mixture with this acid, and if the proportions be rightly adjusted, great decrease of temperature is observed. It attracts watery vapor rapidly from the atmosphere, and is therefore used to promote evaporation by the air pump.

It is said that, in the course of a month, sulphuric acid will absorb water

486. Hyposulphuric acid.

487. Origin of the name, oil of vitriol, &c.

488. Properties of sulphuric acid, &c. Its affinity for water, &c.

enough from the air, to double its weight; and that the affinity is not satisfied till the weight of the acid is augmented six fold. By reason of this affinity, sulphuric acid corrodes organic substances powerfully, causing their oxygen and hydrogen to unite and form water, while their carbon remains. It is on this account that this acid often appears deeply colored; the color arising from the carbon of minute portions of vegetable water which have fallen in and been decomposed. Wood may be stained black by washing it with very dilute sulphuric acid, and then warming it so that the water may be dissipated and the action of the acid favored by the heat. Water acidulated with this acid, may also be used as a sympathetic ink, letters formed with it being rendered apparent on warming the paper. It dissolves minute portions of charcoal and sulphur. The former communicates to it a blue green, or brown tinge and the latter a pink or brown; the color depending in each case on the quantity dissolved.

489. Its strength may be tested by its specific gravity or, by ascertaining the quantity of carbonate of soda required to neutralize a known quantity of the acid; 100 grains of the alkali will saturate 92 of pure acid.

Ordinary sulphuric acid freezes at 15° , F. below zero. Its boiling point is 620° , F.

491. The strongest sulphuric acid which can be prepared by the ordinary method is a hydrate, still containing one atom of water to one atom of acid. But it can be procured perfectly anhydrous by means of *fuming sulphuric acid*. This substance is the result of a very old process, still in use at Nordhausen, in Germany.

It is heavier than the common sulphuric acid and emits dense white fumes when exposed to air, especially if the atmosphere be moist. It consists of acid and water, in such proportions that it may be considered a compound of one equiv. of anhydrous, and one of hydrated sulphuric acid. The anhydrous acid being volatile below 122° , while the hydrous requires a temperature of 620° , it is easy to separate them by distillation at a very gentle heat.

The anhydrous acid passes over as a perfectly transparent and colorless vapor and is condensed in the cool receiver, into a white and crystalline, or a transparent, glassy solid, according to the rapidity of cooling.—It is liquid in summer, unless artificially cooled.—It has a greedy attraction for water, combining with the moisture of the air and forming dense white fumes if exposed; and if thrown into water it evolves great heat causing a hissing and boiling like red hot iron.

492. *Natural History*. Sulphuric acid occurs abundantly in nature in combination with earths, forming salts, of which the most plentiful are sulphate of lime, (gypsum or plaster of Paris,) and sulphate of baryta, (heavy spar;) but it is seen seldom in an uncombined state, except near volcanoes. A large deposit of sulphur in Java in the crater of an extinguished volcano is the source of a stream of diluted acid, which in the rainy season flows down the mountain, destroying the vegetation along its banks.

Professor Eaton mentions a pond near Rochester, N. Y. the waters of which, especially in a dry season contain some quantity of it. This acid, or any of its soluble salts can be detected in solution, by the addition of

489. Tests of the strength of this acid. Freezing and boiling points.

491. Anhydrous sulphuric acid. How procured? Separation of the hydrous acid. Properties of the anhydrous acid.

492. Natural history. Tests of sulphuric acid.

solution of hydrochlorate of baryta when a heavy white precipitate will be formed, which is insoluble in acids and alkalies.

493. *Hydrous Sulphuric acid*, which is the common acid of commerce is obtained by the following process: apartments being prepared, lined with sheet lead, and 8 parts of sulphur to 1 of nitre (saltpetre) broken into fragments are put upon iron plates. The mixture being inflamed, the door is closed. The floor is covered with water to the depth of some inches, which water absorbs the acid as fast as it is formed. The acidulated water is drawn off and concentrated by heat, in leaden boilers until found to be of the proper specific gravity.

Rationale. The process of the combustion is the formation of *sulphurous acid* from the sulphur and *deutoxide of nitrogen* from the nitre. The latter combining with the oxygen of the air is changed into *nitrous acid*. The *sulphurous* and *nitrous* acids then combine with the watery vapor, and form a crystalline solid, composed of *sulphuric acid*, *hyponitrous acid*, and *water*. When this solid drops into water, it is instantly decomposed, the *sulphuric acid* being retained in the water, and *nitrous acid* and *deutoxide of nitrogen* escape. The *nitrous acid* thus set free, as well as that formed by the *deutoxide* and oxygen of the air, again combines with the moist *sulphurous acid*, and forms the solid, which sinks to the water and is again decomposed. This process continues until the whole of the sulphur and nitre is changed into *sulphuric acid*, and absorbed by the water on the floor of the leaden chamber.

Sulphur and Hydrogen.

494. *Hydro-sulphuric* or *Sulphuretted Hydrogen** consists of 1 sul.=16+1 hyd.=1. equiv. 17. This is a gas, formed by heating sulphur in hydrogen, or by bringing sulphur and hydrogen together in a nascent state.

Fig. 96.



Let a portion of sulphur be put into a vessel, (Fig. 96,) to the neck of which is fitted a bag of hydrogen gas; as the sulphur is heated it volatilizes, and its vapor rising unites with the hydrogen to form sulphuretted hydrogen. The gas may be collected over water.

495. Its specific gravity is 1.18, a little more than that of atmospheric air; it requires a pressure of 17 atmospheres to reduce it to the liquid state. It is a colorless gas, of a most *fetid odor*, as may be perceived in putrid eggs, or the washing of a gun-barrel. Its taste also is unpleasant, of which the water of sulphuretted springs is an example. It is poisonous even when mixed with a large quantity of air. Small birds were destroyed by an atmosphere containing $\frac{1}{1550}$ part of this gas. It does not support combustion, but

* Sometimes called hydro-thionic acid, from the Greek *hudor*, water, and *theion*, sulphur.

493. Hydrous sulphuric acid. *Rationale.* Sulphate of ammonia.

494. Combinations of sulphur with hydrogen.

495. Nature, and formation of sulphuretted hydrogen. *Properties.*

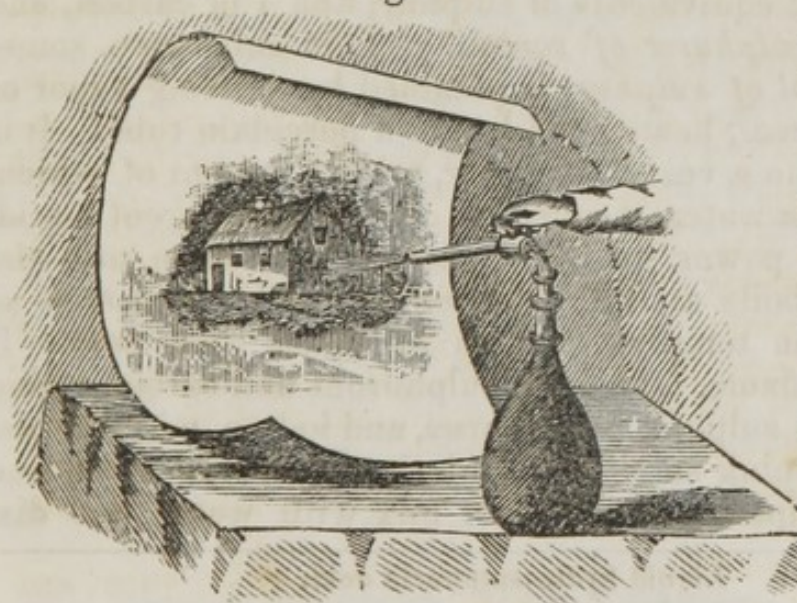
burns with a pale blue flame; the products of its combustion are water and sulphurous acid. It also explodes on being ignited, when mixed with air, or oxygen.

496. Potassium, tin, and some other metals decompose this gas when heated in it, uniting with the sulphur and liberating the hydrogen. Electric sparks, or a platinum wire ignited by galvanism, will also decompose it. In these experiments, the hydrogen evolved is equal in bulk to the hydro-sulphuric acid decomposed.

Hydro-sulphuric and sulphurous acids mutually decompose each other, the oxygen of the one uniting with the hydrogen of the other, and the sulphur of both being deposited. Nitric acid poured into a phial of this gas, decomposes it by furnishing oxygen; sulphur is deposited, and water, and deutoxide of nitrogen are formed. Water at 60° F., if freed by boiling, from other gases, will absorb about its own bulk of this gas, and afford a solution which has the odor, taste, and chemical action of the gas itself, and may therefore be used as a test. This solution is very easily decomposed by substances which yield oxygen, and even by exposure to air; the oxygen uniting to the hydrogen of the hydro-sulphuric acid, and the sulphur being deposited. This cause accounts for the constant deposition of sulphur from the water of sulphuretted springs.

497. Hydro-sulphuric acid is an important test for metals, in solutions of which, it produces precipitates of metallic sulphurets; these precipitates are of different colors, by which we are enabled to ascertain what metal is present. The gas acts also on many insoluble metallic compounds; thus, white paint, (carbonate of lead,) and the cosmetic pearl white, (oxide of bismuth,) are rendered black, owing to the formation of the black sulphurets of lead, and of bismuth. At sulphuretted springs, some ludicrous changes of complexion have occasionally happened to ladies beautified with pearl white.

Fig. 97.



The acetate of lead, in solution, is colorless, but let a drawing be made with it in this state, and then exposed to the action of a stream* of hydro-sulphuric acid gas, (Fig. 97,) the lines will become black, as if made with a lead pencil.

This gas also tarnishes gold and silver, its sulphur combining with those metals to form sulphurets.

* The stream of gas is invisible, though represented in the figure to aid in understanding its design.

496. Decomposition. Absorption by water.

497. Action on metals, and metallic compounds.

Chlorine may be used to purify an atmosphere contaminated with sulphuretted hydrogen.

498. *Hydro-sulphuric acid*, reddens litmus paper, and combines with the fixed alkalies, and with ammonia; its relations to the metallic oxides are perfectly analogous to those of the other hydracids.

Liquid hydro-sulphuric acid. Mr. Faraday condensed this gas under a pressure of 17 atmospheres, so as to form a limpid and oily fluid

499. *Hydrosulphurous acid*, called *bisulphuretted hydrogen*, is a yellow, viscid, semifluid, heavier than water, and having, in a lower degree, the same odor and taste as hydrosulphuric acid. It is easily decomposed by heat into *sulphur* and *hydro-sulphuric acid*. It contains 2 atoms of sulphur, to 1 atom of hydrogen.

500. *Chloride of sulphur*. This is a compound of one equivalent of each constituent, and is formed, directly, by passing chlorine over flowers of sulphur gently heated. It is a volatile liquid of a red color, when seen in mass, but greenish yellow, when viewed in a thin stratum. It decomposes water rapidly, the chlorine taking the hydrogen of the water; at the same time sulphur is deposited, and sulphurous and sulphuric acids are formed. Its vapor also decomposes the moisture of the air, giving fumes which affect the eyes powerfully, and which probably consist of the same acid products.

Bromide of sulphur is a red, volatile, oily liquid, which decomposes water with great violence, and which is obtained by the direct action of bromine on sulphur. It is decomposed by chlorine, and chloride of sulphur is formed.

Iodide of sulphur is likewise formed by direct action of its elements, aided by heat. It is a dark solid and is decomposed by heat.

501. There is only one known compound of sulphur and carbon. It contains 2 equivalents of sulphur, and 1 of carbon, and is therefore a *bisulphuret of carbon*. This substance, sometimes called *alcohol of sulphur*, is obtained by passing vapor of sulphur over charcoal, heated red hot in a porcelain tube. It is to be conducted into a vessel of water, at the bottom of which, as it is heavier than water, it collects. It is a transparent liquid, of great refracting power, an acrid and pungent taste, and disgusting odor. It boils at 110° Fahrenheit, and evaporates so rapidly at common temperatures, as to cause great cold. It burns with a blue flame, producing sulphurous and carbonic acid gases. It dissolves sulphur, phosphorus, and iodine, with the last giving a beautiful pink solution. Chlorine decomposes it, and unites with the sulphur. It will not mix with water, but dis.

498. Acid properties. Liquid hydro-sulphuric acid.

499. Hydro-sulphurous acid.

500. Chloride, bromide, and iodide of sulphur.

501. Bi-sulphuret of carbon. Properties. Hydroxanthic acid.

solves readily in alcohol and ether, from which solution water precipitates it. When an alkali is put into the alcoholic solution, it becomes neutralized, owing to the formation of a new acid, which has been called *hydroxanthic* acid, from the yellow color of its salts. This latter acid appears to consist of carbon, sulphur, and hydrogen, the hydrogen and an additional dose of carbon, being derived from the alcohol.

502. *Selenium*.—*Equiv.* 40. *Sp. Gr.* 4.32. Selenium was discovered by Berzelius in 1818. It had been observed, by a manufacturer of sulphuric acid at Fahlun, in Sweden, that the sulphur, after sublimation, deposited a reddish mass. This was submitted to the examination of the Swedish Chemist, who obtained, by analysis, a very minute proportion of an apparently new substance, the remainder of the mass being a compound of mercury, tin, arsenic, lead, copper, zink, iron, and sulphur. This new substance, Berzelius named *selenium*, from the Greek, *selene*, the moon (on account of its resemblance to the metal tellurium, so called from *tellus*, the earth.) The substance in which the sulphur and selenium were thus found united, was iron pyrites, (sulphuret of iron,) from the mines of Fahlun. Selenium has since been found in combination with minerals in the Hartz mountains in volcanic products of the Lipari islands and in pyrites of the isle of Anglesea in England. It was regarded, by its discoverers, as a metal, but being an imperfect conductor of heat and electricity, it appears to belong to the class of simple non-metallic elements.

503. *Physical and chemical properties*. It is solid at common temperatures, brittle, opaque, and inodorous; at 212° Fahrenheit, it begins to liquefy, and fuses at a temperature a few degrees higher. If partly cooled when in this state, it appears like wax, and may be drawn out by the fingers, into long, transparent, elastic threads, which appear red by transmitted light, but grey, and of a metallic brilliancy, when seen by reflected light. At 650° Fahrenheit it volatilizes, becoming a yellow vapor, suddenly cooled, produces a red powder, resembling the flowers of sulphur, except in color. If sublimed in the air, without taking fire, its vapor is red and without odor. But when heated in the flame of a lamp, heightened by a current of air from a blow pipe, it tinges the flame a light blue color, and emits a strong odor, resembling that of decayed horse-radish, in which property it resembles tellurium. In many of its properties, selenium resem-

502. Discovery of selenium. Origin of the name. With what substances united, and where found. Why not classed among the metals? Properties of selenium.

503. Physical and chemical properties.

bles sulphur; and in its specific gravity and metallic lustre, it resembles metals.

504. *Selenium and Oxygen. Selenic Acid.* Seleni. $1=40+\text{ox. } 3=24$. Equiv. 64. Selenic acid may be obtained by dissolving 1 part of *selenium*, in 3 parts of *nitric acid*, and boiling the mixture. The *selenium* decomposes the *nitric acid*, and a solution of *selenic acid* is formed; this may be evaporated to dryness, and then appears as a white mass, which may be sublimed on raising the temperature; the color of the vapor resembles that of chlorine. Selenic acid has a sour taste, reddens vegetable blues, and has a strong affinity for salifiable bases. It powerfully attracts water, and like sulphuric acid, gives out much heat when mixed with it. When exposed to heat, it volatilizes without any decomposition. When heated with hydro-chloric acid, selenious acid and chlorine gas are evolved, and the selenio-hydro-chloric acid, like the nitro-hydro-chloric, (aqua regia,) dissolves gold. Selenic acid also dissolves gold, but not platinum.

505. *Selenious Acid.* Sel. $1=40+\text{ox. } 2=16$. Equiv. 56. When selenium, heated to its boiling point in a close vessel, is supplied with a current of oxygen gas, it burns with a pale, blueish green flame; selenious acid sublimes, and if condensed in a cool receiver, will form long, striated, prismatic crystals. Its taste is sour, and somewhat burning; it is readily decomposed by substances which have a strong affinity for oxygen. Its affinity for water is such, that it attracts it from the air. It was discovered by Berzelius, and being until recently, supposed the only acid of selenium, was termed *selenic acid*. But since an acid compound is now known to exist, in which selenium unites with a higher proportion of oxygen, the latter must be considered as the true *selenic acid*.

506. *Oxide of selenium.* Seleni. $1=40+\text{ox. } 1=8$. equiv. 48. The composition of this substance is somewhat doubtful, though it is supposed to contain 1 atom of oxygen and 1 of selenium. It is formed by heating selenium in a close vessel with atmospheric air.

507. *Proto-chloride of selenium* may be obtained by passing *chlorine* gas over *selenium*; it is a liquid of a brown color, heavier than water. It is decomposed by water, forming muriatic and selenious acids. *Per-chloride* of selenium is obtained by adding chlorine to the proto-chloride.

The *Bromide* of *Selenium* was obtained by Serullas, by causing *selenium*, in minute portions, to be brought in contact with *bromine*, combination ensued with a disengagement of heat. At the common temperature, it was solid, orange colored, and soluble in water.

Hydro-selenic acid, or *Seleniuretted hydrogen* is a compound of 1 atom of selenium=40, and 1 of hydrogen=1, making its equivalent 41. Its discoverer, Berzelius, found it to be, in many of its properties, similar to sulphuretted hydrogen. Silliman suggests, that the noxious properties of the latter compound may be often increased, by the presence of selenium, as sulphur is often contaminated with it. Hydro-selenic acid may be obtained by dissolving seleniuret of iron in muriatic acid. Its solution reddens litmus paper, and gives a brown tint to the skin. It is readily decomposed by the

504. Composition, and mode of obtaining selenic acid. Properties. Selenio-hydrochloric acid. Selenic acid with metals.

505. Composition and formation of selenious acid. Properties. Salts. Discovery and former name.

506. Composition and formation of the oxide of selenium.

507. Compounds of selenium with chlorine. Bromide of selenium. Hydro-selenic acid. Phosphuret of selenium. Sulphuret of selenium.

action of air and water, and gives a red color to moist substances. It acts injuriously on the animal system.

Phosphuret of selenium is obtained by bringing *selenium* into contact with *phosphorus*, when in a state of fusion. It is inflammable and very fusible. *Sulphuret of selenium*, as obtained by Berzelius, was an orange colored precipitate, formed after conducting *hydro-sulphuric acid* into a solution of *selenic acid*.

508. Having considered the *non-metallic elements*, with the combinations which they form with each other we will give a tabular view of the same, according to the arrangement we have adopted; viz; the division into *two* classes of *electro-positive*, and *electro-negative* elements. These elements exist in the three different states of *gaseous* or *aeriform*, *volatile*, and *fixed*, as represented on the table.

TABLE I.

NON-METALLIC ELEMENTS.

	<i>Electro-Negative.</i>	<i>Equiv.</i>	<i>Electro-Positive.</i>	<i>Equiv.</i>
Aeriform.	Oxygen.....	8	Hydrogen.....	1
			Nitrogen.....	14
Volatile.	Chlorine.....	36		
	Bromine.....	75		
	Iodine.....	124		
	Flourine.....	10		
Fixed, or Solid.			Sulphur.....	16
			Phosphorus.....	12
			Selenium.....	40
			Carbon.....	6
			Silicon.....	8
			Boron.....	8

509. The binary compounds of the basic non-metallic elements are arranged in the following table, under three divisions, viz. the *acid*, the *alkaline* and the *neutral*. The *proportions* are given, in which their component parts unite, with the *equivalent* number of each, showing the ratio in which their binary compounds will combine with other bodies.

TABLE II.

BINARY COMPOUNDS OF THE NON-METALLIC ELEMENTS.

<i>Equiv.</i>	added to	<i>Equiv.</i>	ACID. <i>Electro-Negative.</i>	<i>Equiv.</i>	ALKALINE OR BASIC. <i>Electro-posit.</i>	NEUTRAL.	<i>Equiv.</i>
1	Chlorine	1	Oxygen.....			Protoxide of Chlorine	44
	Ditto	4	Ditto.....			Peroxide of Chlorine	68
	Ditto	5	Ditto Chloric acid	76			
	Ditto	7	Ditto Per-Chloric acid	92			

508. Repeat the names and equivalents of the *Electro-negative* and *Electro-positive* non-metallic elements with the state in which they are obtained.

509. What are the binary compounds of these elements, and their equivalents? Which are acid, which alkaline and which neutral?

<i>Equiv.</i> added to	<i>Equiv.</i>	ACID. <i>Electro-Negative.</i>	<i>Equiv.</i>	ALKALINE OR BASIC. <i>Electro-posit.</i>	NEUTRAL.	<i>Equiv.</i>
1 Bromine	5 Oxygen	Bromic acid	115			
Ditto	1 Chlorine	.....			Chloride of Bromine	111
1 Iodine	5 Oxygen	Iodic acid	164			
1 Hydrogen	1 Oxygen	.....			Water	9
1 Ditto	2 Ditto	.....			Protoxide of Hydrogen	17
1 Ditto	1 Chlorine	Hydro-chloric acid	37			
1 Ditto	1 Bromine	Hydro-bromic acid	76			
1 Ditto	1 Iodine	Hydro-iodic acid	125			
1 Ditto	1 Flourine	Hydro-fluoric acid	11			
1 Nitrogen	1 Oxygen	.....			Protoxide of Nitrogen	22
1 Ditto	2 Ditto	.....			Deutoxide of Nitrogen	30
1 Ditto	3 Ditto	Hypo-nitrous acid	38			
1 Ditto	4 Ditto	Nitrous acid	46			
1 Ditto	5 Ditto	Nitric acid	54			
1 Ditto	4 Chlorine	.....			Chloride of Nitrogen	158
1 Ditto	3 Iodine	.....			Iodine of Nitrogen	386
1 Ditto	Bromine	.....			Bromide of Iodine	(?)
1 Ditto	3 Hydrogen	.....			Ammonia	17
1 Carbon	1 Oxygen	.....			Carbonic oxide	14
1 Ditto	2 Ditto	Carbonic acid	22			
2 Ditto	3 Chlorine	.....			Perchloride of Carbon	120
1 Ditto	1 Ditto	.....			Proto-chloride of Carbon	42
1 Ditto	2 Hydrogen	.....			Subcarburetted Hyd.	8
2 Ditto	2 Ditto	.....			Percarburetted Hyd.	14
2 Ditto	1 Nitrogen	.....			Cyanogen	26
1 Boron	2 Oxygen	Boracic acid	24			
1 Ditto	2 Chlorine	.....			Chloride of Boron	80
1 Ditto	Flourine	.....			Fluoride of Boron	
1 Silicon	1 Oxygen	.....			Oxide of Silicon	16
1 Ditto	Chlorine	.....			Chloride of Silicon	(?)
1 Ditto	1 Flourine	Fluo-silicic acid gas	18			
1 Phosphorus	1 Oxygen	Phosphorous acid	20			
1 Ditto	2 Ditto	Phosphoric acid	28			
2 Ditto	1 Ditto	Hypo-phosphorous acid	32			
1 Ditto	1 Chlorine	.....			Proto-chloride of Phos.	48
1 Ditto	2 Ditto	.....			Per-chloride of Phos.	84
Ditto	Bromine	.....			Bromide of Phos.	(?)
Ditto	Iodine	.....			Iodine of Phos.	(?)
1 Ditto	2 Hydrogen	.....			Proto-phosphuretted Hyd.	14
1 Ditto	1 Ditto	.....			Per-phosphuretted Hyd.	13
1 Sulphur	2 Oxygen	Sulphurous acid	32			
1 Ditto	3 Ditto	Sulphuric acid	40			
1 Ditto	1 Ditto	Hypo-sulphurous acid	24			
2 Ditto	5 Ditto	Hypo-sulphuric acid	72			
1 Ditto	1 Hydrogen	Sulphuretted Hyd.	17			
2 Ditto	1 Ditto	Bi-sulphuretted Hyd.	33			
1 Ditto	1 Chlorine	.....			Chloride of Sulphur	52
Ditto	Bromine	.....			Bromide of Sulphur	(?)
Ditto	Iodine	.....			Iodide of Sulphur	(?)
Ditto	Carbon	Bi-sulphuret of carbon	(?)			(?)
1 Selenium	3 Oxygen	Selenic acid	64			
1 Ditto	2 Ditto	Selenious acid	56			
1 Ditto	1 Ditto	.....			Oxide of Selenium	48
Ditto	Chlorine	.....			Chloride of Selenium	(?)
1 Ditto	1 Hydrogen	Hydro-selenic acid	41			
Ditto	Phosphorus	.....			Phosphuret of Selenium	(?)
Ditto	Sulphur	.....			Sulphate of Selenium	(?)

We see that ammonia is the only alkaline compound of this class of substances.

METALS.

OR THE SECOND CLASS OF ELECTRO-POSITIVE ELEMENTS.

CHAPTER XXI.

GENERAL OBSERVATIONS UPON THE METALS.—FIRST CLASS OF METALS, OR THOSE WHICH FORM ACIDS WITH OXYGEN.

510. The metals vary greatly among themselves in their *physical* properties. Some, as gold and platinum, are the heaviest substances known; while others, as sodium and potassium are lighter than water. Mercury is liquid at the common temperature and can be solidified only by cold far below that of the freezing point of water; but platinum remains solid even under the influence of the most intense heat. In their *chemical* affinities, metals differ greatly. Potassium and sodium have so great an attraction for oxygen, that they become oxidized from mere exposure to the air; while silver and gold can with difficulty be made to unite with oxygen.

511. The distinctive characters of the metals are as follows;

1st. They are all good conductors of *electricity* and *heat*; the former passes through them instantaneously, the latter progressively, though rapidly.

2d. They are *positive electrics*, that is they go to the negative pole in the galvanic series, when combined with oxygen, chlorine, iodine, bromine, or sulphur; and *their oxides* have the same destination, when combined *with acids*.

3d. They are opake; they reflect the light powerfully, and with a peculiar glitter, termed the metallic lustre. This property is retained by the metals when divided into the minutest particles.

4th. Though good conductors, they are bad *radiators of heat*.

5th. They are *fusible* at different degrees of heat; and when melted retain their lustre and opacity.

6th. They possess in different degrees a peculiar *tenacity*, which renders them *malleable* and *ductile*, or capable of being extended under the hammer or drawn into wire.

7th. They are capable of *combining with oxygen*, thus *forming oxides* that bear a metallic appearance; those oxides, by uniting with acids, saturate them and form *salts*.

510. Variety in the properties of metals.

511. General characteristics.

512. Of all substances in nature, none have, from the earliest ages of the world, more attracted the attention of mankind than the metals. To the experiments of the alchemists, in their attempts to transmute the baser metals into gold and silver, the science of chemistry owes its existence. Yet notwithstanding the researches of the alchemists, so late as the fifteenth century, only seven metals, appear to have been discovered; viz. gold, silver, iron, copper, lead, mercury, and tin, with a few ores and combinations with other metals.

513. The metals have been variously classified by different writers. It has been common to arrange them according to their relative affinities for oxygen, which vary so much, that while one class part with oxygen, by application of a *slight degree* of heat, another class retain it so strongly that it requires the greatest power of the voltaic pile to effect their disunion. But though the *extremes*, in respect to affinity for oxygen, may widely differ, there are many metals included between those which part easily with oxygen and those which strongly retain it which renders it difficult to class them upon this principle.

It is well for science, that its foundations stand firm, though some of its superstructures may fall. Though in mental and moral science, classification varies with almost every writer, yet *truth is immutable*, and those various classifications are but as so many mirrors in which she is exhibited in different lights. The same is true in the physical sciences; one mode of classification brings out in bold relief one set of properties, and another mode brings into light other properties, which, but for this kind of distinction, might not have been duly observed.

Classification.

514. We shall arrange the metals into four classes.

1st. Those which form acids with oxygen.

2d. The alkaline metals, or those whose *oxides* are either fixed alkalies, or alkaline earths.

3d. Earthy metals, or those whose oxides are earths.

4th. Metals whose oxides are not regarded as earths or alkalies.

515. The Metals of the *first class*, or those which form acids with oxygen, are 13 in number, as follows, viz. *arsenic, antimony, columbium, litanium, chromium, molybdenum, tellurium, tungsten, vanadium, uranium, manganese, cobalt, and tin.*

512. Early attention of mankind to this class of substances.

513. Various classifications of metals.

514. Division of metals adopted.

515. Metals of the first class.

516. *Arsenic*.—*Equiv.* 38. The name is supposed to be derived from the Arabic, *arsanak*, signifying strong and deadly qualities. It was noticed in combination with sulphur, by the Greek philosopher Dioscorides under the name of *sandarac*. In 1773, Brandt discovered it to be a distinct metal. The substance usually called arsenic is the *arsenious acid* or *white oxide of arsenic*. Arsenic has a metallic lustre, resembling that of polished steel; it is brittle and granular in its texture. Exposed to the air it becomes tarnished, and covered with a blackish substance, which appears to be a protoxide of arsenic. Thrown upon burning coals, arsenic burns with a blue flame, volatilizing in the form of white vapors, and with a strong smell of garlic. It is sometimes found pure and native, but it is more commonly combined with the ores of other metals, especially iron and cobalt; by roasting these ores, the arsenic, which is very volatile, vaporizes and condenses in receivers prepared for the purpose.

517. Two compounds of arsenic and oxygen are known to exist.

	Arsenic.	Oxygen.
Arsenious acid,	38 or 1 equiv.	12 or $1\frac{1}{2}$ equiv.
Arsenic acid,	38 " "	20 or $2\frac{1}{2}$ equiv.

518. *Arsenious Acid*, sometimes called the *white oxide of arsenic*, and *rats bane*, is a white substance, offensive to the taste, and a deadly poison, not only when taken into the stomach, but when applied to a wound, or when its vapor is inhaled. Though soluble in warm water, a portion of the acid, in the form of a white powder, will be found suspended as the liquid becomes cool. This circumstance has often led to the detection of attempts to destroy life by this poison.

There are different tests by which the presence of this mineral may be detected. In the solid state, it may be known, in the open air, when heated, by its peculiar odor, like that of garlic. In solution it forms a white precipitate with lime water; and a yellow sulphuret of arsenic with hydro-sulphuric acid. Sulphuret of potassium, and sulphuret of sodium precipitate this substance in yellow flakes; but it is necessary to add some drops of acetic or hydro-chloric acid that may unite with the base of the sulphurets, otherwise there will be no precipitate. Writers on medical jurisprudence by omitting this circumstance, have led to errors in attempts to detect the presence of arsenic. In so important a trial as that of determining the presence of arsenical poison in the stomach of a deceased person, there should be a resort to various tests, and therefore while one portion of the contents of the stomach is subjected to the action of one test, other portions should be tried by other means. The nitrate of silver precipitates a white powder in solution of arsenical compounds, which, with ammonia, forms a

516. Derivation of the word arsenic. Discovery. Mode of obtaining the metal. Properties. Native state.

517. Compounds of arsenic and oxygen.

518. Synonymes of arsenious acid. Properties. Various tests.

yellow *arsenite* of silver. Ammoniacal sulphate of copper produces an apple green precipitate, which is the *arsenite of copper* or *Scheele's Green*. The effect of arsenic upon the animal system is speedy and violent. The *perhydrate of iron* with ammonia, is one of the best antidotes for this poison. Owing to the property of this substance of preserving dead bodies from decay, the stomach and intestines of those who have been poisoned with it have been found undecomposed some years after death.

519. *Arsenic Acid* may be obtained by boiling arsenious acid with nitric acid, which yields a portion of its oxygen, giving off nitric oxide. This acid has a sour metallic taste, reddens vegetable blues, and forms with alkalies neutral salts, called *arseniates*.

520. Arsenic in powder, takes fire in chlorine gas, forming *chloride of arsenic*. It unites with *iodine* by a gentle heat, forming the *iodide of arsenic*, which is a deep red compound. *Bromine*, by mere contact with metallic arsenic, burns with vivid light and heat, forming a volatile *bromide of arsenic*. *Arseniuretted hydrogen* is highly destructive to animal life. A German philosopher, M. Gehlen, in making experiments with it, inhaled its vapor, and died in consequence, with intense suffering. It extinguishes combustion, but is itself kindled by burning bodies, and burns with a blue flame. The *Sulphurets of arsenic* exist as natural minerals. The red sulphuret is known by the name of *realgar*; a yellow sulphuret is called *orpiment*; this is the basis of the paint known as king's yellow. The sulphurets of arsenic, though poisonous, are less so than the acids.

521. *Antimony*.—*Equiv.* 44. The name of this mineral is derived from *anti*, against, and *monakos* a monk, the improper use of it as a medicine, by a German monk, in the 15th century, having caused the death of many of his fraternity. What is termed crude antimony in commerce, is the native sulphuret of this metal.

In its pure state, antimony is a shining metal, of a silvery white color, a scaly texture, brittle, and gives off a peculiar odor, on being rubbed. It melts below red heat; and when suffered to cool slowly, often presents upon its surface marks of crystalization, resembling fern-leaves. It fuses at 810° F. and sublimes in dense white fumes, combining with oxygen. When in a state of powder it inflames spontaneously in chlorine gas, and burns with a bright white flame. The product is a liquid, which becomes solid on cooling. This chloride from its consistence was formerly called *butter of antimony*. The *per-chloride* is obtained by adding *nitro-muriatic acid*, hydro-chloro-nitric, to antimony; it is a volatile, fuming liquid.

522. The *Protoxide* of antimony is obtained by dissolving in water, proto-chloride of antimony; a white powder is precipitated called *powder of algaroth*, which is a sub-chloride of *antimony*. A solution of potash being added to this powder, the chlorine combines with the potash, and the metal uniting with the oxygen of the water, forms the *protoxide of antimony*. When heated to redness in an earthen crucible, antimony disengages a thick white smoke, which being condensed, forms a white crystalline substance

519. Mode of obtaining arsenic acid, its properties and salts.

520. Combinations of arsenic with chlorine, iodine, bromine, hydrogen and sulphur.

521. Supposed derivation of the name. Antimony of commerce. Properties. Chlorides.

522. Protoxide.

formerly called *argentine flowers of antimony*; this is similar in its composition to the protoxide.

523. *Deutoxide of antimony*. When metallic antimony is digested in strong nitric acid, the metal is oxidized at the expense of the acid, and a white hydrate of the peroxide is formed; on exposing this substance to a red heat, water and oxygen gas are disengaged, and the peroxide is reduced to a *deutoxide*. As this combines with alkalis, it has been called *antimonious acid*.

524. The *Peroxide* or antimonious acid forms salts with alkalis called *antimoniates*. It is changed by heat into the deutoxide.

525. The *Sulphuret of Antimony* is found extensively as a native combination; it may also be prepared by art, by fusing antimony with sulphur, and the compound is, in all respects, similar to the native mineral. When this sulphuret is slowly roasted in a *shallow* vessel, it gradually loses sulphur, and attracts oxygen, and may then be melted into a glassy, semi-transparent substance, which is called the *glass antimony*. The medicine known as *tartar emetic* is a triple compound of tartaric acid, protoxide of antimony and potassa, called *antimoniated tartrate of potassa*.

526. *Alloys of antimony*. Antimony may be made to combine with most of the metals. A very slight mixture not exceeding the $\frac{1}{200}$ of the whole mass is sufficient to destroy the ductility of gold, and even its fumes alone will produce that effect. Combined with lead, it becomes the alloy called type metal, which is used for *printing types*.

527. As a medicinal agent, when properly employed, this metal is highly valuable. It was not, however, until long after its discovery that its nature seems to have been well understood. From its fatal operation in many instances, the French parliament, early in the seventeenth century, at the suggestion of the medical faculty, proscribed the use of this medicine. This decree was, however, soon revoked and antimony again received in favor.

528. *Columbium*.—*Equiv.* 144. This metal was discovered by Mr. Hachett of England in 1801, who detected it in a black mineral belonging to the British Museum, which had been sent by Gov. Winthrop from New London in Connecticut, to Sir Hans Sloane, founder of the museum. The new substance was named *Columbium*, by its discoverer, in honor of the country from whence it had been sent. The mineral from which *columbium* is obtained is now found in Chesterfield, Mass. and Haddam, Conn.

529. Professor C. U. Shepard succeeded in obtaining the metal, by the de-

523. Deutoxide of antimony or antimonious acid.

524. Peroxide, or antimonious acid.

525. Sulphuret of antimony. Glass of antimony. Tartar emetic.

526. Alloys of antimony.

527. Medicinal properties.

528. Discovery of columbium. Origin of the name, &c.

529. Identity of tantalum and columbium.

composition of the mineral. But this is one among the refractory metals which are extracted with difficulty from rare minerals. Their discovery reflects honor on those who have so industriously sought them out, and gives new interest to science: although this metal, hitherto, has not been applied to any useful purpose in the arts.

About two years after the discovery of columbium, Ekeberg a Swedish Chemist extracted the same substance from the mineral called *tantalite*, and supposing it to be a new metal he called it *tantalum*. In 1809, Dr. Wollaston proved that this was indetical with columbium, and tantalum was accordingly stricken from the list of simple bodies.

530. Columbium is of a dark iron color. It is very hard, insoluble in acids, and soluble in alkalies. It unites with oxygen but in one known proportion, one equivalent of the metal, 144, being combined with one of oxygen 8=152. This compound, sometimes called the *oxide of columbium*, reddens litmus paper, and combines with salifiable bases, properties which are characteristics of acids. The salts of this acid are called *columbates*.

531. *Titanium. History.* Discovered in 1781, by Mr. Gregor of Cornwall, England, in black sand; but its character was not then fully ascertained. Afterwards, in 1795, Klaproth published an analysis of a crystalized mineral, known at that time as red schorl; though he did not entirely succeed in reducing it to a metallic state he inferred that it was the oxide of a new metal, which he named *titanium*. In 1822, Dr. Wollaston discovered this metal in some minute copper-colored crystals, presented to him by the Rev. Dr. Buckland, who had found them in the slag of an iron furnace at South Wales.

They conducted electricity, had a specific gravity of 5, 3, and were so hard as to scratch a polished surface of rock crystal. They become oxidized, by being heated with nitre, and were converted into a white substance, which was considered an oxide of titanium. Similar crystals of titanium have since been found at other iron works, where they have sometimes been mistaken for iron pyrites. In its purest native state, this metal is combined with a small portion of iron, which renders it slightly magnetic. It is infusible, tarnishes in the air, and is easily oxidized by heat.

532. The *protoxide of titanium* is of a blue color, and is supposed to exist in the mineral called *anatasse*, but its composition and properties are doubtful. With lime and silex it forms the mineral called *sphene*.

533. The *peroxide* exists nearly pure in the mineral called *titanite* or *rutile*. When pure, this oxide is nearly white; it possesses some acid properties, and is sometimes called *titanic acid*. The oxides of titanium have been used in porcelain painting. Silliman states that titanium is found

530. Properties of columbium and its combination with oxygen. Oxide of columbium. Its salts.

531. History of titanium. Properties of crystals of titanium. Resemblance to iron pyrites. Titanium combined with iron, &c. Properties of the metal.

532. Protoxide. Anatasse. Sphene.

533. Peroxide. Properties, &c.

frequently in the primitive rocks of the United States. Its equivalent number is not fully known.

534. *Chromium*.—*Equiv.* 32. So named from the Greek. *kroma*, on account of its tendency to form colored compounds. It was discovered by the French chemist, Vauquelin, in analyzing the chromate of lead, a beautiful red mineral from Siberia. It is a white and brittle metal, susceptible of high polish, and only imperfectly fused at very high temperatures. It is not changed by air, but absorbs oxygen at a red heat. Sulphur, phosphorus and chlorine are the only combustible, non-metallic elements which combine with it. It exists in nature only in the state of a chromate or an oxide.

535. Many of the gems owe their beautiful tints to this metal. Its acid gives the red color to the ruby: its oxide the green color to the emerald. Chromate of iron, is found in marble and serpentine, to which they are probably indebted for their beautiful variety of colors. New Haven and Milford in Connecticut, and Baltimore in Maryland, furnish fine specimens of chromate of iron.

536. *Protoxide of Chromium* is a green, pulverulent substance, infusible, undecomposable by heat, and insoluble in water. It was discovered by Vauquelin. It may be obtained by decomposing the chromate of mercury at a very high temperature. The mercury is disengaged in vapor, and the chromic acid resolved into oxygen and the protoxide of chromium. This oxide is sometimes found on the surface of chromated lead; it is this which causes the green color of the emerald and many magnesian rocks. It is employed in the arts; it is used in porcelain painting to give a fine green color; and is the coloring used in artificial gems which are made to imitate the emerald. There is a *brown oxide* which some suppose to be a distinct substance composed of one equivalent of chromium and one of oxygen; it has been called *chromous acid*, and *deutoxide of chromium*. By others it is considered a mixture of green oxide and chromic acid.

537. *Chromic Acid* exists in nature, in combination with lead, forming the chromate of lead of Siberia and Brazil; it imparts to the ruby its peculiar hue of dark red. It may be obtained from its concentrated solution in ruby red crystals. It is very

534. Derivation of the name chromium. Discovery, properties, &c. Combination with oxygen, and non-metallic combustible elements. How found in nature?

535. Coloring properties, &c.

536. Properties, discovery, and mode of obtaining protoxide of chromium, Its use. Brown oxide of chromium.

537. Chromic acid.

soluble in water, has a sour taste, and forms colored salts, called *chromates*, with alkaline bases, and metallic oxides. When exposed to strong heat, oxygen is disengaged, and the acid changes to the green oxide. It destroys the color of indigo, and most vegetable and animal coloring matters; a property advantageously employed in calico printing, and which depends on the facility with which it yields its oxygen. It gives with mercury, a cinnibar red; with silver, a carmine red; with lead, orange yellow; with tin, green; and with borax, a beautiful emerald-green color.

538. *Fluo-chromic acid gas* is disengaged, when a mixture of *fluor spar* and chromate of lead is distilled with sulphuric acid, in a leaden retort. This gas acts rapidly upon glass. Chromium forms a red gas with chlorine, called *chloro chromic acid gas*; it is obtained by the action of fuming sulphuric acid on a mixture of chromate of lead, and chloride of sodium. A *chloride* of chromium, is obtained by transmitting dry chlorine over a mixture of chromium and charcoal, heated to redness in a porcelain tube. This chloride is a crystalline sublimate of a purple color. *Sulphuret of Chromium* is a dark gray substance, consisting of one equivalent of each of its elements. *Phosphuret of Chromium* is a porous substance, of a light gray color.

539. *Molybdenum*.—*Equiv.* 48. The name of this mineral is from the Greek *molubdaina*, lead, it being at first confounded with black-lead, or plumbago as were all metals which are light, friable, soft, of a greasy feel, and which stain the fingers, or paper. Scheele first proved that plumbago is a carburet of iron, and molybdenum the *sulphuret* of a new metal. It has not been found pure, in a native state; the sulphuret of molybdenum is common in the Alps, and Austria, and is found, in small quantities, in the primitive rocks of the United States.

540. When the sulphuret of molybdenum is distilled in nitric acid, *molybdic acid* is obtained, in the form of a yellowish white, heavy powder. This being mixed with oil, and placed in a crucible lined with charcoal, is heated intensely, and the acid disengaging its oxygen, is reduced to a pure metallic state. It has never been obtained except in *small globules* of a gray color. It is among the most infusible metals. At the ordinary temperature, it has no action upon oxygen; but at a red heat, it unites with it forming a white sublimate of molybdic acid.

541. The *protoxide* of molybdenum is black, the *deutoxide*, or *molybdurous acid* is a brown, and *molybdic acid* is yellowish-white. Berzelius states that there are three *chlorides* of molybdenum. A native *sulphuret* of molybdenum, of a ruby-red color has lately been discovered. This metal has yet been of little use in the arts; but its coloring properties are peculiar, and may, hereafter, be advantageously applied.

538. Fluo-chromic acid gas. Chloro-chromic acid gas. Chloride of chromium. Sulphuret of chromium.

539. Derivation of the name Molybdenum. By whom distinguished from plumbago? In what state, and where found.

540. How is it obtained? Properties.

541. Character of its oxides and acid. Chlorides. Sulphuret. Uses of the metal.

542. *Tellurium*.—*Equiv.* 32. Was discovered in 1782, by M. Muller, in the gold mines of Transylvania, and named by Klaproth, from *Tellus*, the earth, in accordance with the ancient method of naming the metals after the planets. Tellurium has been found in the state of an alloy, with gold, silver, lead, copper, iron, and sometimes with all these metals united.* It is brittle, of the color of tin, with some lustre. It fuses readily, and is the most volatile of all the metals, except osmium and mercury. When distilled in close vessels, it sublimes, and its vapor condenses into brilliant metallic drops. When heated in contact with the air, it oxidizes, and burns with a sky-blue flame, edged with green. It gives off a gray smoke, of a pungent, nauseous odor, resembling that of the vapor of selenium, and which has been compared to the odor of decayed horseradish. This vapor condenses into a white *oxide of tellurium*. It unites both with alkalies and acids, to form salts. Tellurium is a rare mineral. Silliman supposes it exists in the town of Munroe in Connecticut.

543. *Telluretted Hydrogen gas* may be obtained by mixing together oxide of tellurium, hydrate of potassa, and charcoal, at a red heat, and acting upon the mixture by dilute sulphuric acid. The combination of hydrogen and tellurium which ensues, is a gas which, like sulphuretted hydrogen, manifests acid properties. It forms a claret colored solution with water, burns with a black flame, and deposits the oxide of the metal.

544. *Tungsten*.—*Equiv.* 96. This metal was first discovered in Sweden; its name signifies, in the Swedish language, *heavy stone*. It is the heaviest metal known, except iridium, gold, and platinum.

The ores of this metal are *tungsten* or *tungstate of lime*, *yellow oxide of tungsten*, and *wolfram* or *tungstate of iron*, and *manganese*. In these ores, tungsten exists in the state of tungstic acid, and has been found native in no purer form. The mineral is first decomposed in order to obtain the acid; the latter, in the form of a whitish powder, is then made into a paste with oil, and heated intensely in a crucible, lined with charcoal. The presence of small metallic globules, indicates the reduction of the metal.

It is of an iron gray color, of a brilliant lustre, and so hard as scarcely to yield to the file. It is very infusible.

545. The *oxide of tungsten* is formed by the action of hydrogen gas on

* For the process of obtaining the metal from its ores, see the author's Dic. of Chem., article Tellurium. See also Silliman's Elements, Vol. II. p. 160.

542. Discovery of tellurium, and origin of its name. With what metal found? Properties. White oxide of tellurium. Localities of tellurium.

543. Telluretted hydrogen gas.

544. Discovery of tungsten, &c. Origin of the name. Ores of this metal. How obtained from its ores? Color &c.

545. Oxide of tungsten. Tungstic acid. Chlorides. Localities of tungsten ores.

tungstic acid, at a low heat. It is of a dark chocolate color; and when polished resembles copper. This oxide does not unite with acid to form salts.

Tungstic acid is of a yellow color; it has no action on litmus paper; its acid properties are so feeble, that its salts are readily decomposed by most other acids.

Tungsten unites in three proportions with chlorine, forming *chlorides*. The ores of tungsten have been found in the cobalt mines in Chatham, and Monroe in Connecticut.

546. *Vanadium*.—*Equiv.* 68. It was recently discovered by M. Sefstrom, director of the school of mines at Fahlun in Sweden. It was named from *Vanadis* a Scandinavian deity. Its properties resemble those of chromium, with which it might easily be confounded. Professor Del Rio, many years since, supposing that he had found a new metal in the brown lead ore of Zimapan in Mexico, sent some specimens of it to the French chemists at Paris, who pronounced them to be merely impure chromium. Since the discovery of vanadium the opinion of Del Rio has been confirmed, and the ore pronounced to be a *vanadate* of lead; the same substance has been lately discovered in a mineral from Wanlockhead in Scotland. Like chromium, it appears to possess peculiar coloring properties. *Vanadic acid* is red, and fusible. The *oxide* is of a dark brown color.

547. *Uranium*.—*Equiv.* 208. It was discovered in 1789, by Klaproth, and named from the Greek, *uranos*, the heavens. The ores which contain this metal, are very rare. Combined with carbonic acid, it forms *chalcocite*, or green mica. Its ores are reduced with difficulty, and it has only been obtained in small quantities. It is of a dark grey color, hard, and brittle. The *protoxide* is of a dark green color; it unites with acids, forming salts of a green color. It is employed in the arts, for giving a black color to porcelain. The *peroxide* is of an orange color, and most of its salts have a similar tint. It is used for giving an orange color to porcelain.

548. *Manganese*.—*Equiv.* 28. It is never found native in the metallic state, the substance known in the arts by this name, being an impure oxide. Owing to its great affinity for oxygen, it is usually found in nature combined with it, though sometimes in the state of a phosphate, and a sulphuret.

"The black oxide of manganese was described by Scheele, in the year 1774, as a peculiar earth; Gahn subsequently showed that it contained a new metal, which he called *magnesium*, a term since applied to the metallic base of magnesia, and for which the words *manganese* and *manganum* have been substituted." *Turner*. The pure metal may be obtained by heating, for an hour or two, over a powerful air furnace, a mixture of the black oxide, oil, and charcoal, in a black lead crucible; on cooling the mixture, metallic masses will be found with the charcoal at the bottom of the crucible.

549. This metal, in some of its properties, resembles iron; it

546. Vanadium. Its discovery and name. Mistake of the French chemists. Acid and oxide of vanadium.

547. Discovery of uranium. Name. Ores. Properties. Compounds with oxygen.

548. How is manganese found in nature? By whom discovered. Original name. How obtained pure?

549. Properties. Action with air or oxygen, or with hydrogen, nitrogen, &c. Phosphuret. Chloride.

is of a gray color, very hard and brittle. It is very infusible, readily acted upon by air, tarnishing and at length crumbling into a brown powder. At the ordinary temperature, it has no action on atmospheric air, or oxygen gas; but at a high temperature, it soon oxidizes. It is not acted upon by hydrogen, nitrogen, boron, or carbon, and does not easily combine with sulphur, though a natural sulphate of manganese exists. At a high temperature, it combines with phosphorus, forming a white, and brilliant *phosphuret*. It absorbs chlorine rapidly, forming a very soluble, greenish *chloride*.

550. The *protoxide*, or green oxide of manganese, is obtained by igniting the deutoxide in contact with hydrogen or charcoal. Its rich green color on exposure to the air, changes to brown.

The *deutoxide*, or brown oxide, remains when the peroxide is heated to afford oxygen gas. It is found in large native crystals, in the Hartz mountains.

The *peroxide*, called also the black oxide, is that which, by heat, disengages half an equivalent (4 parts,) of oxygen, and is therefore commonly used for the purpose of obtaining oxygen gas. To obtain oxygen gas from the peroxide of manganese, it is sufficient to apply red heat to the latter, but if sulphuric acid be added to the peroxide of manganese, the presence of the acid appears to increase the disposition of the peroxide to give up its oxygen, by combining with the deoxidized manganese. This is a case of *disposing affinity*. This oxide occurs in large masses of an earthy appearance, and mixed with other substances, such as oxide of iron, carbonate of lime, and siliceous earth. It is sometimes found in groups of crystals, and is an essential ingredient in a mineral called *black wad*.

551. A *red oxide* of manganese, supposed by some, to be a mixture of the peroxide, and the deutoxide, and by others, a definite, compound, imparts to glass or borax a beautiful violet color; the amethyst owes its rich color to the presence of this oxide.

If a mixture of 1 part of powdered black oxide of manganese, and 3 parts nitrate of potassa, be thrown into a red hot crucible, and continued there until no more oxygen is disengaged, a green-colored, fused mass is obtained, called *mineral chameleon*, from its property of assuming different colors. On putting this substance into water, a green solution is obtained, which soon passes into blue, purple, and red; at length a brownish matter, the red oxide, subsides, and the liquid becomes colorless. These phenomena are explained as follows: the peroxide of manganese, when fused with potassa, absorbs oxygen from the atmosphere, and is thereby converted into *manganic acid*, which unites with the alkali; the changes of color, are owing to the combination of manganic acid with different proportions of potassa. By evaporating the red solution rapidly, small, prismatic, purple crystals are obtained; these are the *manganate* of potassa.

There is also supposed to be a *manganous acid*, or an acid with a smaller proportion of oxygen. The *manganate* of potash, being acted upon by

550. Protoxide. How obtained. Deutoxide. Peroxide. Use of sulphuric acid in the process for obtaining oxygen from the peroxide of manganese.

551. Red oxide of manganese. Mineral chameleon. Manganic acid, how formed? Manganous acid.

substances that attract oxygen, as alcohol, and carbonate of manganese, loses its red color, and becomes a green *manganosite* of potash, the acid in the latter being reduced to the *manganesious*, containing but three equivalents of oxygen, while the *manganesic* contains four equivalents.

552. Chlorine gas for chemical experiments, and liquid chlorine for bleaching, are usually obtained by the agency of the peroxide of manganese in combination with hydrochloric acid. The acid, consisting of one equivalent of chlorine and one of hydrogen, is decomposed by the loss of its hydrogen, which, by uniting with one equivalent of oxygen given off by the peroxide of manganese, produces one equivalent of water. The chlorine being set free, passes off in a gaseous state. The loss of oxygen by the manganese, having converted the peroxide to a protoxide, the latter unites with an equivalent of undecomposed hydro-chloric acid, and forms a hydro-chlorate of the protoxide of manganese. Manganese unites with chlorine in two proportions, forming a pink colored *proto-chloride*, with one equivalent of each element; and a *per-chloride* with one equivalent of manganese and four of chlorine. The latter is prepared by putting sulphuric acid into a solution of manganese, and then adding fused sea-salt. The hydrochloric and manganesic acids mutually decompose each other, producing water and the per-chloride of manganese; the latter is a vapor, which at first appears of a yellowish green tint, but condenses into a dark colored liquid. When the per-chloride vapor is introduced into a flask, the sides of which are moist, the color of the vapor changes instantly, and a rose-colored smoke appears. Manganese combines with fluorine, forming a *fluoride* of manganese, which at first appears in the form of a greenish yellow vapor. When mixed with atmospheric air, it assumes a beautiful purple red color. It acts on glass. On account of rendering glass colorless, the black oxide of manganese was formerly, called by the artists, *glass-maker's soap*. According to Pliny it was used two thousand years ago.

553. *Cobalt*, *Equiv.* 26. The name is derived from, *Kobalas*, the supposed demon who infests mines, impeding the operations of the miners, and destroying their lives. Though employed in the fifteenth century for the purpose of coloring glass blue, it was not known to be a simple element until obtained from its ores by Brandt of Sweden, in 1733. It is hard, brittle, of reddish grey color, and weak metallic lustre. It is magnetic, a property which was formerly ascribed to the presence of some iron, but a magnetic needle has been made of pure cobalt. It is found in connexion with ores of iron and copper, but chiefly with arsenic.

When the arsenical ore of cobalt is heated, the arsenic exhales in vapor, and the oxide of cobalt remains. This operation is carried on extensively in Saxony; the labor being performed by criminals who are condemned to be thus slowly destroyed, for crimes which incur the punishment of death. The white oxide of the arsenic of commerce is mostly thus obtained.

554. *Protoxide of Cobalt*, is formed when cobalt is slowly

552. Process for obtaining chlorine by the aid of per-oxide of manganese. Chlorides and fluoride of manganese. Fluoride of manganese.

553. Origin of the name Cobalt. Discovery. Properties. Ores. How obtained from the arsenical ore?

554. Protoxide of cobalt. Peroxide. Statement of M. Gmelin respecting the formation of cobaltic acid. Zaffre. Smalt. Powder-blue. Use of cobalt in the manufacture of porcelain.

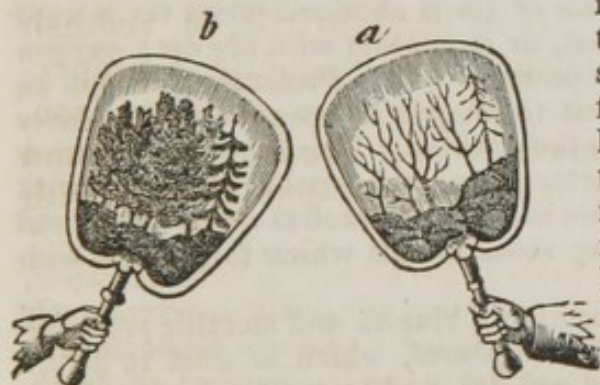
oxidized by being heated in the open air. It is at first blue, gradually becomes darker, and an intense heat melts it into a blue-black glass. The *Peroxide* is formed by igniting the protoxide, and exposing it to the action of the oxygen of air; it rapidly absorbs oxygen, becoming first of an olive-green color, and then black. By continued powerful heat a portion of oxygen is expelled, and the substance becomes again a protoxide.

Though we have classed cobalt with the metals which form acids with oxygen, there is some doubt as to the existence of a *Cobaltic Acid*. M. Gmelin from a solution of ammonia and nitrate of cobalt obtained crystals of a double salt, supposed by him to consist of nitrate, and *cobaltate* of ammonia, the latter consisting of *cobaltic acid* and ammonia.

The *Zaffre* of commerce is an impure oxide of cobalt. *Smalt* is formed by heating the oxide of cobalt with a mixture of sand and potassa; the result is a beautiful blue colored glass. This, when ground fine, is called *powder blue*; it is used by laundresses as a very delicate bluing for muslins and laces, in paper manufactories to give a blue tint to paper, and is employed in painting. Cobalt, being the only blue color which will endure the heat of a furnace, is highly valuable to manufacturers of porcelain. The ancients are supposed to have used this oxide, mixed with oil in their painting; and this is given as a reason for the blue drapery and skies, in some old pictures being so durable.

555. *Sympathetic Ink* may be made by digesting the oxide of cobalt in hydro-chloric acid, and diluting with water. Words written with this solution of hydro-chlorate of cobalt will be invisible till brought near the fire, when the writing will appear of a bright green tint. The acetate and nitrate of cobalt will present a blue color on being warmed.

Fig. 98.



Let a paper fire-screen (Fig. 98,) represent a landscape where the trunks and leafless branches are sketched in Indian ink, and paint the foliage and fore-grounds with the hydro-chlorate, and the sky and distant mountains with the acetate or nitrate of cobalt; while the picture is cold, it represents merely the outline of a landscape, or a winter scene, as at *a*; on bringing it near the fire, it will be transformed to a summer landscape, with green trees and a clear blue sky, as at *b*. On being removed from the fire, the scene will gradually lose its verdure, and resume its winter dress.

The cobalt of commerce was at first wholly furnished by Saxony. The ores of this metal are now found abundantly in Sweden, in a mine in Cornwall in England, and in various parts of America. In Franconia, in New Hampshire, cobalt is found

in arsenical iron ore; and in Chatnam, Connecticut, associated with nickel. It has been found in many specimens of aerolites or meteoric stones.

556. *Tin*.—*Equiv.* 58. This appears to have been among the few metals known in the first periods of history. It is named by Moses in connexion with "gold, silver, brass, iron, lead, and every thing that may abide the fire." The Phœnicians obtained it in commerce, passing in their wonderful voyages the pillars of Hercules,* and visting Britain, the *Ultima Thule*† of that period. The most ancient and extensive tin mines are in Cornwall in England. It is found in primitive mountains, in Saxony, Siberia, France, and Mexico.

The alchemists, who often divided their attention between the mysteries of astrology and alchemy, considering that there were some secret sympathies between the planets and the metals, named tin, *Jupiter*, because like that planet it had a brilliant appearance. It was called also by the Latin name, *stannum*.

557. *Tin Plate*, in which form this metal is used for a variety of purposes, consists of sheets of iron coated with tin. *Tin Foil* is made from the finest tin, beaten out with a hammer. Tin is a white, brilliant metal, with a silvery lustre. It is neither very hard nor ductile and has, little tenacity. It is flexible, and in bending gives a peculiar crackling sound. It is among the most fusible of the metals; it is vaporized by the heat of the compound blow pipe. It is so soft as to be cut with a knife, or scratched with a pin. Its odor and taste are peculiar; it tarnishes on exposure to the air. If steam be passed over tin heated to redness, it decomposes the water and combines with the oxygen, while the hydrogen gas is disengaged.

558. *Tin and Oxygen*. The *protoxide* of tin is obtained when tin is kept for some time melted in an open vessel, or in contact with the air; oxygen is absorbed and the product is a gray powder. The *Protoxide* has such an affinity for oxygen, that when heated to redness in open vessels it unites with another proportion, and becomes the *peroxide*. The latter is of a straw yellow color; and exhibits the character of an acid capable of uniting with potash and other alkalies. It has been called by Berzelius *stannic acid*, and we have therefore classed tin among those metals which form acids with oxygen.

559. Tin combines with *sulphur*, forming a blueish and metallic *proto-sulphuret*, and a beautiful gold-colored *bi-sulphuret*, which is used to give a golden color to bronze, and japanned articles, and to excite electrical machines. *Nitric acid* oxidizes but does not dissolve tin. The nitro-muriatic

* Straits of Gibraltar.

† The remotest land.

556. Ancient use of tin; its localities. Names.

557. Tin Plate. Tin Foil. Properties of tin. Combination with oxygen.

558. Compounds formed by tin with oxygen.

559. The combinations of tin. Alloys.

acid dissolves it with effervescence, forming a salt called the *per-muriate* of tin, which is employed in dyeing, especially to change the color of cochineal from crimson to a bright scarlet. The *proto-chloride* of tin is prepared by boiling tin filings in hydro-chloric acid. It is much used as a deoxidizing substance, especially for precipitating metals from their solutions. The *bi-chloride*, formerly called the *fuming liquor of Libavius*, is a volatile liquid, which emits copious white fumes. It inflames the oil of turpentine; and has a strong attraction for water, which changes it to the *permuriate*. The *bi-chloride* may be formed by heating metallic tin in an atmosphere of chlorine; it contains two equivalents of chlorine, united to one of the metal.

Alloys of Tin. The alloys of tin with copper in different proportions form *bronze*, bell metal, and a beautiful white substance used for the reflectors of telescopes.

CHAPTER XXII.

METALS OF THE SECOND CLASS.

Alkaline metals, or those whose oxides are fixed alkalies, or alkaline earths.—Order 1, *Metals which with oxygen, form the fixed alkalies*

560. The metals of this class, from their apparent doubtful character, were at first called *metalloids*.* They differ from copper, lead, gold, &c., and other well known metals in their less specific gravity, some being lighter than water. In their metallic lustre, and in uniting with oxygen to form oxides which, in their turn form salts with acids, they exhibit distinguishing properties of metals.

Order 1.—Metals, *which, with oxygen, form the fixed alkalies*, as potassium, sodium and lithium.

561. The metals of this order have so great an attraction for oxygen, that they decompose water at the moment of contact; the resulting *oxides* are distinguished by being soluble in water, are hot, and biting to the taste, change vegetable blue colors green, and yellow colors brown, and have a caustic action on animal substances. They are called *alkalies*, and their metallic bases are called *alkaline* metals.

Ammonia is an alkali, but its base is not a metal, like the bases of po-

* The Greek termination is from *eidos*, similar to; the term *metalloids* signifies similar to metals.

560. Why were the metals of this class called metalloids? Order 1. Order 2.

561. Attraction of these metals for oxygen. General properties of the oxides of these metals. What alkali has not a metallic base?

tassa, and soda ; it being a compound of nitrogen and hydrogen. Sir Humphrey Davy, after having discovered potassium and sodium, in two of the alkalies, was induced to make a series of experiments upon ammonia, with the expectation of discovering a metallic base, *ammonium*. But instead of this the decomposition of ammonia resulted in the disengagement of the two non-metallic elements, hydrogen and nitrogen.

562. *Potassium*.—*Equiv.* 40. This metal is obtained by the decomposition of potassa, (or potash,) which was, formerly, considered as a pure alkali, but is now known as the *oxide of potassium*. Sir Humphrey Davy, about the year 1807, became deeply interested in experiments on voltaic electricity ; having first observed its power in separating the elements of bodies known to be compound, he was led to examine its effects on potash and soda, until that time ranked among undecomposable elements. His first attempts on those alkalies, were made upon their aqueous solutions, but the water only was decomposed. He then caused a thin piece of pure hydrate of potassa, to communicate with the opposite poles of a powerful voltaic apparatus. The potassa soon became fused ; oxygen gas was evolved at the *positive pole*, and small *metallic* globules appeared at the surface connected with the *negative pole*.

The active and comprehensive mind of Davy, on witnessing the success of the experiment, anticipated the great changes which his discovery was destined to produce in chemical science. Possessing the rare combination of ardent enthusiasm with cool philosophical research, he must have contemplated the victory of his genius with peculiar emotions. He foresaw that the elevation of his fame must be commensurate with that immortal science, the boundaries of which his labors have done so much to enlarge.

563. The discovery of potassium, by Davy, stimulated the French Chemists to new efforts, and Gay Lussac and Thenard, in 1810, succeeded in obtaining the metal, without the aid of electricity, and in greater quantities than Davy had done. Their process consists in bringing fused hydrate of potassa, in contact with iron turnings, heated to whiteness in a curved gun-barrel. The iron attracts the oxygen from the alkali, and its metallic base is disengaged.

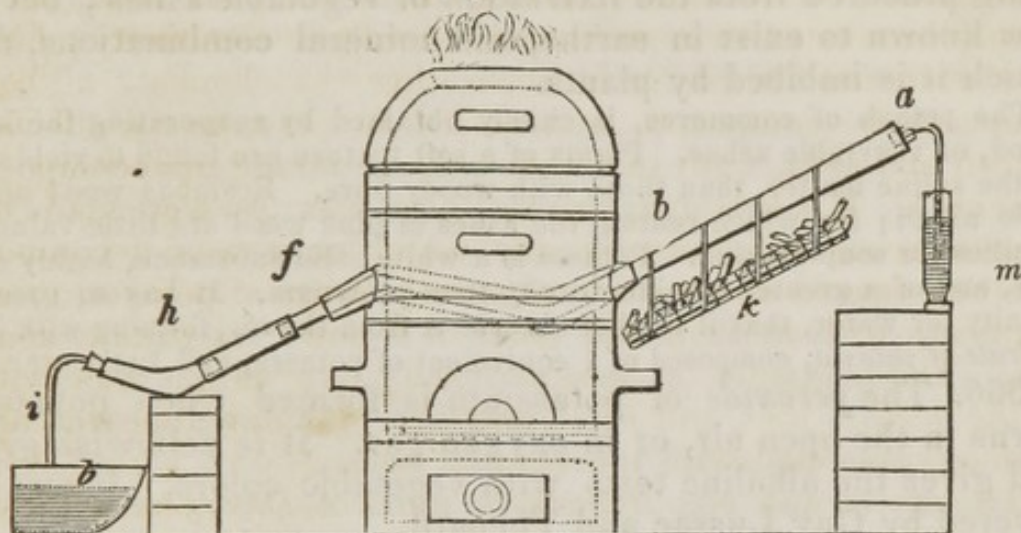
The curved gun-barrel is represented at *a*, *b*, and *f* ; (Fig. 99,) the iron turnings are placed within, between *f*, and *b*, which part is covered with a lute of infusible clay, made of five parts of sand, and one of potter's clay. Between *a* and *b*, are placed pieces of solid hydrate of potassa. A tube of safety is to be luted to the end, *a*, and immersed in mercury in the glass vessel, *m*. To the smaller end of the barrel, is fitted a piece of copper tube, and to this, a small copper receiver *h*, which is to receive the potassium. A tube of safety, *i*, communicating with this receiver, dips into

562. What substance contains potassium ? History of the discovery of the metallic bases of potassa and soda by Davy.

563. Process discovered by Gay Lussac and Thenard, for obtaining potassium without the aid of electricity.

mercury contained in the vessel, *b*. The furnace should now be heated until the barrel between *b* and *f*, or that portion containing the iron turnings, is of a white heat, the other parts of the barrel being kept cool by the application of wet cloths. The barrel having become white hot, the hydrate of potassa is melted by igniting charcoal contained in the moveable cage, *k*, and will then flow down upon the ignited iron turnings, hydrogen gas which was contained in the hydrate of potash, will issue through the safety tube, *i*; the oxygen of the potassa will combine with the iron turnings, while the potassium passing off in vapor, will be condensed in the copper receiver at *h*.

Fig. 99.



564. *Properties.* Potassium (or *kalium*) resembles other metals in many properties, but differs from most of them, in being of a *less specific gravity* than water. Its affinity with oxygen is so great, that it cannot be preserved, except immersed in some substance, from which oxygen is excluded, such as ether, or naphtha, or in exhausted glass tubes, hermetically sealed.

At 32° Fahrenheit, it is brittle, and when broken, exhibits through a microscope, a white, crystalline appearance. It is solid at the common temperature, though soft, and easily moulded with the fingers. In color and lustre, it resembles mercury; its specific gravity is 0.865. It becomes fluid at 150° Fahrenheit, and at a red heat, sublimes in the form of a greenish vapor.

On exposure to the air, it tarnishes, becomes of a bluish color, and changes into the *protoxide* of potassium. When heated with oxygen gas, it burns with intense light and heat; exhibiting a rose colored flame, and forming, by its combination with oxygen, the *deutoxide* of potassium. When thrown upon water, potassium acts with great violence, swimming on its surface, and burning with great splendor; hydrogen, is evolved and ox-

564. Resemblance of potassium to other metals; its difference in one particular. Why potassium cannot be kept in the open air. Properties. Effects of exposure to the air. Of burning in oxygen gas. Action with water.

ide of potassium or potassa, is found in solution. If ice be used instead of water, it burns with equal force. This effect is owing to its rapid absorption of oxygen, from which so much caloric is disengaged, that the hydrogen gas, resulting from the decomposition of water, is inflamed.

565. *Protoxide of potassium*, or potassa, is commonly known by the name of *potash*, from the pots or vessels in which it was made. It was at first called *kali*, and *vegetable alkali*, on account of its being procured from the lixiviation of vegetable ashes; but it is now known to exist in earths, and mineral combinations, from which it is imbibed by plants.

The potash of commerce, is chiefly obtained by evaporating the ley of wood, or vegetable ashes. Plants of a soft texture are found to yield more of the saline matter, than those with woody fibre. Resinous wood affords little alkali; for which reason, the ashes of pine wood are little valued in families for soap-making. Potassa is a white solid substance, highly alkaline, and of a greater specific gravity than *potassium*. It has so great an affinity for water, that it readily absorbs it from the air, forming with it the *hydrate of potassa*, composed of 1 equivalent of potassa, and 1 of water.

566. The *peroxide* of potassium is formed when potassium burns in the open air, or in oxygen gas. It is yellowish green, and gives the alkaline tests with vegetable colors. It was discovered by Gay Lussac and Thenard.

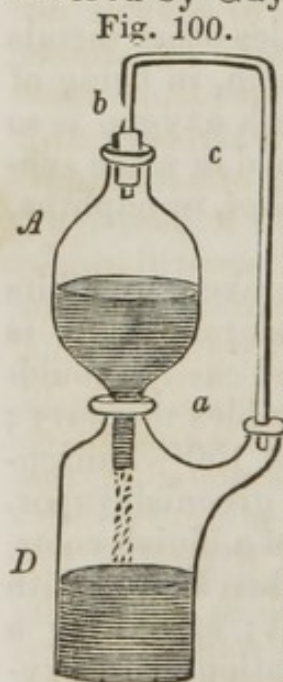


Fig. 100.

The *hydrate of potash*, or caustic potash, is the peroxide of potassium, combined with 1 equivalent of water; and such is the affinity between them, that the water cannot wholly be expelled by the most intense heat. It is a white, solid mass, which fuses at a red heat, disengaging caustic, alkaline vapors. This substance is often cast into sticks for the use of surgeons, who employ it as a caustic. Pure hydrate of potassa is obtained by boiling a solution of potash or pearlash with quick lime. This solution is then to be filtered through a funnel, the throat of which is covered with folds of linen; but since potash absorbs carbonic acid rapidly, when exposed to the atmosphere, Mr. Donovan invented the filtering apparatus here represented, (Fig. 100.)

A is the filtering funnel, having its throat obstructed by a fold of linen to serve as a strainer; the solution being poured in through the mouth at b, the funnel is closed by a cork fitted to the tube, c, and connected at a, with the receiving vessel, D. The filtration will now proceed at the slow rate which the nature of the operation requires, and without exposure to any more air than was contained in the vessels at the beginning.

567. Potassium inflames spontaneously in chlorine gas, and burns with

565. Synonymes of the protoxide of potassium. Potash of commerce, how obtained? Different proportions of potash in plants. Properties of potash.

566. Peroxide of potassium. Hydrate of potassa. Mode of obtaining pure hydrate of potassa. Donovan's filtering apparatus.

567. Combinations of potassium with chlorine, iodine, bromine, &c.

great brilliancy, forming *chloride of potassium*. This chloride is also formed when potassium is heated in hydrochloric acid gas, hydrogen being at the same time evolved. Potassium has a stronger affinity for chlorine than for oxygen, as its oxides are decomposed by chlorine gas.

Iodide of potassium is formed, with an emission of light, when the two elements are heated in contact. There is a *Bromide of potassium* formed by saturating hydrate of potassa with bromine.

Hydrogen and potassium unite in two proportions, forming in the one case, a gray solid hydruret, and in the other, a gaseous hydruret, destitute of color. Thenard states, that when potassium is heated in ammoniacal gas, the hydrogen of ammonia is disengaged, and the potassium unites with the nitrogen, forming nitruet of potassium. The sulphuret of potassium is readily formed by the combination of the two elements by means of heat. It has a red color, and is very fusible.

Potassium unites with phosphorus, forming a *phosphuret*. It also combines with cyanogen, forming a *cyanide* or *cyanuret of potassium*.

568. *Sodium*.—*Equiv.* 24. This metal in many of its properties resembles potassium. And was discovered by Sir H. Davy, soon after his discovery of potassium. It may be obtained by the same electrical and chemical processes, with pure hydrate of soda; but requires, in its decomposition, a stronger voltaic power, and a higher degree of heat.

Properties. It is brilliant like silver, when kept from the air; is solid at the common temperature, soft and ductile like wax. It is somewhat heavier than potassium, its specific gravity at 59° Fahrenheit, being 0.972. It therefore nearly floats on water. It is less fusible than potassium; becomes fluid at about 190° Fahr., but does not vaporize, except at a very high temperature. Its attraction for oxygen is less energetic than that of potassium. Its combustion with this gas does not take place till near ignition; it then burns with a yellow flame, and bright scintillations, producing a yellow compound, which is a mixture of the protoxide and deutoxide of sodium. It fuses on cold water, with a hissing noise, appearing like a globule of silver, and gradually melting away; but without emitting light. On hot water, there is an appearance of sparks and flame. In this combustion, the sodium unites with the oxygen, forming soda. Sodium tarnishes on exposure to the air, in consequence of its attraction for oxygen; and like potassium, should be preserved in some substance in which it is insoluble, and which is free from oxygen.

569. The *protoxide of sodium*, or soda, is obtained by burning sodium in dry atmospheric air, or when sodium is oxidized by burning on water. It is solid, white, caustic, turns to green vegetable blue colors, deliquesces by attracting carbonic acid from the air, and becomes efflorescent. It exists in nature, only

568. Analogies of sodium and potassium. Properties. Attraction for oxygen. Combustion in oxygen. Action with water. Effect of air on sodium.

in combination with acids, and some metallic oxide. Like the protoxide of potassium, its affinity for water is such, that, at the highest temperature, it always retains a certain quantity; and can only be obtained in the state of a *hydrate*, or with 1 equivalent of water.

The *peroxide* of sodium, is obtained by heating sodium to redness in an excess of pure oxygen. It is an orange colored substance. It is resolved by water, into oxygen and sodium, and loses part of its oxygen by heat.

"Soda, (or rather the hydrate of soda,) is distinguished from other alkaline bases, by the following characters. 1st. It yields with sulphuric acid, a salt, which, by its taste and form, is easily recognized as Glauber's salt, or sulphate of soda. 2nd. All its salts are soluble in water, and are not precipitated by any re-agent. 3d. On exposing its salts by means of platinum wire to the blow pipe flame, they communicate to it a rich yellow." *Turner.*

570. *Chloride of Sodium.* This union of sodium and chlorine is the compound so well known in all countries, as *common salt*. This substance, which exists extensively in nature in a solid form, as in rock salt, and in solution in salt springs and sea-water, was formerly called *muriate of soda*, being regarded as a compound of muriatic acid and soda. But as it may be formed by the direct combination of sodium and chlorine, it is evident that it is a binary compound consisting of a metallic base and a simple non-metallic element. When sodium is burned in chlorine gas the result of the combustion is chloride of sodium.

It may also be formed by heating sodium in hydro-chloric gas, the chlorine unites with sodium and hydrogen is liberated. Sea-water is a hydro-chlorate of soda, but by evaporation becomes chloride of sodium; for hydro-chlorates are changed into chlorides by heat, or by evaporation. Hydro-chlorate of soda, for example, consists of hydro-chloric acid and soda, (oxide of sodium,) the hydro-chloric acid gives off its hydrogen, and the soda its oxygen; these uniting form water, which passes off by evaporation, while the chlorine is left in combination with sodium. The hydro-chlorate of potassium, in the same manner, forms chloride of potassium. The chloride of metals are changed into hydro-chlorates by the decomposition of water; the hydrogen of the water uniting with the chlorine of the chloride forms hydro-chloric acid; and the oxygen of the water forms with the metal an oxide, and again the combination of the hydro-chloric acid with this oxide constitutes a salt called a *muriate*, or *hydro-chlorate*.

571. *Properties.* The chloride of sodium (common salt) is

569. Protoxide, how obtained? Properties. Peroxide. How is soda distinguished from other alkaline bases?

570. Composition of chloride of sodium. Synonymes. How proved to be a binary compound? How produced. How does sea-water become chloride of sodium? Chlorides of metals changed into muriates.

571. Properties of chloride of sodium.

transparent and colorless: it crystalizes in cubes. Its taste, though used as a standard of comparison for saline bodies, cannot be defined, except negatively, that is, it is not sour, bitter, sweet, metallic, or astringent. It is grateful and agreeable; it decrepitates at red-heat, and suffers igneous fusion without being decomposed. By an increased heat, it vaporizes in a white smoke, which condenses in the cold. It is remarkable for being equally soluble in cold, as in hot water; it is almost insoluble in alcohol. In the arts, salt is often used to increase the intensity of fire; this it does by accumulating and transmitting heat to the surrounding combustibles. It gives to flame a yellowish tinge.

572. *Chloride of soda* (*chloride of oxide of sodium*), is formed when chlorine gas is passed through a solution of soda or its carbonate. "It emits an odor of chlorine, and possesses the bleaching properties of that substance in a high degree. When kept in open vessels it is slowly decomposed by the carbonic acid of the atmosphere with evolution of chlorine; and the change is more rapid in air charged with putrid effluvia; because the carbonic acid produced during putrefaction, promotes the decomposition, of the chloride. On this depends the efficacy of this chloride in purifying air loaded with putrescent exhalations. Chloride of soda may be employed in bleaching and for all purposes, to which chlorine gas, or its solutions, was formerly applied."—*Turner*.

573. Sodium unites with iodine and bromine; and among the combustible bodies, with sulphur, phosphorus and selenium. It forms *alloys* with many of the metals. Its *salts* are numerous and important.

Silliman remarks, "the great prerogative of sodium is to attract oxygen, in which function it is only inferior to potassium. Both these remarkable bodies are *endowed* with such a degree of activity, and their chemical relations are so numerous, as almost to realize the brilliant suggestion of their illustrious discoverer, that they approach to the character of the imaginary alkahest of the ancient alchemists. Nothing can be more unexpected than that common salt and sea weed should contain each a metal, or wood ashes another. In the present state of our knowledge we must regard potassium and sodium as elements. As they exist abundantly in minerals, we can understand how in the processes of vegetable life, they should become constituent parts of plants."

574. *Lithium*.—*Equiv.* 10. This mineral is the base of a new alkali called *lithia*, discovered in 1818, by M. Arfwedson, then a young student in the laboratory of Berzelius. Its name is from the Greek, *lithos*, a stone. It has hitherto only been found in minerals, as the *petalite*, *spodumene*, *tourmaline*, in some varieties of mica, and in certain waters of Bohemia.

572. Chloride of soda.

573. Combinations of sodium with other simple elements, &c. Silliman's remarks.

574. Discovery of lithium. Derivation of the name. Where found.

575. *Lithia* or *oxide of lithium* is obtained by a complicated process* from its mineral combinations. It is a white, caustic substance, changing vegetable blue colors green, and is in most respects, analogous to soda and potassa. Its tendency to act upon platinum is such, that, according to Berzelius, that metal can always be depended on to detect the presence of lithia in any mineral.

576. Sir Humphrey Davy succeeded in decomposing lithia by galvanism; but the metallic base was so rapidly oxidized, and thus reconverted into alkali, that it could not be collected. The pure metal was, however, observed sufficiently to show it to be of a silvery whiteness like sodium, and it burned with bright scintillations.

Lithia is distinguished from potassa and soda by its power of saturating a greater quantity of any acid. The *chloride of lithium* dissolves in alcohol, and the solution burns with a red flame. "The salts of lithia when heated on platinum wire before the blow-pipe tinge the flame of a red color."—*Turner*.

CHAPTER XXIII.

SECOND CLASS OF METALS.

Order II. Metals which, with oxygen, form alkaline Earths. Barium, Strontium, Calcium, and Magnesium.

577. *Difference between the alkaline earths and the fixed alkalis.* They are less soluble in water, less fusible and not volatile by any heat hitherto applied. *Resemblance.* In common with the fixed alkalis, the alkaline earths are acid and caustic, give the alkaline test with vegetable colors, form soap with oils, and combine with acids to form salts. They belong to a natural class of bodies called by the general name of earths, and which, until recent discoveries, were supposed to be simple elements.

578. *Barium.*—*Equiv.* 70. This metal is little known. It was obtained by Sir H. Davy, in 1808. It is of an iron gray color, with little lustre; it is heavier than water, its specific gravity being 4. It attracts oxygen from the atmosphere and

* See Dictionary of chem. art. oxide of Lithium.

575. Lithia. Its properties.

576. Lithium obtained by Davy. Properties. Lithia distinguished from potassa and soda. Chloride of lithium. Colored flame of the salts of lithia.

577. How do the oxides of the metals of the 2nd. order differ from those of the 1st. order? What resemblance between them?

578. Discoverer of barium. Properties. Attraction for oxygen. How is baryta obtained? Its absorption of oxygen. Properties of baryta. Hydrate of baryta. Crystals of the hydrate of baryta. Test furnished by solution of baryta.

from water, and, crumbles into a white powder, which is the *protoxide of barium*.

The *protoxide of barium*, commonly called *barytes* or *baryta*, was so named from the Greek, *barus*, ponderous, on account of its great specific gravity. It was discovered by Scheele in 1774. *Baryta* is obtained by the decomposition of the carbonate of *baryta*, effected by means of heat. It is the sole product of the oxidation of barium in air, or water. When heated with oxygen gas, it absorbs it and becomes the *deutoxide* of barium. *Baryta* is a gray powder, possessing alkaline properties as distinct as those of potash and soda, except that it is less caustic and less soluble in water. It has a great affinity for water. When mixed with that liquid it slakes in the same manner as quick lime, with the production of more intense heat, and even light is said to be sometimes, evolved. The result of this process is a *hydrate* of *baryta*, consisting of one equivalent of *baryta* 78, and one of water 9, making its combining equivalent 87. The *aqueous solution* of *baryta* furnishes a valuable test of the presence of carbonic acid, in the atmosphere, or in other gaseous mixtures. The carbonic acid unites with the *baryta*, and a white insoluble carbonate of *baryta* is precipitated.

579. *Peroxide of barium*, may be obtained by heating *baryta*, (the *protoxide* of barium,) in oxygen gas. The peroxide is of a greenish gray color, possessing most of the alkaline properties. Exposed to heat, it loses a portion of oxygen and becomes a *protoxide*.

All the *soluble* salts of *baryta* are poisonous. The carbonate, which dissolves in the juices of the stomach, acts on the system as a poison.

The sulphate of barium is inert, being perfectly insoluble.

Barium forms with different elements, a *chloride*, *iodide*, *bromide*, *fluoride*, *sulphuret*, *cyanuret*, *sulpho-cyanuret*, and *phosphuret*.

580. *Strontium*.—*Equiv.* 44. This is the metallic base of *strontia*, an earth so similar to *baryta*, as to have been considered the same until about 1791, when Dr. Hope, of Edinburgh, extracted what he considered as a new earth, from *strontianite*, a mineral found in the lead mine at Strontian in Scotland. It resembles barium in being very ponderous and in general appearance. Sir H. Davy obtained the metallic base, *Strontium*, by a process analogous to that by which he evolved potassium from potassa.

581. The *protoxide of strontium*, (or *strontia*,) exists in nature, only in combination with carbonic and sulphuric acids. It may be obtained by the decomposition of the native carbonate of

579. Peroxide of barium. Salts of *baryta*. Chloride, &c.

580. Of what is strontium the base? What does it resemble? Discovery, &c.

581. Protoxide. Peroxide. How found in nature? How obtained? Hydrate of *strontia*. Colored flame of *strontia*. Peroxide, &c. Binary compounds. Salts of *strontia*.

strontia, or of the prepared nitrate. When mixed with water, it slakes violently like baryta, and produces intense heat, forming a white powder, which is the *hydrate of strontia*, composed of one equivalent of strontia, and one of water. Strontia gives to the flame of burning alcohol, a blood-red color. The *peroxide of strontium*, has only been obtained in the state of a hydrate. It may be prepared by pouring a solution of the protoxide, or strontia, into oxygenated water; the *hydrated peroxide* precipitates in pearly scales.

Sulphate of strontium, is found on the shores of lake Erie, and in some other parts of this continent. The *carbonate* is more rare. The artificial *nitrate*, is used in forming the blood-red fire of fire-works.

Strontium unites with chlorine, iodine, and sulphur, forming binary compounds. Strontia forms salts with acids, resembling the salts of baryta.

582. *Calcium*.—*Equiv.* 20. This metal does not exist pure, in a native state. Its oxide, lime is very abundant. Calcium is of a silvery whiteness, heavier than water, and solid at the common temperature; its affinity for oxygen is so great that it absorbs it from most other bodies, and oxidates, or becomes lime in contact with air, or water. The existence of a metallic base in lime, had been suggested by Berzelius, before its actual discovery by Davy. When lime is subjected to the action of the galvanic battery, oxygen is evolved at the positive pole and, calcium appears at the negative pole. The quantities of this metal hitherto obtained, have been too small to afford an opportunity for the study of its properties.*

583. The *protoxide of calcium*, or lime, is extensively diffused in nature; it constitutes a part of the teeth and bones of animals, exists in many vegetable combinations, and forms a large portion of the rocky strata of the earth. It was formerly called *calcareous earth*. In Latin, it was called *calx*, a word supposed to be derived from the Arabian *kalah*, to burn, from which comes *calcine*; thus, a burnt mineral, is said to be *calcined*.

Lime is not found pure in nature; but is obtained by *calcination* of *carbonate of lime*, which exists in various forms, as limestone, chalk, marble, &c. For purposes of commerce, lime is obtained sufficiently pure, by calcining the common limestone in lime kilns. For use in the laboratory,

* Dr. Hare in 1839 was engaged in attempts to obtain calcium, when he exhibited to the author, with much exultation a few small silvery grains of the metal not much larger than a pin's head, which he had just obtained by decomposing lime.

582. Calcium. Properties. Existence of the metallic base of lime suggested by Berzelius. How obtained?

583. Protoxide of calcium, its composition. Its existence in nature. Meaning of the terms *calcareous*, and *calcine*. Modes of obtaining lime. Calcined lime. Its properties. Promotes the fusion of other bodies.

powdered white marble, chalk, or shells are heated in a covered crucible; the carbonic acid is expelled, and pure lime remains. When fully calcined, lime will not effervesce with acids. In its pure state, it is called *quick lime*. It is a white earthy solid, having an astringent, and alkaline taste, and giving the alkaline test with vegetable colors. When moist, it corrodes animal substances. Its specific gravity is 2.3. Though very infusible, it melts before the galvanic current. Notwithstanding its *infusible* nature, it is remarkable for promoting the fusion of other mineral bodies, and, therefore, is employed in the reduction of metals.

584. Lime has a great affinity for water, which when added to it, produces intense heat; the water, in solidifying, sets free a large portion of caloric, and unites with the lime, forming a *hydrate of lime*.

This appears in the form of a white, bulky powder, consisting of 1 equivalent of lime, 28, with 1 of water, 9, making its equivalent number 37. This well known process is called *slaking*, or *slacking* lime, and the hydrate is called *slaked* or *slacked* lime. This hydrate requires a large proportion of water to dissolve it, as may often have been noticed by those who prepare lime for white-washing walls, brick-layer's mortar, &c; and it is a singular fact, that, for this purpose, it requires more hot, than cold water; thus, on heating a cold solution of lime-water, lime is precipitated. A hydrate of lime is formed when quick lime is exposed to the air; it gradually crumbles to powder, as the hydrating process goes on. This *air slaking* changes the peculiar properties of lime, while the mere water slaking does not; this is because the lime, in absorbing moisture from the air, also acquires carbonic acid, and then becomes carbonate of lime, which is insoluble, and effervesces with acids.

Lime-water is a solution of the hydrate made by mixing with it, a large proportion of water; its taste is acrid, and it gives the alkaline test with vegetable colors. It is not caustic, and is a valuable medicine. It absorbs carbonic acid from the atmosphere, and should be kept in well stopped bottles.

Mixed with sweet oil, it forms an excellent liniment for burns.

The *milk of lime*, is made by mixing with the hydrate, merely sufficient water to give it a liquid form, of the consistence of a thin paste. It is used for the purpose of purifying gases from carbonic acid gas; by causing them to pass through this preparation, the carbonic acid gas is absorbed by the lime. The simple lime water is used for the same purpose, though from having less of the earth in solution, it is less effective. *Crystals of hydrate of lime* may be obtained by placing lime-water under the exhausted receiver of an air pump, with sulphuric acid in another vessel. The acid having the property of absorbing watery vapor, facilitates the process of evaporation.

585. The *peroxide* or *deutoxide of calcium* may be formed by passing oxygen gas over ignited lime.

Chloride of Calcium. The metal calcium is too rare to be

584. Hydrate of lime, or slacked lime. Action of air upon quick lime. Lime water. Milk of lime. Crystals of hydrate of lime.

585. Peroxide of Calcium. How is the chloride of calcium formed? What change takes place when this chloride is dissolved in water? Chloride of lime. How prepared? How does it act as a disinfecting agent? Is it a definite compound?

united directly with chlorine, to form the chloride; but when pure lime, (protoxide of calcium,) is heated in chlorine, the latter unites with calcium, and oxygen is disengaged. When dissolved in water, it forms, by a new arrangement of elements, the *hydrochlorate of lime*. This forms, with snow, one of the most powerful *freezing* mixtures. It is valuable for medicinal purposes; and may be easily prepared by dissolving powdered marble in hydrochloric acid.

Chloride of Lime (chloride of the oxide of calcium) is the combination of chlorine with lime. It possesses the bleaching, and other important properties of chlorine, and is, in many respects analogous to chloride of soda, (see § 572.) It was formerly called *oxymuriate* of lime, or bleaching powder. It is prepared by exposing newly slaked powdered lime to an atmosphere of chlorine gas. The chlorine combines with lime, forming a dry white powder, having a smell of chlorine, and a strong taste. Its watery solution exposed to the air, gradually disengages chlorine, and thus acts as a disinfecting agent. It is doubtful whether chloride of lime is a *definite* compound;—according to Dr. Hare, its elements do not constitute a regular atomic combination.

586. *Fluoride of calcium* according to theory, is composed of 1 equivalent of calcium, 20, and 1 of fluorine, 10. It is found native, and constitutes the beautiful mineral called *fluor spar*, which is sometimes manufactured into ornamental vases. Its usual color is that of a rich purple, but by exposing it to different degrees of temperature, artists have found means of forming it into a variety of beautiful colors. The finest varieties are obtained from the Derbyshire mines in England. The term *fluor*, was given to this mineral, because, being fusible, it is used as a flux for ores.

587. We have before remarked, (see § 298,) that the subject of fluorine and its compounds, is involved in obscurity. Since fluorine has never yet been obtained in a separate state, there can be no synthetic proof, (or proof by a direct combination of the two elements,) of the existence of a fluoride of calcium, as there is by the union of chlorine and sodium, of a chloride of sodium. The existence of the fluoride of calcium is only inferred by analogy. When fluor spar is decomposed by hydro-sulphuric acid, the result is analogous to that obtained by the decomposition of common salt, or chloride of sodium. It is supposed that the hydrogen of the water in the sulphuric acid, uniting with fluorine of the fluoride, forms hydro-fluoric acid in the one case, and with the chlorine of the chloride in the other, forms hydro-chloric acid; while the oxygen of the water, uniting with the disengaged calcium, and sodium forms lime and soda; these newly formed alkalies, combining with the sulphuric acid, the result is, in the one case, a solid sulphate of lime, and in the other, a solution of sulphate of soda. The af-

586. Fluoride of calcium, composition, from what mineral obtained, &c.

587. The existence of this fluoride inferred by analogy. Decomposition of fluor-spar by hydro-sulphuric acid. Apparent analogies in the decomposition of fluor-spar and common salt, by sulphuric acid and water. Artificial fluor-spar. Combination of calcium with iodine, &c. Salts of lime. Their uses.

finities which determine the change, are the attraction of fluorine and chlorine for hydrogen, of calcium and sodium, for oxygen and of lime and soda, for sulphuric acid.

If lime, (oxide of calcium,) be added to hydro-fluoric acid, much heat ensues, the hydrogen of the acid forms water with the oxygen of the lime, and the fluorine and calcium uniting, form the same substance as fluor spar, or fluoride of calcium. This compound may be obtained by digesting newly precipitate carbonate of lime, in an excess of hydro-fluoric acid.

The iodide, bromide, sulphuret, and phosphuret of calcium, have been little studied, and their properties are but imperfectly known.

The *salts of lime*, as the sulphate, carbonate, &c., constitute a large portion of the minerals of the globe, and enter into the composition of vegetable and animal substances. Few substances are of more general utility than lime; it is used in medicinal preparations; in the laboratory as an important re-agent; in soap-making, to disengage carbonic acid from potash and soda; in agriculture, in building, and in various other arts and manufactures.

588. *Magnesium*.—*Equiv.* 12. Sir H. Davy failed in his attempts to procure this metal from magnesia, by galvanic power; but succeeded better by subjecting solutions of the sulphate and nitrate of magnesia, to the action of the voltaic battery. It has since been obtained by the action of potassium on chloride of magnesium, heated to redness in a tube of porcelain. It has a brilliant silvery lustre; when heated intensely, it burns with a vivid light, and unites with oxygen, forming a white oxide, or the powder called *magnesia*. When thrown into water, it gradually changes into the same white oxide.

589. The *oxide of magnesium*, or *magnesia*, exists in combination with acids, extensively, in the mineral kingdom, forming a component part of *talc*, *soap-stone*, *serpentine*, and *asbestos*. It exists in sea water, and in many mineral springs.

Magnesia may be obtained pure by heating the carbonate of magnesia, and thus expelling the carbonic acid. The product is called *calcined magnesia*; this, in most cases, is preferable as a medicine, to the carbonate, because no gas is generated by it in the stomach.

Properties. Magnesia is a white, earthy powder, having neither taste nor odor. It gives the alkaline test with vegetable colors, though less strongly than the other alkaline earths. It has the essential character of alkalinity, that of forming neutral salts with acids. It absorbs water, and carbonic acid from the atmosphere. It is a mild, harmless substance, very infusible, and

588. How has magnesium been obtained? Properties of this metal.

589. Oxide of magnesia, &c. How obtained pure? Calcined magnesia, Properties of magnesia. Its alkaline properties, &c. Hydrate of magnesia. Its sulphate soluble. Infusible nature of magnesia. What substance promotes its fusion? Magnesian clays useful in porcelain manufacture. Chloride of magnesium. Chloride of magnesia. Remarks on the division of the metals founded on the nature of their oxides.

insoluble. Minerals which contain a large portion of magnesia, are infusible, as soap-stone, which is used in furnaces.

Chloride of magnesium is obtained by passing chlorine gas over magnesia heated to redness; in which process, oxygen gas is evolved. A *chloride of magnesia* is prepared by mixing a solution of chloride of lime, and sulphate of magnesia; it seems to possess properties analogous to those of the chlorides of soda and lime.

We have now completed our examination of the two orders in the second class of metals, including all whose oxides are either fixed alkalies, or alkaline earths. The distinction which we have made with respect to the metals, is, perhaps, rather conventional than natural. There is a gradual decrease of alkalinity, from potash to magnesia, and, an equal increase of earthy properties; so that it might be considered as somewhat doubtful, whether magnesium should be classed among metals whose oxides are *alkaline earths*, or pure *earths*.

CHAPTER XXIV.

THIRD CLASS OF METALS.

Earthy Metals; or those whose oxides are Earths.

590. The existence of the metals of this class rests upon strong analogy, rather than the results of experiments. They exist in nature, only in the form of oxides, which are known by the general name of *earths*; having neither the alkaline taste, nor giving the alkaline test with vegetable colors.

591. *Aluminum*.—*Equiv* 10. This is the metallic base of the earth *alumina*, (alumine of pure clay.) Sir H. Davy failed in his attempts to obtain this metal by galvanic power, though he proved that alumina was an oxidized body; for when heated to whiteness, and brought into contact with the vapor of potassium, potassa was generated, which is an evidence that oxygen was imparted to the potassium by the body in contact.

Dr. Wohler has succeeded in obtaining the metallic base of alumina, by heating a mixture of dry chloride of aluminum with potassium. On throwing the mass into water, a granular metal, resembling gun-powder falls to the bottom of the vessel. When the powder is rubbed on a hard substance with a burnisher, the particles adhere strongly, and form a surface which strongly reflects light, and is a conductor of electricity; in the state of powder, it is a non-conductor. It burns with great splendor, when heated in oxygen gas, and with the evolution of so much heat as partially to fuse the alumina, which is formed, and which is one of the most infusible of all substances.

590. Evidence of the existence of these metals. Nature of their oxides.

591. What is aluminum? Davy's attempts to decompose alumina. How did Wohler obtain the metallic base of alumina? Properties of the metallic substance obtained.

592. *Oxide of Aluminum, alumine, or pure clay*, is widely diffused in nature. It is a constituent of every soil, and of almost every rock; is the basis of porcelain, pottery, and bricks, and forms a part of fuller's earth, ochres, pipe-clay, &c. It constitutes either alone, or with other substances, in a crystalline form, most of the precious stones, as the topaz, sapphire, ruby, and garnet. Its affinity for vegetable coloring matter, is made use of in the preparation of lakes, for painting, and in dying and calico printing. Its name is from *alumen*, the Latin name of *alum*, of which it is the basis. It was considered as a simple substance, until the discovery of the alkaline metals suggested that it might be a metallic oxide.

593. Pure alumine is seldom found in nature; it may be obtained from alum, (*sulphate of alumina and potassa*), by precipitating its solution by a carbonate of soda, or potassa; a white bulky hydrate of alumine is thus obtained, which, when washed and subjected to intense heat, becomes anhydrous, leaving the pure alumine in the form of a white powder. It has neither taste nor smell, and has no effect on vegetable colors. It is fusible at a very strong heat forming a vitreous substance, so hard as to scratch glass. Though insoluble in water, pure alumina attracts it powerfully. Dr. Henry states, that after ignition, it attracts water so fast from the air, that balances show the increase of weight. It is this thirst, (to use a metaphorical expression,) of alumina for liquids which renders potter's clay, and fuller's earth so useful as absorbents of oil and grease, when carpets, or silken, or woollen cloths are thus soiled. The aluminous earth in powder, is laid thickly, upon the spot, and some bibulous paper, (that is, coarse paper without sizing, which readily imbibes moisture,) placed over the powder; a warm flat-iron, should be set upon the paper, that the oil to be withdrawn, may be kept in a fluid state, and thus acted upon by the absorbent earth. The paper assists in the process of absorption.

After removing once or twice the saturated earth and paper, and replacing them with other, the oily matter will be found wholly extracted. Spanish white, or oxide of bismuth, from its possessing the same absorbing property, has been found almost equally useful in similar cases.

Though alumine is insoluble in water, it forms with it a ductile, plastic, cohesive and infusible paste, susceptible of being moulded into regular forms, a property on which depends its use in the manufacture of porcelain and common pottery. But as alumine shrinks by heat, it is necessary that silica which does not possess this property, should be united with it in pottery. The natural clays often contain a sufficient portion of silica; when they do not, manufacturers mix with the clay-paste, siliceous sand, or pul-

592. Oxide of aluminum. Its existence in nature. Affinity for vegetable coloring matter. Origin of the name alumine. When first supposed to be a compound body?

593. How may pure alumine be obtained? Properties of pure alumine. Attraction for water. Absorbent properties of potter's clay and fuller's earth. Process for extracting oil by their agency. Property of alumine which renders it useful in porcelain manufacture. Why silica should be united with it in pottery. Use of magnesia with alumine in pottery. Injurious effect of a large proportion of lime. Difference in the processes of glass making and pottery. Application of the contraction of clay by heat to the construction of a pyrometer.

verized flints. Magnesia which enters into the composition of clays, is, from its infusible nature, and from its contracting but little in the fire, a valuable ingredient. But if lime exists in the clay in any great proportion, it will injure the ware, by acting as a flux, and thus melting the vessels while baking them, destroying their regularity of form. Though the manufactories of glass and pottery, may seem to be but branches of one art, they are entirely different, while glass is softened by heat, and wrought at a high temperature, clay is wrought when cold and afterwards hardened by heat. The contraction of clay by heat, is so regular according to the increase of temperature, that Wedgewood's *pyrometer*, or instrument for measuring high degrees of heat, has been constructed upon this property. Pieces of clay of certain definite dimensions, exhibit the same amount of contraction, when exposed to the same degrees of heat.

594. Pure alumine was formerly called *argil*, from the Latin *argilla*, pure clay; aluminous earths, or those containing clay have hence been called *argillaceous*; and clay slate is called *argillite*.

595. Alumina appears to possess both the properties of an acid and an alkali. Of an acid, by uniting with alkaline bases, and of an alkali by uniting with acids to form salts. It is characterized by the following properties. 1st. It is separated from acids as a hydrate, by all the alkaline carbonates, and by ammonia. 2nd. It is precipitated by potassa or soda, but the precipitate is, commonly, re-dissolved by an excess of the alkali.

Chloride of Aluminum, was obtained by Prof. Oersted, some years ago, by a direct combination of the two elements; by acting on this compound with an amalgam of potassium and mercury, and expelling the mercury by heat, he obtained a metallic substance which he believed to be aluminum, or the metallic base of alumina; and he requested Wohler to pursue the investigation. The latter did not succeed, until he substituted pure potassium for the amalgam. (See § 591.)

596. *Zirconium*.—*Equiv.* 33. In 1824, Berzelius succeeded in decomposing the earth, *zirconia*, and obtained a peculiar substance, black, like charcoal, which neither oxidates in the air, water, nor in any of the acids, except hydrofluoric, when hydrogen gas is disengaged. It burns intensely when heated in the open air, absorbs oxygen, and becomes zirconia, or the oxide of zirconium. Berzelius did not consider it a metal; it possesses some metallic lustre, but has not yet been proved to be a conductor of electricity. It combines with sulphur, forming a chestnut-brown sulphuret, like that of silicon.

The *oxide of zirconium*, or *zirconia* is a white earth, which was first discovered in a mineral of Ceylon called *jargoon*, from whence came the name. This earth is now found in the minerals called *hyacinth* and *zirconite*. It resembles alumina in

594. Derivation of the word argillite.

595. Acid and alkaline properties of alumina. Two distinguishing characteristics of alumina. Chloride of aluminum.

596. Decomposition of Zirconia by Berzelius. Properties of the substance obtained by Berzelius by this decomposition. Oxide of Zirconium

its pure white color, insolubility with water, and in being tasteless and without odor.

597. *Glucinum*.—*Equiv.* 26. It was obtained in 1758, by Wohler, on decomposing the chloride of *glucinum*, by heating it with potassium. The process is similar to that for obtaining aluminum, (see § 591.) *Glucinum* appears in the form of a dark gray powder, which by polishing, acquires a metallic lustre, and burns in the open air with a vivid light. *Oxide of Glucinum*, or *glucina* was discovered by Vauquelin in 1795 in the beryl, and by him considered as a simple substance, it was at first called *berillia*; the name *glucina* which was afterwards given, it, is from the Greek, *glukos*, sweet, its salts having a sweetish taste. It is found in the beryl, emerald, and a few other rare minerals. Like alumine it is a soft, white powder, and adheres to the tongue like pure clay.

598. *Yttrium*.—*Equiv.* 32. It is obtained from *yttria*, a Swedish mineral of the earthy class which was discovered by Gadolin in 1794, in Ytterby, and Sweden. The *metal* is of a grayish-black color and a scaly texture. The earth, *yttria* resembles *glucina*, but may be distinguished from it by the purple color of its sulphate, and by being insoluble in potassa.

599. *Thorinum*.—*Equiv.* 59. In 1816, Berzelius, in analyzing the Swedish minerals which afford *yttria*, supposed he had discovered a new earth, which he named *thorina*, from *Thor*, an ancient Scandinavian deity. But this earth, he afterwards found to be the phosphate of *yttria*. In 1828, he received from Norway, a black heavy mineral, now called *thorite*, which, on analysis, was found to contain a new earth resembling the substance he had named *thorine*. On account of this analogy, and perhaps to remind the scientific world that, if he had misnamed one substance, he had made ample compensation by the discovery of another to fill the vacancy, he applied to this new mineral the exploded name, *thorina*. *Thorinum*, the base of *thorina*, is obtained in the same manner as the metals of the other pure earths by the action of potassium on its chloride. Its *oxide*, *thorina* is distinguished among the earths for its snowy whiteness. A *carbonate of thorina* is formed by heating *thorina* with sugar, this furnishes carbon, which the oxygen of the air changes to carbonic acid, and the latter uniting with *thorina* forms a carbonate.

597. *Glucinum*, when obtained? Properties. Discovery of *glucina*. Names. Where found? Properties.

598. Discovery of *yttria*. Properties of *yttrium* and of its earthy compound, *yttria*.

599. The name *thorinum* improperly applied by Berzelius. How is *thorinum* obtained? Properties of *thorina*. How distinguished? Carbonate of *thorinum*.

600. The atomic weight of the metals of the third class, is yet in a degree doubtful, as are also the combining proportions of their oxides. Neither the metals, nor their oxides, can be easily obtained in sufficient quantities for the purpose of thorough, and extensive experiments. Though aluminous earth exists every where around us, pure alumine is obtained but by a tedious and delicate process; and its metallic base is with still more difficulty set free. The other pure earths, are obtained from rare minerals, and their separation is attended with equal difficulty as that of alumina.

CHAPTER XXV.

FOURTH CLASS OF METALS.

Metals whose oxides are not regarded as acids, alkalies, or earths.

601. In the 1st class of metals, we have found those, which, by combining with a large proportion of oxygen, form *acids*, thus we have arsenic acid, chromic acid, &c. In the 2d class we met with metals whose combinations with oxygen were *alkalies*; as potash and soda. The 3d class exhibited metals, which, by combining with oxygen, form insipid *earths*, with neither acid, nor alkaline properties, as alumina, &c. In these three classes, the metals, with few exceptions, are little known, except in the laboratory of the chemist; while their *oxides*, (by which term, in its most general sense, we mean combinations with oxygen, whether acid, alkaline, or earthy,) are, in general, familiar to all.

In the 4th class or that we are now to consider, we shall find metals, whose oxides are neither acids, alkalies nor earths. These metals have been familiar to mankind, from the earliest ages. From their having less affinity for oxygen, than those of the other three classes, they may be exposed to the air without oxidating. A few newly discovered metals of this class are, as yet, but little known.

602. *Iron*.—*Equiv.* 28. This most useful metal is, by the wise Author of Nature, extensively diffused over the whole earth. It is found in combination with most earths and stones, and exists in vegetable and animal substances. Its ores are numerous, and exist in greater quantities than those of all other

600. Metals of the third class but imperfectly understood.

601. Review of the three classes of metals examined. Metals of the fourth class, how differing from the other classes?

602. Iron abundant in nature. Known to the ancients. Modern applications of iron.

metals, sometimes forming mountain masses. It appears to have been known to the Hebrews, as early as the time of Moses; and other ancient nations were acquainted with its use. Its capabilities were, however very imperfectly known. The gradual application of it to the various objects of human ingenuity and industry seems to mark the progress of the arts and sciences. The moderns only have applied it to the manufacture of printing presses, steam-engines, chain-bridges, watch springs, magnets, conductors of electricity, &c. &c.

603. *Properties.* Iron is very *infusible*; it has been melted at a heat of 158° of Wedgwood's pyrometer, which would be equivalent to 2200° F. It is an excellent conductor of caloric, and softens and dilates when heated. It is the only metal which takes fire by the *collision of flint*. It becomes heated by *percussion*. Sparks which appear when the smith draws from the forge a bar of iron at a white heat, are burning portions of the iron. Iron will burn in oxygen gas, with brilliant scintillations. There is no flame, because iron does not vaporize. It decomposes water, even at common temperatures. When iron filings are put into water, hydrogen gas is slowly evolved. Water in the state of steam, is rapidly decomposed by passing through iron filings in a heated gun-barrel, and for every grain in weight of the disengaged hydrogen, the iron gains 8 grains of oxygen, (see § 315.)

604. *Protoxide of Iron* is the base of the native *carbonate of iron*, and the *green vitriol* of commerce. It was discovered by Gay Lussac, who, in heating the peroxide of iron with dry hydrogen gas, in a porcelain tube, found that water was formed, and the metal had lost a portion of oxygen. Its color is dark-blue, and when melted with vitreous substances, it gives them the same tint. It is less powerfully attracted by the magnet, than metallic iron. When exposed to the air, at common temperatures, it takes fire and burns vividly, absorbing oxygen, and becoming again the peroxide.

When metallic iron is put into diluted sulphuric or muriatic acids, hydrogen is evolved, and protoxide of iron formed. Its proportion of oxygen may be determined by collecting and measuring the gas which is evolved. Its salts, particularly when in solution, absorb oxygen with such rapidity that they are employed in eudiometry.

605. *Peroxide of Iron.* In the composition of this oxide, we have one and a half equivalent of oxygen, with one of iron, (§

603. Effects of heat on iron. Combustion in oxygen. Decomposition of water by the action of iron.

604. Protoxide of iron. Discovery. Properties. How may its proportion of oxygen be ascertained? Affinity of its salts for oxygen.

605. Peroxide of iron.

604,) a fact appearing at variance with the atomic theory, which does not admit of *half* an *atom*, and which gives 8 as the proportion by weight, in which oxygen unites with other bodies.

606. We have formerly alluded to exceptions to this general law (§ 226.) According to the views there expressed, we may obviate the necessity of the fraction, by supposing a lower combining equivalent of oxygen, than has yet been admitted; that is, calling the half equivalent, or 4, the atomic weight of oxygen; this would give two equivalents of oxygen in the protoxide, and three in the peroxide. This would not change the statement of relative proportions or chemical equivalents of any of the combinations of oxygen. But 8 seems, with very few exceptions to be the combining proportion of oxygen, and Chemists are not generally disposed to break up the arrangement now almost universally adopted, of considering the proportion of oxygen with hydrogen in water as its combining equivalent.

The peroxide of iron, sometimes called red-oxide, exists in nature, and is known to mineralogists under the name of *red-hæmatite*. The *brown-hæmatite* is a *hydrate* of the peroxide of iron: *ochres* are mixtures of the hydrated red-oxide and clay.

607. The peroxide may be made by dissolving iron in nitro-hydro-chloric acid, and precipitating by ammonia or other alkali, and then washing, drying and calcining the precipitate at a low red-heat. When fused with vitreous substances it imparts to them a red color. Its salts are mostly of the same hue. *Iron rust* is produced by the slow oxidation of the metal in the air, promoted by water, or the moisture of the atmosphere, and containing some carbonic acid. *Black oxide of Iron*. The black scales which appear after burning iron wire, or iron filings in oxygen gas, are a mixture of the blue and red oxides of iron, and in a variable proportion. Thus, on heating a bar of iron in the open air, the outer layer of the oxidated scales contains a greater proportion of the oxide than the inner; this is because it was more exposed to the oxygen of the air. The native black oxide of iron is often found in crystals; it constitutes the *loadstone* or *magnetic iron*.

“On digesting this oxide in sulphuric acid, an olive colored solution is formed, containing two salts, sulphate of the peroxide and protoxide, which may be separated from each other by means of alcohol. These mixed salts, give green precipitates with alkalies, and a very deep-blue ink with infusion of nut-galls. The black oxide of iron is the cause of the dull green color of bottle glass.”—*Turner*.

608. *Chlorides of iron* were formerly called *dried muriates of iron*. The *proto-chloride* is obtained by dissolving the metal in diluted muriatic acid, and thus obtaining *proto-muriate* of iron; after evaporating the solution, the dried mass is heated to redness in a porcelain tube from which the air is excluded; and in this state it is the proto-chloride of iron.

The *perchloride* may be obtained by burning iron wire in chlorine gas. It is of a reddish color, and when dissolved in water, forms a red colored *per-muriate* or *per-hydro-chlorate* of iron.

606. Remarks upon its half atom of oxygen. Synonymes. Hydrate of the peroxide of iron. Ochres.

607. How may the peroxide of iron be formed? Properties. Coloring property. Iron rust. Black oxide of iron, formed by the combustion of iron in oxygen or air. Native black oxide, or loadstone. Salts formed with this oxide and sulphuric acid.

608. Synonymes of chlorides of iron. Proto-chloride. Per-chloride. Compounds of iron with bromine, iodine, and phosphorus.

Iron unites with *Bromine* and *Iodine* forming a *bromide*, and *iodide*, and with phosphorus forming a *phosphuret*. The *phosphate* of iron (phosphoric acid with iron) is sometimes contained in the metal, and is injurious to it, by rendering it brittle at common temperatures.

609. *Carburets of Iron*. Iron combines with carbon in several proportions; but the most important of these combinations are *steel* and *plumbago*. *Steel* is but the *sub-carburet* of iron and contains a lower proportion of carbon than any other compound. The proportion of carbon in steel is very small, not generally exceeding one pound, in one hundred and fifty. By fusion it forms cast-steel. The experiment has been tried of enclosing small diamonds in the cavities of soft iron, and igniting the mass; the diamonds disappear, and the iron is converted into steel. This experiment shows, that the diamond and carbon are essentially the same substance; and that it is the union of carbon with iron which forms steel. If a drop of any acid fall upon steel, the carbon is attracted by it, and a black spot appears. A drop of strong green tea will produce a black spot upon a steel knife. This is owing to the gallic acid contained in the tea. With pure iron acids do not produce the same effect.

Plumbago or *graphite* was called black-lead from the common idea that its metallic appearance was owing to lead. The term is still used, though it is now known that *plumbago* contains no lead; but consists of about 10 parts of iron, united with 90 of carbon. It is the *percarburet* of iron. It exists abundantly in nature, and may be formed by art, by exposing iron with charcoal to a violent and long continued heat. As *plumbago* is infusible in furnaces, it is used for crucibles. It is much used in the manufacture of pencils, and is employed in iron to protect it from rust.

610. The *proto-sulphuret* of iron, or *magnetic iron pyrites* is of a brown color and metallic lustre. It may be obtained by fusing iron and sulphur together. It is much more fusible than pure metal; hence if a bar of iron at a white heat, be rubbed with a lump of sulphur, the two substances combine, forming the *proto-sulphuret*, which melts and runs down in drops (§ 480.) It is found in large quantities, in various parts of the United States. At Strafford, Vermont, there is an extensive manufactory of sulphate of iron, (*green vitriol* or *copperas*,) from a mine of the *proto-sulphuret* found in its vicinity. There is a similar mine on the east side of the Hilderberg mountain a few miles from Albany.

The *deuto-sulphuret*, is the common *iron-pyrites*, which exists in great abundance in nature. It is of a yellow color, and often mistaken for gold.

609. Iron with carbon. Steel. Iron changed to steel by heating with diamonds. Cause of the black spot produced by tea upon a steel knife. Plumbago.

610. Proto-sulphuret of iron, &c. How obtained? Localities. Deuto-sulphuret.

It cannot be artificially formed. When heated it loses one equivalent of sulphur, and is thus converted into the *proto-sulphuret*.

611. Though iron exists in almost every situation, *pure* native iron is seldom found. In *meteoric stones* magnetic iron is always found alloyed with nickel and cobalt, metals with which it is never associated in any iron ore found in the earth. This fact increases the interest that must be felt in these mysterious masses, which occasionally fall upon the earth. If, as some suppose, they be projected from distant volcanoes, why should they be unlike any other natural combinations which exist in mines or the bowels of the earth, as far as man has penetrated? If they do not belong to the earth, from whence do they originate? Some say from volcanoes in the moon, others that they are formed in the atmosphere, and others that they are little globules, which, like the earth, revolve around the sun, and fall through the atmosphere, because they come within the sphere of the earth's attraction. The iron found in these meteoric stones, is magnetic, as are also the cobalt and nickel combined with it.

612. To obtain iron from its ores, for commerce, its oxides alone are reduced. These are often combined with sulphur, arsenic, or some other substances which would render iron brittle. By *roasting* the ore, or subjecting it to a strong heat, these volatile substances are expelled. It is then mixed with charcoal and lime at a high temperature. The charcoal absorbs the oxygen of the ore, and the lime acts as a flux by combining with *silex*, clay, and other impurities, and forms a fusible compound called *slag*. The melted metal, being heavier than the slag, sinks to the bottom of the furnace from whence it is drawn by means of a stop-cock. This is the *cast-iron* of commerce; it contains some carbon and un-reduced ore. By a further process of heating, rolling and hammering it is softened, and converted into *malleable or wrought iron*.

The Latin name of iron, *ferrum*, gives names to some of its compounds; as *ferruginous* earth, or earth which contains iron; *ferro-cyanic* acid, composed of iron and cyanogen, &c.

613. *Nickel*.—*Equiv.* 26. It is found in nature in the state of an *oxide*, and an *arseniate*; but most abundantly, as a *sulphuret* united with arsenic, a small quantity of iron, copper, and cobalt. It is found in Chatham, Connecticut, associated with cobalt. It was proved to be a peculiar metal by Bergman, in 1775. Before that time, the ores containing it, had been supposed to be alloys of iron and copper. Hence its names *kupfer nickel*, copper nickel; the term nickel being applied because it

611. Pure native iron. Magnetic iron in meteoric stones. Opinions respecting the origin of these stones.

612. Iron of commerce. How obtained? Cast and wrought iron. Latin name of iron and its compounds.

613. Nickel, how found in nature? When proved to be a peculiar metal? Properties. Action with heat. Combination with oxygen. &c.

looked like copper though it did not yield it. Like iron and cobalt, nickel is attracted by the magnet ; and may be rendered magnetic. It is difficult of fusion, though highly volatile. If heated to a red heat in contact with the air of oxygen, it becomes an olive green oxide.

It is supposed that nickel unites with oxygen in two definite proportions. It forms *alloys* with many of the metals. It has been remarked (§ 611) that meteoric stones contain nickel in combination with iron and cobalt. These metallic compounds are remarkable for bearing exposure to the weather without rusting. Large masses have lain in the open air, in Siberia, Peru, and Louisiana, apparently for ages, with very little appearance of rust.

614. *Zinc*.—*Equiv.* 34. This metal, sometimes called *spelter*, is obtained either from *calamine* (native carbonate of zinc) or from *zinc blende*, the native sulphuret. As it is a volatile metal, it is always obtained by distillation. The zinc of commerce was formerly brought from China. It is now extensively manufactured in Europe. It is found in some parts of the United States, as in the Southampton, Mass. lead mines, with granite and gneiss; also in crystals in lime rock, near the Genesee river. It resembles lead but is of a lighter color. It melts at about 700° , and crystalizes when slowly cooled. When heated without being exposed to the air, it sublimes, without any change of properties. If heated in the air, it absorbs oxygen rapidly, exhibiting a beautiful flame of a brilliant greenish color, and the newly formed oxide flies upward, in the form of white flowers, formerly called *flowers of zinc*, or *philosophical wool*. When heated to a white heat, in a covered crucible placed in a furnace, on suddenly removing the cover, it bursts into flame and burns with a brilliant white light. The metal may be stirred with an iron rod to expose other portions of it to the air; and then if held aloft, and poured slowly upon a brick or stone floor, it descends in a burning sheet, and is dashed about in a fiery spray. This metal is little affected by the air or moisture, and is therefore not liable to rust by exposure to them. On this account, it has been applied in the manufacture of kitchen utensils, and water pipes. But it is found to be attacked by fat substances, especially when aided by heat; and also by the weakest acids; its use is, therefore, become very limited, except in the laboratory.

615. Sir H. Davy, on observing the peculiar property of zinc to resist corrosion, was led to make trial of it for the sheathing of vessels. Copper,

614. From what mineral, and how is zinc obtained? Zinc of commerce, where now manufactured? Localities in the United States. Properties. Action of heat upon this metal. Why is zinc not liable to rust? What property of zinc prevents its extensive use for common purposes?

615. Effect of protecting the copper sheathing of ships from corrosion, by means of zinc. Objections to the use of zinc for the sheathing of ships.

which had hitherto been in use for that purpose, oxidizes so rapidly in water, as to become, in a short time, unfit for service. The copper was found to derive its oxygen from atmospheric air dissolved in water, while the oxide of copper thus formed, uniting with the muriatic acid of the sea water, produced a sub-muriate of the oxide of copper. If, by any means, the copper could be secured against oxidation, it would not form a salt with muriatic acid—and according to Davy's electro-chemical theory, it only combines with oxygen because, by contact with that body, it is rendered electro-positive. By rendering the copper negative, it would then be in the same electrical state as oxygen, and the two would have no tendency to combine. Davy accomplished his object of rendering copper permanently negative, by bringing in contact with it, zinc, which when the two metals were in this state of contact, was positive, and the copper, consequently, of the opposite, or negative electricity. Thus the oxidation of the copper sheathing, was found to be prevented by a small piece of zinc, no larger than the head of a nail, affixed to a sheet of 40 or 50 inches of copper. The copper was found, after many weeks of exposure to the action of sea-water, to be perfectly bright, whilst the zinc appeared to be slowly corroding. Triumphant as the success of this experiment at first appeared, it was found, on the application of it to practical purposes, to be attended with an unexpected embarrassment, and that, unless a certain degree of corrosion took place on the copper bottom of the ship, its surface became foul from the adhesion of seaweeds, and shell-fish. The salts of copper had in fact, served a useful purpose, in preventing these organic substances from fixing themselves in so poisonous a bed. Zinc plates have been substituted in the place of copper; but they are found to be liable to an accumulation of organic substances. A merchant in New York, sheathed the bottom of a ship with zinc plates, fastened with zinc nails; but she returned from her voyage so exceedingly foul, that he was obliged to remove the zinc, and substitute copper. Marine vegetables and even large oysters were found adhering to the zinc. Thus, in the wise economy of the Almighty, that which cannot be decomposed for the purpose of entering into new combinations, is used as a matrix to multiply and support organic existence.

616. The *protoxide* of zinc is very rare in nature. It is obtained by the combustion of the metal in the open air. Thenard supposed that he obtained a *deutoxide*, and Berzelius describes a *peroxide*, but the former was admitted by its discoverer, to have had but an ephemeral existence, and the latter is considered a form of the protoxide.

Chloride of zinc, from its soft consistence, called *butter of zinc*, is formed by the combustion of zinc filings in chlorine gas. It is of an oily appearance, very volatile and deliquescent. Water changes it to the *muriate* of zinc.

The natural sulphuret, called *zinc blende*, exists extensively in masses, and in crystals, which are sometimes semi-transparent and afford beautiful gems. The *white vitriol* of commerce, is the sulphate of zinc. Its most important alloy is with copper, constituting brass; and in other proportions, pinch-beck, Dutch gold, &c. Its amalgam with mercury, is used for exciting electrical machines.

616. Protoxide of zinc. Other supposed oxides. Chloride of zinc. Sulphur et of zinc. White vitriol. Alloys of zinc. Amalgam.

617. *Cadmium*.—*Equiv.* 56. This was discovered by Stro-meyer, in 1818. During the reduction of zinc ore by charcoal the cadmium, which is very volatile, flies off in vapor. Oxygen has no action upon it at the ordinary temperature, but when heated in the air, it burns with a yellow flame, forming an orange colored oxide. It is also oxidated by nitric acid, in which it is more easily dissolved than in any other acid.

Oxide of cadmium, exists in nature, combined with carbonic acid and silica, in calamine, and other zinc ores. It may be obtained by heating the metal in contact with atmospheric air. *Sulphuret of cadmium* occurs native in some of the ores of zinc. M. Stromeyer obtained it by heating sulphur and cadmium. It was of a beautiful orange color, and on a careful evaporation, crystalized in transparent, gold colored laminæ. It is thought by mineralogists that the Missouri lead mines may afford abundance of both zinc and cadmium.

618. *Cerium*.—*Equiv.* 56. It is found in a rare Swedish mineral, called *cerite*. It has also been found with *yttria* in the *ytthro-cerite*. Its qualities are little known. There are two *oxides of cerium*; the *protoxide* is a white powder. When heated in open vessels, it absorbs oxygen, and becomes the *peroxide*, which is of a fawn-red color.

CHAPTER XXVI.

METALS OF THE FOURTH CLASS CONTINUED.

619. *Lead*.—*Equiv.* 104. This metal has been known from the earliest periods of history. It was called by the alchemists, *Saturn*; because, as this deity, (according to mythological fable,) devoured his children; so lead, in the process of *cupellation*,* absorbs, or devours most of the metals. The Latin name for lead is *plumbum*.

Properties. Lead is of a bluish white color, and gives a disagreeable odor on rubbing; its specific gravity is 11.352. It is

* The oxides of lead have the property of combining with most of the metals, except gold, silver, and platinum, and on this account are used for purifiers, by a process called *cupellation*, a term derived from *cupel*, the name of a peculiar kind of vessel used in the operation. In this process, the lead melts first, and carries with it, in fusion, all the baser metals.

617. Discovery of cadmium. Oxide. Sulphuret.

618. Cerium and its oxides.

619. Alchemistical name of lead. Latin name. Properties. Action with heat, dry air and oxygen. Effect of moisture, combined with air or oxygen. Effects of fusing and heating in open vessels. Various uses. Action of acids upon lead.

soft and flexible, and has a strong metallic lustre, when recently cut ; but soon tarnishes, on exposure to the air. It is one of the most fusible of the metals ; melting much below red heat ; it crystalizes on cooling. Atmospheric air, and dry oxygen gas, have no action upon it ; but when moist, they soon cover it with a gray coat of the protoxide of lead. When fused in open vessels, a gray film is formed on its surface, which is a mixture of metallic lead and the protoxide ; and when strongly heated, it volatilizes in fumes of the yellow oxide of lead.

On account of its abundance, and the facility with which it is wrought, lead is much employed in the arts. It is extensively used for aqueducts, reservoirs, chambers for the manufacture of sulphuric acid, printing types, and covering and sheathing gutters, and roofs of buildings. It is employed in medicine. Many of its compounds are poisonous to the human system.

It has been asserted that leaden pipes for conducting water are unsafe, on account of the supposed danger of the water becoming impregnated with the metal and thus operating as a poison. Dr. Turner considers that the salts in spring-water, by gradually forming an insoluble film on the metallic surface of leaden pipes, effectually secure it against any change which would cause it to re-act upon the water. Lead is acted upon by acids, which promote its absorption of oxygen and carbonic acid from the atmosphere. Vinegar contains acetic acid ; and pickles should not, therefore, be kept in pots of earthen ware glazed with lead, as the acid corrodes the lead and forms poisonous salts.

620. *Protoxide of lead*, exists in nature only in combination with acids forming salts. It is prepared in laboratories, by decomposing any salt of lead by potassa or soda.

When first precipitated, it is white because it contains water or is hydrated, but when dried by heat and air it becomes yellow. This, in commerce, is called *massicot*. When the protoxide is partly fused in the air, it unites with about 4 per cent of carbon, and is called *litharge* ; The protoxide forms with acids all the salts of lead, most of which are white. It readily unites with earthy bodies when fused with them, forming the *lead-glazing* for pottery, *flint-glass*, and *pastes* for artificial gems. The protoxide of lead increases the refractive and dispersive power of glass more than any substance, so that the gems made with it resemble the diamond, but may easily be distinguished by their inferior brilliancy and hardness.

621. *Deutoxide of lead* is formed by heating the protoxide in open vessels with free access of air. This is known in commerce as *minium* or *red lead*. It is used in potteries for glazing, in the manufacture of flint glass, and as a paint for oil colors. It is also used for the coloring of red wafers which are consequently poisonous. *Peroxide* or *tritoxide of lead* is obtain-

620. Protoxide of lead. Massicot. Litharge. Union of the protoxide with acids, and with earths. Use of the protoxide of lead in glass artificial gems.

621. Deutoxide of lead. Red lead. Its uses. Peroxide of lead. Drying oil.

ed by digesting the deutoxide in nitric acid, which dissolves one part, leaving the other combined with a large portion of oxygen. This oxide is of a brown color, called *puce* or *pea-colored*. It is not used in the arts, or in medicine.

Fixed vegetable oils, if heated with the oxides of lead, dissolve a portion of them, and are converted into what is called *drying-oil*.

622. *Chloride of Lead* may be obtained by the action of chlorine gas on thin plates of lead. It is soluble in hot water, and is then considered a *muriate of lead*. A compound of the chloride and protoxide of lead forms the paint called *patent-yellow*.

The *sulphuret* of lead exists abundantly as a natural ore, called *galena*. This is the only ore which is wrought for the purpose of extracting lead. Galena is called *potter's lead-ore*, because it is used in pottery for glazing. This ore is abundant in the United States. The Missouri lead-mines are remarkable for their richness. There is a lead mine of considerable extent in Southampton, Mass. From specimens of galena found in that locality, we should infer that it might hereafter prove valuable, when improved processes for carrying on mining operations, and reducing metals, shall be better understood in this country.*

The proportion of silver in lead ore is judged of by *cupellation*; a small piece of metallic lead is heated under a muffle, upon a cup of ashes made by burning bones. The lead oxidizes, the oxide is absorbed by the ashes, and a button of silver remains.

623. Lead forms various *alloys*; among the most important, is that with antimony for printing types. With tin, lead forms alloys of different kinds, as *pewter*, in which tin constitutes more than half the compound, organ-pipes, tin foil, and nails used for some purposes in ship-building, because they do not rust in salt water. The *solder* of the tinners is composed of lead and tin. A compound of lead, tin and bismuth, melts below 212° , so that spoons made from it melt in boiling water.

Fig. 101.



* In 1821, the author received from Charles Bates, Esq. some remarkably fine specimens of galena from the Southampton lead mine, and was informed that the working of the mine had been attempted, but afterwards relinquished on account of the difficulty and expense attending it.

622. Chloride of lead. Muriate of lead. Patent yellow. Sulphuret of lead or galena. Lead mines of the United States. Silver obtained from lead ore by cupellation.

623. Alloys of lead. Lead tree. How formed. Theory of the lead tree.

Lead is precipitated from its acid solutions both by iron and zinc. The *lead tree* (or *arbor saturni*) * exhibits a beautiful arborescent crystalization of pure metallic lead, precipitated by means of zinc. A small lump of clean zinc (Fig. 101,) is suspended by a thread from the stopper of a transparent glass bottle, containing an ounce of the acetate of lead (sugar of lead,) dissolved in a pint and a half of water. The lead is gradually precipitated upon the zinc, shooting forth into brilliant crystalline branches. The tree will continue to increase during several days, if the solution be suffered to stand undisturbed, and forms a beautiful and scientific ornament for a mantel piece. The precipitation of the lead, is at first, a chemical phenomenon. The zinc attracts the acetic acid from the solution of acetate of lead, and the lead is set free. The precipitation of the lead upon the zinc is supposed to be caused by galvanic influence. The two metals represent the two poles of the voltaic apparatus, and as the presence of diluted acid develops electrical agencies, a mutual attraction between the metals ensues.

624. *Copper*.—*Equiv.* 64. This is said to have been discovered in the isle of Cyprus and dedicated in heathen mythology, to the worship of Venus; hence the alchemists termed this metal, Venus. The Latin name, copper or *cuprum*, is derived from Cyprus. The implements of war, and domestic utensils of the ancients were mostly made of bronze, or some other alloy of copper and tin.

Copper is found pure in native masses and crystals, it is the only metal, except titanium, which is of a red color; it is very malleable, ductile, and elastic, and is the most sonorous of the metals. When rubbed, it emits a peculiar, nauseous odor. The pure metal and its compounds are all poisonous. It fuses at a white heat, and if the heat is urged further, it volatilizes in visible fumes. On cooling slowly, it crystalizes in quadrangular pyramids. Copper filings thrown into a strong fire, burn with a green flame. It does not strike fire with flints, and is therefore used for the nails, hammers and other implements used in the manufacture of gunpowder. But when exposed to the compound blow-pipe it burns with a green flame, and light too intense for the eye. On account of the color of its flame the salts of copper are sometimes used in artificial fire-works.

Copper is little changed by a dry atmosphere; but when exposed to air and moisture, it becomes thinly coated with a green sub-carbonate. As this metal is poisonous, culinary vessels of copper should never be used except when perfectly clean, or well tinned. When heated to redness, copper oxidizes, and becomes covered with brown scales.

625. The *red protoxide* of copper may be obtained by igniting

* Tree of Saturn.

624. Origin of the name copper. This metal known to the ancients. How found in nature? Color and other properties of copper. Action with heat. Why copper nails and hammers used in operations connected with the manufacture of gun powder. Combustion of copper. Color of the flame. Formation of sub-carbonate of copper. Copper vessels for culinary purposes. Oxidation of copper.

625. Protoxide of copper. How obtained?

in a close vessels 64 parts metallic copper with 80 parts of the peroxide, the metal takes from the peroxide 1 portion of oxygen, and the latter is thus reduced to the protoxide, of which, as 64 added to $80 = 144$, there are 144 parts.

626. The protoxide of copper is dissolved by some of the acids, as also by ammonia; in solution with the latter it is colorless: but, on exposure to the air, it becomes blue, owing to the formation of the peroxide. The salts of the protoxide rapidly absorb oxygen from the air, and become per-salts; that is, the base of the salt changes from the protoxide to the peroxide, and the salt is, in consequence, changed from a *proto-salt* to a *per-salt*. The protoxide exists in nature; beautiful crystals of it are found in the mines of Cornwall, and in Connecticut and New Jersey.

627. *Peroxide*, or black oxide of copper, is formed by exposing the metal, for some time, to red heat, in the open air. The peroxide of copper is insoluble in water: it does not give the alkaline test with blue vegetable color, but unites acids to form salts; these salts are either green or blue. With ammonia, it forms a deep blue solution, a property which is peculiar to the peroxide of copper, and which affords a valuable test. It is precipitated of a yellowish white color, by albumen, so that the white of eggs, and other substances containing albumen, are an antidote to the poison of this salt of copper.

628. The *proto-chloride* of copper may be prepared by heating copper filings with twice their weight of per-chloride of mercury, (corrosive sublimate.) The *perchloride* may be obtained by digesting the proto-chloride in muriatic acid, and exposing the permuriate of copper, which is thus formed to a temperature of about 400° F. It is deliquescent in the open air, and becomes again the permuriate, by absorbing moisture, thus changing from white to green.

Sulphuret of copper is a constituent of variegated copper ore. It may be prepared by fusing copper and sulphur together.

Bi-sulphuret is of a yellow color, and more common as a native production, than the sulphuret. It exists in *copper pyrites* combined with proto-sulphuret of iron.

The *alloys* of copper are numerous; that with *zinc*, forming *brass** is perhaps the most important. With *tin*, copper forms bronze, cannon-metal, bell-metal, and coating for the interior of copper vessels, and metallic mirrors. With gold or silver, it

* The manufacture of brass has been practised from remote ages. The ancients confounded copper, brass, and bronze. Brass was, in their view, only a more valuable kind of copper, and they often used the word *æs*, to denote either.

626. Action of the acids and ammonia on the protoxide of copper. Salts. Existence in nature.

627. Peroxide of copper. Properties. Action with ammonia. With potassa and albumen.

628. Chlorides of copper. Proto-chloride. Per-chloride. Sulphuret. Bi-sulphuret. Alloys. Metals which precipitate copper from its solutions Verditer, &c. Native copper. Copper of commerce.

forms coin, and gold and silver ornaments. Zinc, tin, and especially iron, precipitate copper from its solutions.

Exp. Immerse the blade of a knife in a solution of copper, and it will be instantly covered with the metal. The blue paint, *verditer*, is the *hydrate of copper* with a little lime. Native copper exists in various parts of the United States. According to Silliman, it has been found near New Haven, Connecticut, and near lake Superior, and other localities in that region. The copper of commerce is usually obtained from the sulphurets.

629. *Bismuth*.—*Equiv.* 72. The name is supposed to be a corruption of the German *weissmuth*, or white mother of silver. It was formerly called *glazed tin*. It is brilliant, of a yellowish-white color, and very brittle. It is very fusible. At a high heat, and in close vessels, it may be completely volatilized. When melted in the air, its surface becomes covered with a greenish brown oxide.

Oxide of bismuth may be obtained by burning bismuth in the open air, and collecting the fumes. The yellow oxide which is thus obtained, was formerly called *flowers of bismuth*.

When the *nitrate of bismuth* is mixed with water, a precipitate is formed of the sub-nitrate, known as the *pearl white*, (or *blanc de fard*,) of perfumers; from its pearly whiteness it is used as a cosmetic. It is injurious to the skin, and is also liable to assume a tawny hue, in contact with sulphuretted or phosphuretted hydrogen; thus, the effluvia from boiled eggs, and some mineral springs, and even sitting before a fire of mineral coal, may change a brilliant artificial white complexion, into a mulatto color. When the powder of bismuth is heated with chlorine gas, a pale blue light appears, and a white *chloride of bismuth* is formed, which from its oily appearance, was formerly called *butter of bismuth*.

Bismuth is found in the earth in the form of pure ore, of an oxide, a sulphuret, and an arseniate. The only known American locality of native bismuth, is at Munroe, Connecticut.

630. *Mercury*.—*Equiv.* 200. The common name is *quick-silver*. The alchemists named it from the planet mercury. They imagined that by solidifying, it would form silver. The Latin name, *hydrargyrum*, (from the Greek *udor*, water, and *argenon*, silver,) denotes that it was supposed to be liquid silver. Boerhaave is said to have held it in digestion twelve years, in order to obtain a solid precipitate of silver. The alchemists, however, in their vain attempts to change mercury into silver, made many important preparations, which are of great use in medicine, and in the arts.

Properties. Mercury is the only metal that is fluid at the common temperature of our climate. At 40° below zero, F., a cold which sometimes prevails in the polar regions, mercury becomes solid, and forms octahedral crystals. It can also be

629. Origin of the name bismuth. Properties. Oxide of bismuth. Pearl-white, &c. Localities.

630. Origin of the name mercury. Opinion of the Alchemists, &c. Properties. Effect of temperature, &c. From what obtained, &c.

congealed by artificial means. In a solid state, it is malleable, and may be cut with a knife; applied to the skin, it produces a sensation no less painful than that of red hot iron. If a small quantity of solidified mercury be thrown into a glass of water, it melts, while the water is frozen by the loss of its latent heat, and the glass is shivered to pieces. Mercury is white and brilliant, like polished silver. The clean surface of a vessel of mercury, is a most perfect and splendid mirror. Its principal ore is the sulphuret or *cinnabar* from which it is separated by the action of heat upon quick-lime and iron filings. The presence of mercury in ores, may be easily ascertained, as it volatilizes before the blow-pipe.

631. On account of the great weight of this metal, it affords the most perfect means of demonstrating the statistical and moving force of fluids and caloric, is essential in the construction of the barometer, and forms the most useful thermometer. The mercurial cistern for collecting gases, is necessary in many chemical experiments.

The specific gravity of mercury at 47° F., is 13.568. It contracts in congealing, so that its specific gravity is increased to 15.612; thus, frozen mercury sinks in the fluid metal. The boiling point of mercury seems to be about 650°, or a little more than three times the heat of boiling water. Its vapor condenses on cool surfaces, in minute metallic globules. The usual method of purifying mercury, is by distillation. Its vapor is very expansive, having a specific gravity of 6.97, air being considered as unity, or 1. If mercury be heated in strong iron vessels, closely covered, the force of its expansion will burst the vessels. Mr. Faraday proved that mercury volatilizes slightly, without the application of heat. By exposing gold leaf for some time over a vessel of mercury, he found the gold leaf whitened.

632. Mercury, at the common temperature, is not tarnished by atmospheric air or oxygen gas; but at a boiling heat, it gradually becomes a red oxide. Sulphuric and nitrous acids, act upon mercury. The former has no action upon it in the cold; but on the application of heat, the mercury absorbs a portion of oxygen from the acid, sulphurous acid is disengaged, and a sulphate of mercury formed. Nitric acid, without the aid of heat, oxidizes and dissolves mercury, with a disengagement of the deutoxide of nitrogen.

*Oxides of mercury were formerly called mercurial calcs.**

Protoxide, or black oxide of mercury, is formed when mercury

* Metallic calcs, (from *calx*,) were metals which had undergone the process of calcination or combustion, or some equivalent operation.

631. Uses of mercury. Specific gravity. Boiling point. Vapor of mercury. Volatilization of mercury without heat.

632. Oxidation of mercury. Oxides of mercury. Protoxide. Peroxide. *Exp.* Thenard's theory of this process. Decomposition of the peroxide by heat.

is violently agitated, for a long time, in contact with the atmosphere.

Peroxide, or red oxide may be obtained by exposing the metal to heat in the open air.

Exp. The peroxide of mercury may also be obtained by the following process. Mercury is dissolved in nitric acid, and the nitrate so formed is exposed to heat, red fumes are given off, and the peroxide of a beautiful red color appears. The theory of this change, is thus explained by Thenard.* The nitrate of mercury used in this process, is a mixture of the nitrates of protoxide and deutoxide, (peroxide,) of mercury; when exposed to nearly red heat, the nitric acid changes to oxygen, and nitrous acid gas; the latter, not being retained by the oxide of mercury, is disengaged in the form of red fumes; the oxide, now changed by another proportion of oxygen to the deutoxide (or peroxide,) of mercury, remains in the form of deep red scales, called *red precipitate*. When heat will disengage no more nitrous acid, (which acid is easily known by its color and peculiar odor,) the operation is completed, and the peroxide is to be preserved in closely stopped bottles. When heated to redness, it is converted into metallic mercury and oxygen, in the proportion of 16 parts of the latter, to 200 of the former. The peroxide is much employed in medicine.

633. *Proto-chloride* of mercury, *calomel*, was formerly, called *white precipitate of mercury*. It may be formed by bringing mercury in contact with chlorine gas, at common temperatures; also by adding a solution of common salt to a solution of mercury in nitric acid. A white heavy powder is precipitated, which is tasteless, and insoluble in water, and sublimes by heat, without decomposing.

Bichloride or *perchloride* or *corrosive sublimate* may be obtained by heating mercury in chlorine gas, during which process the metal burns with a pale red flame. In constitution, it differs from calomel only, in 1 additional equivalent of oxygen; but its properties are widely different. Its taste is highly acrid and burning; it is corrosive to animal substances, and a strong poison. The best antidote is albumen.

Exp. Place a drop of the suspected liquid on polished gold, and touch the moistened surface with a piece of iron wire or the point of a pen-knife, the part touched will instantly become white, owing to the formation of an amalgam of gold.

* *Traite. de chimie*, Tome II. p. 392. Most elementary writers on Chemistry, state the process for obtaining the peroxide of mercury from the nitrate, without attempting any theoretical explanation. Silliman, (Elements Vol. II. p. 314 and 315.) considers "the nitrate as a compound of peroxide and per-nitrate." This he says is decomposed by heat, till all the fumes cease, and then (page 307) "the oxide will become of a beautiful red color." He does not state the nature of the decomposition which takes place; nor how, by means of it, the whole remaining mass is brought to the state of a peroxide.

633. Protochloride. Perchloride. How obtained. Difference in the constitution of corrosive sublimate and calomel. Properties of corrosive sublimate. *Exp.*

Some animal and vegetable solutions convert the bichloride into the protochloride (that is change the *corrosive sublimate* to *calomel*) as the albumen of eggs with water. "The caustic nature of corrosive sublimate seems owing to its action on animal muscles and membranes."—Turner. Nitrate of silver produces with it a *white* precipitate, chloride of silver and alkalies a *yellow* precipitate, and hydrochloric acid a *black* sulphuret of mercury.

634. *Bicyanuret* sometimes called the *cyanide*, *cyanuret*, or *prussiate of mercury* is obtained by boiling red oxide of mercury, with twice its weight of prussian blue in solution, until the blue color of the latter disappears. The colorless solution of the bi-cyanuret of mercury which is formed, crystallizes in four sided prisms, when carefully evaporated. *Theory*. Prussian blue is the *hydro-ferro-cyanate* of iron. The oxygen of the oxide of mercury unites with the iron and hydrogen of the ferro cyanic acid; while the metallic mercury, and cyanogen, being both disengaged, enter into combination. The peroxide of iron remains in the form of a brown, insoluble mass. It has a disagreeable, metallic taste, and is very poisonous. When heated with sulphur, 1 part of the cyanogen is disengaged, and sulpho-cyanuret of mercury formed.

635. The *proto-sulphurets of mercury*, formerly called *Ethiop's mineral*, may be prepared by adding to melted sulphur, its own weight of mercury. The *bi-sulphuret*, is the *cinnabar*, or *vermilion* of commerce.

It is very valuable in the arts as a paint. It is found in nature, and by its decomposition, affords most of the mercury of commerce. By mixing with iron filings, and heating the mixture, the sulphur passes to the iron, and the mercury is obtained by sublimation. Native cinnabar is usually found in secondary geological formations.

636. *Alloys* of mercury with other metals, are called *amalgams*. The affinities of metals for mercury differ. Some, as gold, silver, and tin, form amalgams with mercury, by mere contact; but in most cases, the fusion of the metal is necessary. Heat decomposes amalgams by volatilizing the mercury. The amalgam of tin and mercury, is fluid at a low heat, which facilitates its use as a coating for glass, to form mirrors. This process is called *silvering*.

Exp. Pour mercury upon a sheet of tin-foil, press it with a weight for a few hours, and the amalgam will be found adhering to the glass from the force of attraction. Articles of gold and silver, when exposed to mercury, lose their peculiar lustre and become tarnished.*

* Some years since the author was invited by Prof. Silliman, to visit the extensive laboratory of Yale College. Being then unacquainted with the amalgamating nature of mercury, and encouraged by the Professor's example, she was about to thrust her hand into the metallic liquid of the large mercurial cistern, when he exclaimed, "take care of your rings," and thus saved her from the chagrin of seeing her gold rings turned to a pewter-color.

634. Bicyanuret of mercury. Synonymes. How obtained? Theory of the process.

635. Sulphurets of mercury.

636. Alloys of mercury. Amalgams. Silvering. Exp.

CHAPTER XXVII.

FOURTH CLASS OF METALS CONTINUED.

637. *Silver*.—*Equiv.* 110. The alchemists called this metal Diana or Luna, (the moon,) on account of its white lustre. Thus, the nitrate of silver is called *lunar* caustic. From the Latin name *argentum*, the term *argentine* is often applied to compounds of silver. Silver is of a brilliant white color, more malleable and ductile than any metal except gold. It may be extended into leaves less than $\frac{1}{10000}$ of an inch in thickness, and drawn into wire finer than a human hair. Its specific gravity is 10.39. It may be volatilized by a very strong heat continued for some time. Neither air nor moisture oxidize silver; when exposed to the action of voltaic currents, it burns with a beautiful light-green flame, and combining with oxygen, forms the oxide of silver. The silver of commerce always contains a small alloy of copper, in which state it is wrought by the silversmith. Silver is used as one of the precious metals, and for various useful and ornamental purposes.

638. Though silver is not easily affected by oxygen, it tarnishes in contact with sulphur and sulphurous compounds. Hence the dark color imparted to silver spoons by boiled eggs, the whites of which contain some sulphur. Nitric and sulphuric acids, oxidate this metal, forming with it lunar caustic, nitrate of silver, and sulphate of silver.

639. Silver is often found pure, in a native state, frequently sulphuretted, often alloyed with other metals, such as gold, antimony, and sometimes blended with sulphuret of lead, and copper pyrites. In Mexico and some other countries, it only needs melting to obtain it pure. Silver is extracted from lead ores by *cupellation*, and from ores where lead is not present, by *amalgamation*. There is some silver in the lead ores found in various parts of the United States; but no silver mines have yet been discovered. The Andes of South America, and the Cordilleras of Mexico are very rich in native metallic silver.

640. *Oxide of Silver* may be obtained by precipitating a solution of the nitrate of silver by potassa or soda. It is of an olive green color, and insoluble in water. When heated to redness, the oxygen is exploded, and the metal revived. There

637. Names of silver and its combinations. Precious metals. Properties of silver. Combustion of silver by means of galvanism. Silver of commerce. Uses.

638. Action of sulphur upon silver. Action of nitric and sulphuric acids.

639. Silver as existing in nature, and native combinations. Extraction of silver from ores. Localities of metallic silver.

640. Oxide of silver. *Exp.* 1. *Exp.* 2d.

is but one oxide of silver composed of one equivalent of silver and one of oxygen, and therefore considered the *protoxide* of silver. Silver, when in solution with nitric, or sulphuric acid, is precipitated in the metallic state by copper and mercury; it then assumes an arborescent appearance, called the silver tree or *arbor Dianæ*.

Exp. 1. Put a globule of silver into a white glass vessel with a dilute solution of lunar caustic, (nitrate of silver); let it stand undisturbed a few days, and a beautiful *silver tree* will appear.

Exp. 2d. Immerse a bright copper cent or wire in a solution of the nitrate of silver, it will be covered with white crystals.

641. *Fulminating Silver*, or *ammoniuret of Silver*, is a very dangerous preparation, exploding by blood heat, or by the slightest touch. It is formed by adding strong liquid ammonia to oxide of silver. The phenomenon of detonation, is ascribed to the action of the oxygen upon the hydrogen of the ammonia, forming steam, which is suddenly exploded, along with the nitrogen and metallic silver.

The *detonating silver* first prepared by M. Descotils is made by dissolving silver in a small quantity of nitric acid, and heating the solution with an equal bulk of alcohol; on cooling, a crystalline powder falls, which must be washed, and dried on blotting paper. M. Liebig and Gay Lussac consider the *fulminating* and *detonating* compounds, to be composed of the oxides of the metals and a peculiar acid, which they call fulminic acid, and that they are therefore salts. "The great explosive powers of these compounds," says Silliman, "probably depend upon the mutual re-action of the *elements* producing aeriform bodies, which are suddenly evolved, and their evolution is not probably connected with electrical agency."*

642. *Chloride of Silver* is produced when silver is heated in chlorine gas, and may also be prepared by mixing hydrochloric acid with a solution of nitrate of silver. It is at first white, but becomes black when exposed to the sun's rays, disengaging hydrochloric acid and forming oxide of silver. The chloride of silver when found native is called horn silver. A mixture of this chloride with chalk and pearlash is employed for silvering brass; such as thermometer scales, clock dials, &c.

643. Silver forms *alloys* with all the metals except nickel. Silver coin is composed of about $\frac{1}{10}$ part of copper. Silver vessels and ornaments are fashioned by hammering, as silver does not cast well. *Silver plate* has a large alloy of copper.

* Silliman's Ele. Vol. II. p. 339. Professor Silliman, who was seriously injured in making one of these preparations, suggests that great caution should be used with respect to them; and remarks that "the little fire crackers or torpedoes are very improperly made subjects of amusement among boys. A twisted paper contains the fulminating silver mixed with sand to produce attrition, and to disguise the powder, and a lead shot to give it momentum, when it is thrown; still, to a person unacquainted with the subject, the paper presents nothing to the eye but a shot and some sand, with some minute white *flocculi*, which might well escape the eye of a common observer."

641. Fulminating silver. Detonating silver of Descotils. Opinions of Liebig and Gay Lussac and Prof. Silliman.

642. Chloride of silver.

643. Alloys of silver. Silver coin, vessels, &c. Silver plating.

644. *Gold*.—*Equiv.* 200. Latin, *Aurum*; French, *or*; called by the alchemists *sol*, the sun, or king of metals. It has been known from the most remote periods. The Peruvians and Mexicans, when first visited by the Spaniards, were acquainted with gold and silver, though ignorant of iron and its uses. Its physical properties had been long known, before its chemical relations were thought of; the latter were developed in some degree, by the labors of the alchemists. Gold is distinguished from all the other metals by its yellow color. It exceeds them all, in ductility and malleability.

It has been computed that 14,000,000 films of gold, like the coating of fine gold wire, would not exceed one inch in thickness, while the same number of sheets of common fine writing paper would form a thickness, of about $\frac{3}{4}$ of a mile. The specific gravity of gold is a little over 19. It is the heaviest of the metals except platinum. It is more fusible than silver, being fused by the common blowpipe, when it is of a dark green color. It may be volatilized by the heat of a current of oxygen gas, directed upon burning charcoal; if a plate of silver be held over the vapor, it will become gilded.

645. The only solvents of gold are *aqua regia*, nitrohydrochloric acid, and liquid chlorine. According to Sir H. Davy, hydrogen of the hydrochloric acid leaves the chlorine and forms water with a portion of the oxygen of the nitric acid, reducing it to nitrous acid. The liberated chlorine, then acts upon, and dissolves the gold, forming with it a chloride of gold.

646. The *peroxide* of gold unites more readily with alkalies than with acids: and is, therefore, by some considered an acid, called *auric acid*, and its salts, *aurates*.

In this case, gold should be transferred to our 1st class of metals, or those which form acids with oxygen. But most chemists consider this compound as a *tritoxide*, consisting of three atoms of oxygen, 24, to one of gold, 200, making its equivalent 224. It is obtained by boiling a solution of the chloride of gold with magnesia; the oxide remains in the state of a yellow hydrate. It is rendered anhydrous by boiling, and then assumes the characteristic brown color of the peroxide. It is insoluble in water, combines readily with alkalies, but unites sparingly with acids. A powerful electric discharge through gold leaf or wire laid between papers, gives rise to a purple substance which has been called the *purple oxide of gold*. This purple oxide is considered by some a *deutoxide*, and by others to be merely gold in a state of minute sub-division.

647. *Chlorides of Gold*. Gold leaf introduced into chlorine gas, takes fire and burns; and if it be suspended in water into which the gas is passed, it is dissolved, and the solution may be concentrated by evaporation. This is probably the *perchloride*. By exposure to a moderate heat, it parts with two thirds

644. Synonymes of gold. This metal early known. Properties.

645. Solvents of gold. Theory.

646. Oxides of gold.

647. Chlorides of gold.

of its chlorine, and is converted into a yellow insoluble *protochloride*.

648. The *perchloride* was formerly called *muriate of gold*. The saturated solution of gold in nitro-hydrochloric acid yields crystals of a deep orange color which rapidly attract moisture from the air. Heat expels the chlorine, and the gold remains as a spongy mass. The action of solar light is sufficient to reduce this chloride, and the glass which contains it, when it is thus exposed, will become lined with a brilliant coat of the revived gold. The solution of perchloride of gold is often used in the arts, for gilding by the agency of substances which, having a strong attraction for oxygen absorb it from the water of the solution, leaving the hydrogen to form hydro-chloric acid with the chlorine, and thus precipitating the gold. Mrs. Fulhame gilded ribbons by moistening them with a solution of *muriate of gold* by means of a camels hair pencil, and holding them over hydrogen gas as it was evolved.

649. The *protochloride of tin*, precipitates the perchloride of gold a beautiful, purple color forming what was formerly called *precipitate of cassius*, and *stannate of gold*. It is this compound which gives to glass and porcelain a rich pink-color. When potassa is added to the solution of perchloride of gold, part of the gold, uniting with the oxygen of the potash, is precipitated in the state of an oxide, while the remaining portion of the gold and the whole of the chlorine combining with potassium, form a *double chloride of gold and potassium*.

Liquid ammonia forms, with the solution of gold, a brownish precipitate called *fulminating gold*.

Exp. If ether be poured into a solution of perchloride of gold, it unites with the metal, and an ethereal solution of gold floats on the surface of the hydro-chloric acid. This was anciently called *auriferous ether*. It is sometimes used for gilding delicate steel instruments.

650. Gold may be combined with iodine, bromine, sulphur and phosphorus. Sulphur does not act on gold as readily as upon silver; the *sulphuret of gold* is formed by passing a current of sulphuretted hydrogen through a solution of chloride or *muriate of gold*.

651. Gold forms *alloys* with many of the metals. *Antimony* and *zinc* destroy its ductility. *Bismuth* produces with it a brittle, pale, yellowish green alloy. *Tin*, or *bismuth* render it spongy, and diminish its specific gravity. The fumes of *lead* give to gold externally a pale yellow, and internally a brown color, and render it very brittle. When united with *iron*, gold becomes magnetic, and harder than steel. *Copper* is united to gold in coin, usually in the proportion of $\frac{1}{12}$. *Nickel* in a certain proportion, forms with gold an alloy resembling brass. *Mercury* readily unites with gold. A gold ring becomes white by mere contact with mercury. This amalgam may be destroyed by exposing it to heat; the mercury volatilizes, and the gold remains unchanged. *Silver* gives to gold a paler color; and, in a cer-

648. Perchloride of gold.

649. Precipitate of perchloride of gold with the protochloride of tin. Precipitate with potassa, &c. Precipitate with liquid ammonia. *Exp.*

650. Combination of gold with iodine, bromine, &c. Sulphuret of gold.

651. Alloys of gold. Carats of gold.

tain proportion, produces with it the green alloy of the gold smith.

The *fineness of gold* is expressed by the number of parts of gold which it contains. It is supposed to consist of 24 parts called *carats*. Thus 24 carats *fine*, is pure, unalloyed gold. If it has 8 parts of alloy, it is said to be 16 carats fine. The native gold of North Carolina is 23 carats fine.

652. Gold is never found in combinations with earthy and siliceous minerals; but exists either in a pure metallic state, or alloyed with other metals. It is sometimes found crystalized in cubes or octahedrals united in little groups, but more commonly in thin scales, spangles or dust. It is found in primitive mountains, and in the sand in the beds of rivers, of alluvial formations, having been washed down from the mountainous regions. It occurs in veins of lead, and silver, and with iron pyrites. The most extensive gold mines, are those of Mexico, Peru, Transylvania, and Hungary. Gold is found in the sands of Brazil, mingled with platinum and diamond. A rich and extensive region of gold exists in the United States; it was discovered in North Carolina, but it has been traced north to Virginia, and south to Alabama and Georgia.

653. Gold may be purified from mixture with the baser metals, by melting it with nitre, and by cupellation with lead; also by dissolving in nitrohydrochloric acid, filtering the solution, and adding proto-sulphate of iron, which precipitates all the gold in the metallic state, leaving the other metals in solution. Gold is separated from silver with greater difficulty than from any other metal; but when an alloy of gold and silver is dissolved in nitrohydrochloric acid, the silver is found in the form of a white, insoluble chloride, and the gold in solution.

654. *Platinum*.—*Equiv.* 96. Was first discovered by the Spaniards, near the river La Plata* in South America. It was first carried to Europe in 1741, by Mr. Wood, an assayer-master at Jamaica, though it had been previously described by Don Ulloa, who accompanied some French academicians to Peru in 1735.

Properties. Platinum is the heaviest of all known substances. Its specific gravity is somewhat over 20. It has a silvery whiteness, is very ductile and malleable, and so soft that it may be cut with scissors, or scratched with the nails. It is infusible by ordinary means, and does not oxidize with the most intense heat of the furnace.

Thus crucibles which are to be exposed to intense heat are made of platinum. It is also a less perfect conductor of caloric than most of the metals, and on this account, and its infusibility, is used for spoons and tongs

* The word *plata* signifies silver.

652. Gold, as found in nature. Geological localities of gold. Geographical localities. Gold mines in the United States.

653. Modes of purifying gold.

654. Discovery of platinum. Origin of the name. Properties. Uses.

for holding substances exposed to the action of the blow-pipe. Thin leaves of platinum, are used for wrapping substances that are to be exposed to great heat. The scarcity of this metal, which renders it nearly as expensive as gold, prevents its being generally used, except for a few chemical, and scientific purposes.

655. Like iron, platinum admits of being *welded* at a high temperature; at a white heat, an imperfect fusion takes place, which covers its surface with a kind of varnish, so that when different pieces are brought together in this state, they may be forged with a hammer, and thus be made to combine permanently. A piece of platinum-wire melts when exposed in the focus of the compound blow-pipe like wax in a common lamp; it scintillates, drops in melted globules, and a portion rises in vapor. It is fused by powerful lenses, and by concave mirrors. It fuses also with fluxes, as borax, and glass, and if kept completely enveloped in charcoal, it may be melted in that substance. Its only solvents are chlorine, and nitro hydrochloric acid.

656. The *protoxide of platinum* is prepared by digesting protochloride of platinum, in a solution of pure potassa. The precipitate is found to consist of 96, or one equivalent of metal, and 8, or one equivalent of oxygen. The equivalent, therefore, of the protoxide of platinum, is 96 Pla. added to 8 ox. = 104. This result is obtained by expelling the oxygen with heat, collecting and weighing it, and then weighing the pure metal which remains. This proves also that 96 is the combining equivalent of platinum.

The *peroxide* is found on decomposition, to yield 16 parts, or 2 equivalents of oxygen, to 96 parts, or one equivalent of metal. The protoxide is black, the peroxide is of a brownish yellow color, when in the state of a hydrate; but on becoming anhydrous by drying it is black. The peroxide is obtained with difficulty; for on attempting to precipitate it from the muriate by means of an alkali, it either falls as a sub-salt, or is held together in solution. Like peroxide of gold, it is a very feeble base, and is much disposed to unite with alkalies.—*Turner*.

657. *Chloride of Platinum*. Platinum does not take fire when introduced in thin leaves into chlorine gas, but a slow combustion of the two substances takes place, forming a *chloride*. When platinum dissolves in nitrohydrochloric acid, a chloride is formed. This is the *perchloride*; it is soluble in water, and decomposes with light. When heated, it gives up a portion of chloride, and becomes the *protochloride*.

When a solution of hydrochlorate of ammonia is added to the perchloride of platinum, a light yellow precipitate is formed,

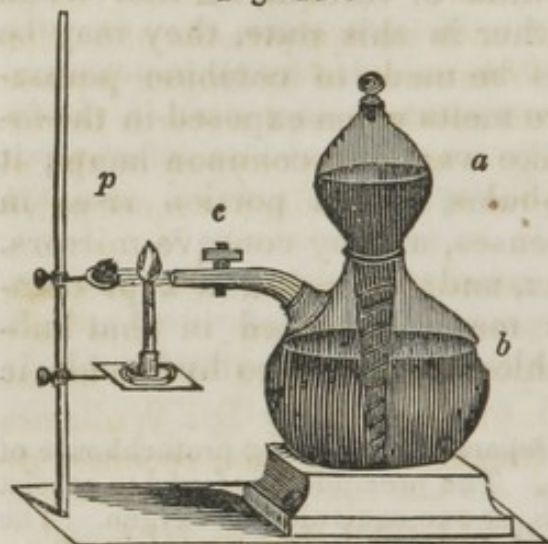
655. Welding of this metal. Fusion of platinum by the compound blow-pipe, &c.

656. Protoxide. Peroxide.

657. Modes in which the chloride of platinum may be formed. Per-chloride. Protochloride. Double hydrochlorate of platinum and ammonia. Spongy platinum. Prof. Dobereiner's invention. Theories to account for the action of hydrogen on platinum sponge. Fulminating platinum. Combinations of platinum with phosphorus, &c.

commonly a double hydrochlorate of *platinum* and *ammonia*. When heating this to redness chlorine and hydrochlorate of ammonia are evolved, and pure metallic platinum remains in a *spongy* mass, called *spongy platinum*, remarkable for its power of igniting a mixture of oxygen and hydrogen gases, and also the vapor of ether and alcohol.

Fig. 102.



tight. Hydrogen gas is now evolved by the action of the zinc upon the water of the sulphuric acid, and by its pressure, forces part of the liquid into the upper vessel through its tube. On opening the stop-cock, *c*, the gas issues forth in a jet, which inflames the spongy platinum contained in a brass cup at *p*; the platinum ignites the stream of hydrogen, and the latter lights the taper which is situated between *p* and *c*, or in the current of burning hydrogen. A candle or taper applied to the jet, may be lighted at any moment, by turning the stop-cock to allow the hydrogen gas to escape.

It has been suggested that the minutely divided spongy platinum, by absorbing a large portion of hydrogen in its pores, generates heat, which the oxygen of the air kindles into flame. Another theory supposes that the sudden ignition of the hydrogen, arises from a galvanic action taking place between that and the platinum; the hydrogen acting the part of the zinc plate.

Fulminating platinum is formed by decomposing sulphate of platinum by excess of ammonia. One grain heated to 400° Fahrenheit, explodes with a flash, and a report louder than that of a pistol.

Platinum unites with *phosphorus* and *sulphur* in two proportions; and is capable of combining with most of the metals.

658. The ore of platinum is found in nature, combined with four recently discovered minerals, viz: *iridium*, *rhodium*, *palladium*, and *osmium*, and also iron and chromium. It is usually seen in flat grains, seldom in pieces so large as an ounce weight. It has been found most abundantly in South America and in Siberia, where it exists in auriferous (or gold bearing) sands, near the Uralian mountains. The four recently discovered metals found in connection with platinum, are yet little known; and have been

procured, but in small quantities. When platinum ore is digested in nitro-hydrochloric acid, the platinum, together with the palladium, rhodium, iron, copper, and lead, is dissolved; while a black powder, consisting of osmium, and iridium, remains. These various metals are separated and purified by very difficult and complicated processes.

659. *Palladium*, is of a silver color. Vauquelin observed that under the gas blow-pipe it burnt with an appearance of brilliant *coronas*, or *aigrettes* of flame. When a jet of hydrogen is passed upon spongy palladium, the metal reddens, and water is formed, by the combination of the hydrogen with the oxygen of the air. Palladium is acted upon by several of the acids, but most powerfully by the nitro-hydrochloric.

The *oxide of palladium* forms with potassa beautiful red salts. Berzelius discovered two *chlorides* of palladium. This metal also has been combined with sulphur, and several other metals. Palladium was first introduced into England by Dr. Wollaston, in 1803; and named after the planet Pallas, then recently discovered.

660. *Rhodium*. Dr. Wollaston obtained this metal from platinum ore, during the period in which he was making observations upon palladium. Vauquelin and Berzelius have since examined it. It is named from the Greek *rodon*, a rose, on account of the rose color of its chloride.

661. Thomson states that there are two *oxides* of rhodium; the black *protoxide*, and the yellow *peroxide*. According to Berzelius, there are two *chlorides*, the one yellow, and the other red; they are formed by passing chlorine gas over the metal.

662. *Iridium*. The name of this metal, is from *iris*, the rainbow so called on account of the changeable hue of its salts. It was discovered by M. Descotils, in 1803. On digesting platinum ore with nitro-hydrochloric acid, a portion, in the form of a black powder, remains undissolved; this consists of a mixture of iridium, and another metal, called *osmium*. Iridium is very infusible. It was melted by Mr. Children's powerful galvanic battery, and appeared as a brilliant, porous, metallic mass, whose specific gravity was 18.06. It is remarkable for its hardness, and for its power of resisting the action of acids; on account of which properties, it is used for the points of metallic pens, as other metals soon become corroded by the gallic acid contained

659. Properties of palladium. Spongy palladium. Oxide. Chlorides, &c. Introduction into England. Name.

660. Rhodium.

661. Oxides of Rhodium.

662. Derivation of the name iridium. Discovery. Found in platinum ore. How fused? Properties, &c.

in ink, and the pens are thus rendered unfit for use. The peculiar hardness of platinum is supposed to be caused by the presence of iridium. According to Berzelius, solutions of iridium may, without the aid of any foreign substance, be obtained of all the hues of the rainbow.

663. *Osmium*. The name from the Greek *osme*, odor, was given on account of the strong odor of one of its oxides, resembling that of chlorine. Berzelius, by passing the oxide of osmium, mixed with hydrogen gas, through a heated glass tube, obtained a compact precipitate of osmium, having a metallic lustre. When heated in the open air, it oxidizes, and dissipates in vapor. Berzelius states that there are at least, three oxides of osmium, containing 1, 2, and 4 equivalents of oxygen. He considers the oxide which emits the strong odor, as the deutoxide.

Osmium heated with chlorine, forms a *chloride*, of a beautiful blue color; if heated with an excess of chlorine, a red *perchloride* sublimes. It unites with sulphur, and forms ductile alloys with gold and silver. This metal in solution, when tested with nut-galls, becomes first purple, and then blue; with ammonia, it changes to a yellow color.

664. *Latanium*, is a newly discovered metal prepared by Mozandes, from the nitrate of latanium.

665. CLASSIFICATION OF METALS.

CLASS I.

Metals which form acids with oxygen.

	Equiv.
Arsenic.	38
Antimony.	44
Columbium.	144
Titanium.	
Chromium.	32
Molybdenum.	48
Tellurium.	32
Tungsten.	96
Vanadium.	
Uranium.	208
Manganese.	28
Cobalt.	26
Tin.	58

CLASS II.

Metals whose oxides are fixed alkalies, or alkaline earths.

ORDER I. Metals whose oxides are fixed alkalies.

	Equiv.
Potassium.	40
Sodium.	24
Lithium.	10

ORDER II. Metals whose oxides are alkaline earths.

	Equiv.
Barium.	70
Strontium.	44
Calcium.	20
Magnesium.	12

663. Origin of the name osmium. Osmium obtained in a metallic state. Its oxidation. Oxides of osmium. Chlorides, and other compounds of osmium. Tests of osmium.

664. Latanium.

665. What metals of the 1st class? 2d Class, 1st Order. 2d Class, 2d Order. 3d Class. 4th Class.

CLASS III.				
Metals whose oxides are <i>earths</i> .				
	Equiv.			
Aluminum.	10	Cadmium.		56
Zirconium.		Cerium.		50
Glucinum.		Lead.		104
Yttrium.		Copper.		64
Thorium.		Bismuth.		72
		Mercury.		200
		Silver.		110
		Gold.		200
CLASS IV.				
Metals whose oxides are neither acids, alkalis, nor <i>earths</i> .				
	Equiv.			
Iron.	28	Platinum.		96
Nickel.	26	Palladium.		56
Zink.	36	Rhodium.		44
		Iridium.		
		Osmium.		
		Latanium.		

666. We have now completed a brief examination of the metals. In an elementary course little more can be expected, than that the pupil will gain a knowledge of general principles, and become familiar with a sufficient number of applications to illustrate these, and impress them upon his memory. But such knowledge is of inestimable value. It furnishes the master-key which will enable him, hereafter, to enter into nature's laboratory and examine for himself the wonderful operations which are there going on. He has learned to avail himself of the aids which the labors of others afford him; and may consider himself as standing at that point where the greatest chemists, who have preceded him, once stood. There was a time when they, too, were beginning to learn; when observation of the power of chemistry to effect the most simple change in the elements around them caused their bosoms to dilate with emotions of delight; and the thought to spring up in their minds, "If *science* can do this, what can it not perform?" A glorious future of discovery and invention dawned upon their fancy, and they followed with untiring steps through labors and difficulties, until success and honor crowned their efforts. Let not the American student fold his arms beneath the mantle of indolence, imagining that Lavoisier and Davy, Vauquelin and Berzelius have discovered all that is to be learned in this department of human knowledge. He should rather consider, that their discoveries and inventions have put into his hands important instruments, for the development of new facts, and the discovery of new principles.

The God of Nature, who has placed no limits to man's desire of knowledge, renders also, the field of inquiry equally illimitable. One newly discovered region in science opens a pathway to many others, and thus there is, and ever must be, an infinite progression in knowledge, suited to the capacities of the immortal mind, and corresponding with the character and dignity of an infinite Creator.

SALTS.

CHAPTER XXVIII.

CRYSTALIZATION. CLASSIFICATION OF SALTS. SALTS OF THE
OXACIDS.

CRYSTALIZATION.

667. Having now examined the *elementary substances* with their union with each other, called *binary* compounds, we shall proceed to describe the *secondary* compounds formed by the union of *three or more simple bodies*. These compounds are called *salts*. As salts under certain circumstances assume crystalline forms, the subject of crystalization may properly precede the description of them.

Crystals are formed of similar particles of matter, which, according to some wonderful and unknown law of nature, arrange themselves into regular, geometrical forms. There is nothing in organic nature more admirable than that process of inorganic matter in which each particle takes its proper place, in order to form, by aggregation, that kind of figure which is peculiar to its own species of matter. The law of molecular attraction may account for the aggregation of particles, but it does not explain why, under certain circumstances they always arrange themselves in perfect symmetry; nor can any satisfactory reason be given for this phenomenon.

668. Solid bodies appear under a variety of forms. In the vegetable and animal kingdoms, figure is the result of organization. The plant bursting from the seed, puts forth roots, stem, leaves, and flowers; and the animal, exhibits its head, limbs, and peculiar features. In both, organic laws prevail, and a living principle converts inorganic matter into nourishment, assimilating it to the substance with which it incorporates. In the mineral kingdom, solids are either irregular, *amorphous** masses, in which the particles cohere without regular order, or exhibit a crystalline structure.

669. *Exp. 1st.* Dissolve crystals of alum, (a double salt of alumine and

* From the Greek *a*, destitute of and *morphe*, regular shape.

667. Substances which have been examined, compounds to be described, &c. Formation of crystals.

668. Forms of organic bodies. Forms of minerals.

669. Effects of slow and sudden evaporation. *Exp. 1st. Exp. 2d, and Exp. 3d.* Crystals with truncated angles and edges.

potash) and suffer the solution to evaporate slowly, you will have the same octahedral (eight sided) crystals as those dissolved. But if the liquid be expelled by a sudden and strong heat, you will find the salt in a shapeless mass, or in confused and irregular crystals.

Exp. 2d. Plunge a lump of alum into a tumbler of cold water, let it remain undisturbed a few days and you will find the surface of the salt eaten, and carved out into a variety of regular forms. (See fig. 103.)

Exp. 3d. Let a few drops of a solution of alum, be put upon a glass plate; in a few days, the particles of alum when examined with a microscope, will be found to have arranged themselves in small *octahedra* (eight sided figures,) (see fig. 104.) Crystals are liable to certain modifications; thus in octahedral figures we may find some whose angles are *truncated*, or appear as if they were cut off or replaced by secondary surfaces; sometimes the edges are also similarly modified; at A, (fig. 105,) *angles* only of the octahedron are truncated, at B, the *edges* only, at C, both the angles and edges.

670. As the soluble salts when thus evaporated, usually assume distinct figures, crystalization gives to the chemist and mineralogist a valuable method of determining the composition and nature of different bodies. The smallest crystals obtained from a drop of solution, are equally perfect in figure as the largest ones, formed in greater quantities of the fluid; and, when viewed through a microscope, furnish evidence, equally satisfactory, of the nature, of the crystalized salt.

Fig. 103.



Fig. 104.



Fig. 105.



671. Different salts may be thus conveniently evaporated in separate small glasses, and their different crystals compared.

Exp. Take common salt, (*chloride of sodium*,) Glauber's salt, (*sulphate of soda*,) Epsom salts, (*sulphate of magnesia*,) and nitre, (*nitrate of potash*,) of each a teaspoonful, and put them into separate wine glasses with water;

670. Advantages afforded by crystalization to the chemist and mineralogist. Small crystals equally perfect in form as larger ones. Comparison of the crystals of different salts.

occasionally stir the mixture, to facilitate their solution, and when the salts are entirely dissolved, put a drop of each solution upon a clean watch glass placed in the sun. As the liquid evaporates, crystals peculiar to each kind of salt, may be seen with a microscope; common salt will appear in *cubes*; Glauber's salt in irregular *six sided prisms*; Epsom salts in *four sided prisms*; nitre in *six sided prisms*; (see fig. 106.) Glauber's salt and nitre, though resembling each other in the form of their crystals, exhibit a marked difference when exposed to the air; crystals of the former effloresce, that is they lose their transparency, and crumble to powder, while those of the latter are not changed by the atmosphere. Nitre is *anhydrous* salt, that is, it contains no water of crystalization.

Fig. 106.



Crystals of Epsom salts.



Crystals of common salt.



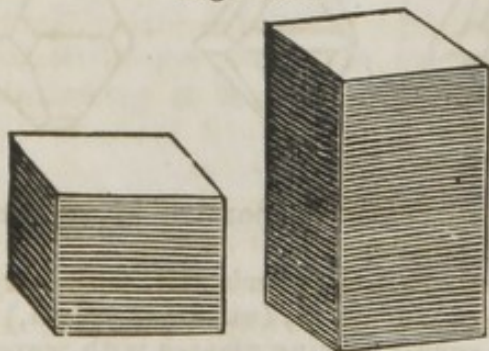
Crystals of Glauber's Salt.



Crystals of Nitre.

672. Crystals, in respect to forms, are divided into *primitive* or *fundamental* and *secondary* or *derived* forms. It is found that though the same substance, may assume different crystalline forms, these are, in general, allied to each other.

Fig. 107.



673. The most common primitive forms are the *four sided prism*, *cube*, *rhomboid*, *tetrahedron*, *octahedron*, *rhomboidal dodecahedron*, *dodecahedron with triangular faces*, and the *triangular prism*.

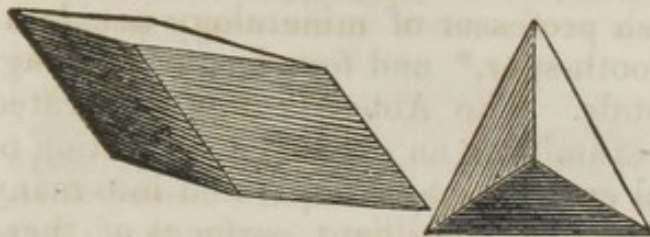
The *four sided prism*, (Fig. 107,) has its sides composed of four equal oblong parrallelograms, and its ends of two square parallelograms; it is sometimes called a square prism. The *cube* has six square equal sides.

671. Crystals of various salts.

672. Division of crystals in respect to forms.

673. Most common primitive forms. Four sided prism. Cube. Rhom-

Fig. 108.



Rhomboid.

Tetrahedron.

The *rhomboid* (Fig 108,) has its opposite sides equal and parallel, but none of these are square, each having two acute and two obtuse angles, while each side of the cube has four right angles.

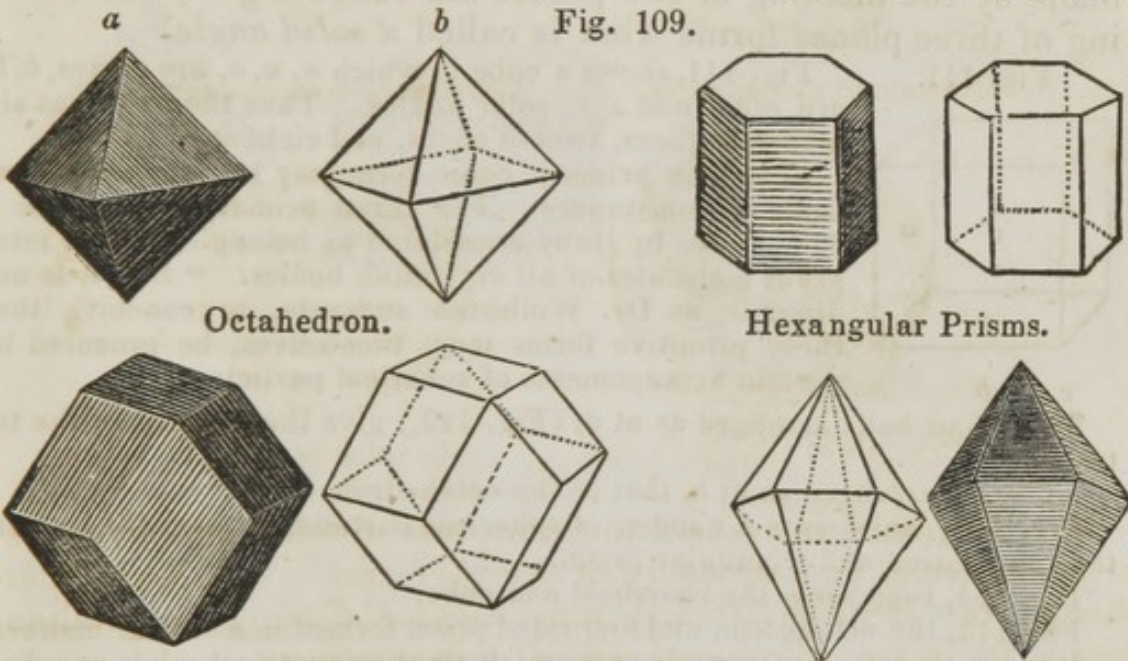
The *tetrahedron* (Fig. 108,) is included within four, equilateral triangular planes.

The *octahedron*, or eight sided figure has all its planes equal, and similar triangles. It may be considered a compound of the tetrahedron. The cut (Fig. 109,) represents a crystal of this form shaded, and the same in outline.

The *hexangular*, or six sided prism; in this, the six sides are similar parallelograms, not square, but oblong; it has six edges and six angles; that is, it is *hexahedral* and *hexagonal*.

The *rhombic dodecahedron*: has twelve sides; each plane being a rhomboid having two acute, and two obtuse angles.

The *dodecahedron with triangular faces* has twelve, equal, triangular sides,



Octahedron.

Hexangular Prisms.

Rhombic

dodecahedron.

Dodecahedron with triangular faces.

Fig. 110.



Triangular Prism.



Parallelopiped.

The primitive forms of crystals might be considered under the *three general classes*; the *triangular* or most simple prism, the *tetrahedron* or most simple solid, and the *parallelopiped*. (Fig. 110.)

674. To some one of these varieties of forms, all crystals, by mechanical division may be reduced. Discoveries in crystallography, as

boid. Tetrahedron. Octahedron. Hexangular prism. Rhombic dodecahedron. Dodecahedron with triangular faces. Triangular prism. Tetrahedron. Parallelopiped.

674. Circumstances which have led to discoveries in crystallography. The Abbe Haüy led to examine the structure of crystals. Planes, edges and angles.

in other departments of science, have been, in part, the result of accident. Gahn, a Swedish professor of mineralogy accidentally broke a piece of dog-tooth-spar,* and found it was an aggregate of rhomboidal crystals. The Abbe Haüy, a celebrated French philosopher, when examining an expensive collection of minerals, let fall a beautiful crystal, which separated into many pieces; struck with the smooth and brilliant surfaces of these fragments, the Abbe was led to an examination of the structure of crystals. He found that all crystals are easily divided in certain directions, leaving smooth and regular surfaces; that the smaller crystals thus obtained, may again be divided into other minute crystals; but the same form is observed in all. Thus calcareous-spar, crystalizes in rhomboids, fluor-spar, in cubes, and quartz in six-sided pyramids.

The surface of a crystal is called its *plane or face*. The lines made by the meeting of two planes are called *edges*; the meeting of three planes forms what is called a *solid angle*.

Fig. 111.

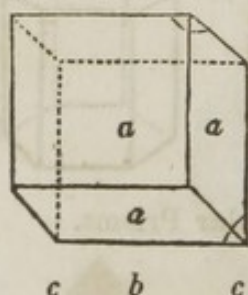


Fig. 111, shows a cube in which *a, a, a*, are planes, *b, b*, are edges and *c, c*, solid angles. Thus the cube has six planes or faces, twelve edges, and eight solid angles.

675. The primary cubic form may be modified by various circumstances. The three primary forms (see § 673,) were by Haüy considered as belonging to the integrant molecules of all crystalline bodies. "But it is not difficult, as Dr. Wollaston suggests, to conceive that these primitive forms may, themselves, be procured by certain arrangements of spherical particles.

Thus, four balls arranged as at *a*, (Fig. 112,) give the element of the tetrahedron.

Six balls, arranged as at *b*, that of the octahedron, &c.

Fig. 113, represents a number of spherical particles aggregated to form the tetrahedron and triangular prism.

Fig. 114, represents the rhomboid and cube.

Fig. 115, the octahedron and four sided prism formed in a similar manner.

Instead, therefore, of assuming several distinct geometrical solids as primitive forms, some philosophers refer to the sphere, or spheroid, as the source of all, and assume it as the figure of the ultimate, mechanical particles of matter."

Fig. 112.

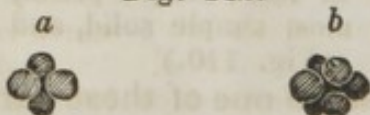


Fig. 113.



* Crystalline carbonate of lime.

675. Modifications of the primary form. Haüy's opinion respecting the primary forms. Dr. Wollaston's suggestion. Opinion of some with respect to the figure of ultimate atoms.

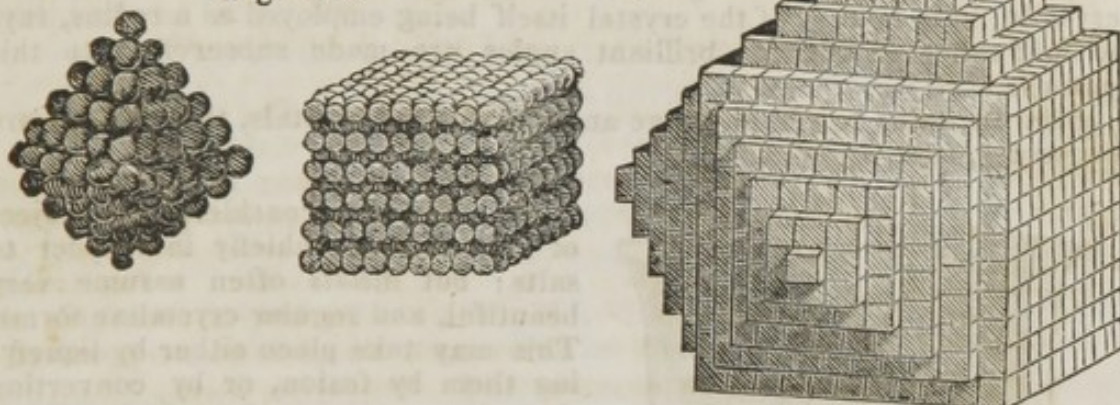
Fig. 114.



to its planes and faces. (Fig. 116.) If a cube be increased by layers of particles applied to all its sides, the edges of the layers being parallel to those of the cube and each layer being made less than that immediately preceeding it, by one row of particles on each of its edges, a dodecahedron, or twelve sided solid, with rhombic faces will be produced, (Fig. 116.)

Fig. 116.

Fig. 115.



Rhombic Dodecahedron.

677. Crystals not only differ one from another, in form, but those of similar form differ in the *angles made by the inclination of the faces*. Thus in the rhomboid, which is characterized by having one of its adjacent angles smaller than a right angle and the other larger, it is evident that the one angle may consist of almost any number of degrees less than 90, and the other of any number below 180, though this must be the amount of the two angles taken collectively; because the four angles of the crystal, must, together, be equal to four right angles, thus $90 \times 4 = 360$, which is the number of degrees of a circle, by which angles are measured. Thus the primitive form of calcareous spar is a rhomboid whose faces are inclined at angles of $105^\circ 5'$, which is more than a right angle, and $74^\circ 5'$, which is less than a right angle, these numbers added together make 180° , which is the sum of two right angles. The primitive form of the mineral called tourmaline, is an obtuse rhomboid, the largest angle of which is $113^\circ 10'$.

678. An instrument (Fig. 117,) called a *goniometer** has been invented for measuring the angles of crystals. Its operation is founded upon the mathematical proposition† that “the opposite angles made by any two lines

* From the Greek *gon* an angle, and *metron* measure.

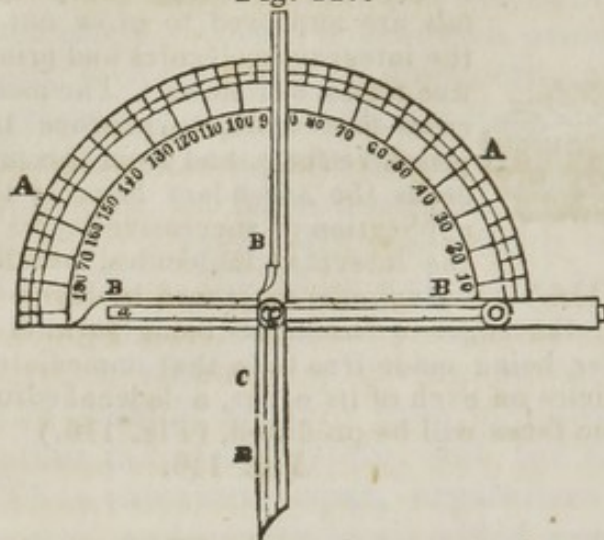
† Euclid, B. I. prop. 15.

676. Manner in which the secondary forms proceed from the primary.

677. Crystals of similar form may differ in the size of their angles.

678. Goniometer. Reflective goniometer.

Fig. 117.



Goniometer, or instrument for measuring the angles of crystals.

ton, which measures with great accuracy the angles of the most minute crystals; here instead of the crystal itself being employed as a radius, rays of light reflected from the brilliant angles are made subservient to this purpose.

679. In order to obtain large and well formed crystals, three things are necessary, *time, space and repose*.

Fig. 118.



become quite hard, it may be broken and the interior of the cavity will be found lined with crystals. Fig. 118, represents the crystallization of bismuth effected in this manner.

681. Crystals are to the mineralogist, what flowers are to the botanist. He reads the chemical constitution of minerals in the mechanical figure which they present, as the botanist decides by the organs of the plant, the class or group to which it belongs. But as various accidental circumstances, to which flowers are not exposed, affect the forms of crystals, it is often

in crossing each other are equal." Thus the angle made by the arms B B, B C B, of this instrument, above and below the pivot on which they revolve, are equal to each other. Therefore if the angle of a crystal be placed at C, and the arms of the goniometer made to close upon its planes, a similar angle will be made by the arms on the opposite side, and this angle may be known by examining the semicircle, A A, which is graduated into 180° . An instrument called the *reflective goniometer* has been invented by Dr. Wollas-

680. We have considered the subject of crystallization chiefly in respect to salts; but *metals* often assume very beautiful, and regular crystalline forms. This may take place either by liquefying them by fusion, or by converting them into vapor; and as the liquid becomes solid by cooling, or the vapor by condensing, the particles arrange themselves in crystals of greater or less regularity. Tin, lead, antimony, and bismuth, all afford crystals. For this purpose they may be melted in a crucible; when the surface cools it should be pierced, and the liquid metal within poured out; when the hollow mass has

679. To obtain perfect crystals.

680. Crystallization of metals.

681. Value of crystals to the mineralogist.

necessary that the inquirer should examine the constituent parts; and this can only be done by the aid of chemical analysis.

Classification of Salts.

682. To facilitate the study of the salts, they have, very properly, been arranged in groups, or genera. As every acid, with few exceptions, unites with every alkaline base, the different kinds of salts thus formed are very numerous, amounting to more than 2.000, though not more than thirty were known a hundred years ago. The names given to the salts were, often, merely arbitrary; but in the present nomenclature, the *name of a salt expresses its composition*, and the *knowledge of its composition recalls its name*. The name of the genus is derived from the *acid*, that of the species, from the *base*; thus *sulphate* is a generic term, including various species, as sulphate of soda, sulphate of lime, &c.

683. The acids are divided into two classes; 1st *Oxacids*, or those acids in which oxygen is united to a combustible body; 2nd *Hydracids*, or acids composed of hydrogen and some other substance. Until the great revolution in chemical science, which took place about the year 1775, it was supposed that oxygen was the only acidifying principle. Berthollet was the first to suggest doubts on this subject, by affirming that sulphuretted hydrogen ought to be regarded as an acid, though composed of hydrogen and sulphur. The discovery of iodine and chlorine, furnished new and convincing proofs that the acidifying property is not confined to oxygen, but exists in other bodies. The number of the binary oxacids amounts to more than twenty, while that of the hydracids is much less.

684. There are four orders of salts viz:—

Order I, Salts of the oxacids.

Order II, Salts of the hydracids.

Order III, Haloid Salts.

Order IV, Sulpho Salts.

Every acid is capable of forming a salt with a base; and such salt may be considered as a distinct genus; but as one element often forms with oxygen several acids, which though they possess individuality, are very similar, we shall consider the various salts formed by such acids as con-

682. Importance of some mode of classifying salts. Difference between the old names of the salts and those which are founded on the chemical nomenclature.

683. Two classes of acids.

684. Orders of salts. What constitutes a general character in respect to salts? Subgenera of salts.

stituting divisions of a genus; thus the nitrites and *hyponitrites* will be classed as *subgenera*, of the genus *nitrate*.

ORDER I. SALTS OF THE OXACIDS.

GENUS I.—SULPHATES.

85. Of all the acids, none has a more decided tendency to combine with salifiable bases, than the *sulphuric*. The number of sulphates is of course very great.

Properties. They have mostly a brittle taste; and are decomposed by baryta, which has a stronger affinity for sulphuric acid, than any other base. All the sulphates may be decomposed by carbon, at a high temperature. The acid and oxide are both decomposed, the oxygen forming with the carbon, carbonic acid, and the sulphur forming with the metal, a sulphuret. At common temperatures, the sulphates neither effervesce with acids nor give off vapors; but the sulphuric acid, by a high heat, may be displaced by boracic, phosphoric, and arsenic acids. Those which contain no water of crystalization, as the sulphate of iron, when exposed to great heat, yield a portion of anhydrous, sulphuric acid. Six of the sulphates are insoluble in water, viz: the sulphates of baryta, tin, antimony, bismuth, lead, and mercury; the sulphates of lime, strontia, silver, and a few others are sparingly soluble; all the others are soluble in water. The soluble sulphates form with hydrochlorate of baryta, a dense white precipitate, which is the sulphate of barytas, and is insoluble.

Among native sulphates, those of lime and baryta are most abundant. Those which are employed in the arts, are usually extracted from native minerals. Some are prepared directly by art, and many by double decomposition.

686. *Sulphate of potassa*, is a white salt, of an acrid and bitter taste; it was formerly much valued in medicine and is known in commerce, as *vitriolated tartar*. It is of use in the manufacture of alum, glass, and salt petre. It is not found native among mineral substances, but exists in the ashes of tobacco and some other vegetables. The bi-sulphate contains twice as much acid as the sulphate.

687. *Sulphate of soda* was discovered by Glauber, a German chemist in the process for obtaining muriatic acid, by decomposing common salt with sulphuric acid. A precipitate of soda was obtained which has been named Glauber's salt in honor of its discoverer. It is contained in the waters of some mineral

685. Why is the number of sulphates great? General properties of this genus of salts. Decomposition, &c. Insoluble sulphates. Soluble sulphates with muriate of baryta. Native sulphates, &c.

686. Properties of sulphate of potassa. Uses. Where found.

687. Discovery of sulphate of soda. Common name. Where it exists in nature. Properties. Crystals. Degree of temperature at which water most readily dissolves it. Effect of the effervescence of this salt. Uses. Bisulphate of soda.

springs, in sea water, in the ashes of sea weed, and sometimes effloresces at the surface of the earth, and upon the walls of cellars, and other excavations. It exists in a mineral found in Spain, called *Glauberite*.

It is a colorless, and very bitter salt, capable of forming very large crystals, and containing 58-100th of the water of crystalization. According to Berzelius, the crystals are composed of 72 parts, or one equivalent of sulphate of soda, and 90 parts, or ten equivalents of water. They undergo the watery fusion on exposure to heat. This salt readily effloresces in the air. It is one of the essential medicines of the family dispensatory. It is used in the arts for the preparation of carbonate of soda, and manufacture of glass. *Bisulphate of soda* is formed by adding sulphuric acid to a solution of sulphate of soda.

688. *Sulphate of ammonia* exists in small quantities in nature; in the neighborhood of volcanoes, and in the waters of the Tuscan lakes. It is usually prepared by the direct combination of ammonia with sulphuric acid.

689. *Sulphate of Baryta*, called *heavy spar* is an abundant product of nature usually found in veins, with metals, sometimes in fibrous masses. It is wholly insoluble in water, and bears the most intense heat without fusion, or decomposition.

The affinity of pure baryta for sulphuric acid, is so great, that when they are brought in contact, ignition is produced. This affinity enables baryta to separate sulphuric acid from all its combinations, giving a white precipitate, in a solution containing no more than one millionth part of baryta. All the salts of baryta, except the sulphate, are poisonous; and this exception is owing to the perfect insolubility of the salt, in the juices of the stomach. If, therefore, any of the poisonous salts of baryta be swallowed, diluted sulphuric acid, a solution of sulphate of soda, or any other alkaline sulphate, would be the proper antidote. The sulphuric acid would unite with the baryta of the poisonous salt, and form the harmless sulphate of baryta.

690. *Sulphate of Lime* is abundant, existing in the form of gypsum, (*plaster of Paris*), alabaster, and silky crystals, called *selenite*. It is found in the ashes of plants, and the water of springs, causing what is called the *hardness* of the latter.

Hard water, or that which contains salts, and consequently acids in solution, decomposes soap, while the oil combining with the earthy base of the salt, floats on the surface of the water; thus it is impossible to form, what the laundress calls *suds*, with hard water. Add soap to a solution of sulphate of lime, and the soap will immediately be decomposed. Sulphate of lime may be formed by adding sulphuric acid to any carbonate of lime, or lime water. When pure it is perfectly white, as in alabaster. Exposed to intense heat, it loses its water of crystalization, and fuses into a white powder; in this state it forms *plaster of Paris*.

688. Sulphate of ammonia.

689. Sulphate of baryta. Why not poisonous.

690. Existence of sulphate of lime in nature. Hardness of water. Preparation of sulphate of lime. Plaster of Paris. Composition of anhydrous sulphate of lime. Of the crystalized sulphate, Anhydrite. Uses of sulphate of lime. Plaster casts.

Anhydrous sulphate of lime consists of one proportion of acid=40, one proportion of lime=28. The compound equiv. is, therefore=68. The crystallized sulphate contains, in addition, two proportions of water, =18, making its equivalent 68 added to 18=86.

The uses of sulphate of lime are various. It is employed as a manure for soils; and with lime plaster to give it a greater durability, firmness, and smoothness; this composition for walls and ceilings is called *hard finish*. This is a great improvement upon the old method of plastering, as it will bear washing with soap and water. Sulphate of lime is much used for statuary. Plaster casts are often taken from persons after death, but with the faithful preservation of their lineaments, there is also, in such busts, but too accurate a delineation of that last repose, which, however sanctified by religious hopes, humanity yet shudders to contemplate.

691. *Sulphate of Magnesia* was first obtained from a mineral spring, at Epsom, England; hence its common name, *Epsom salts*. It is less bitter than the sulphate of soda, which it resembles in taste and medicinal properties. It is sometimes called *Seidlitz salts*, from a village in Bohemia which contains mineral springs strongly impregnated with this salt. It exists in seawater, from which it may be obtained by evaporation. It is also manufactured from magnesian lime-stones. It is found crystallized in large quantities, in lime-stone caverns in Kentucky, and several other of the Western States.

692. *Sulphate of Alumina* exists in nature in a mineral called *aluminate*. It may be formed by mixing alumina with sulphuric acid. The pure sulphate is of little importance; but combined with sulphate of potassa it forms a *double salt of alumine and potash*; which is the common alum of commerce. This salt has an astringent taste, is soluble in water; reddens infusions of purple cabbage slightly; changes blue infusions from the petals of flowers to a green color.

Exp. Suspend a frame work of string, or wires in a vessel filled with a hot, solution of alum, large and beautiful crystals will collect upon the frame, and thus may be formed a variety of pretty ornaments, as baskets, vases, and flowers. Alum crystals contain half their weight of the water of crystallization. When heated, they melt in this water, swelling and frothing, while the water passes off, leaving *anhydrous alum* in a white, light, and spongy mass. When heated with sugar, alum forms a compound which inflames spontaneously; it is known as *Homberg's pyrophorus*. Native *soda alum* is found in South America and in Greece.

The chemical equivalent of pure sulphate of alumina is stated at 58; and the composition of alum is as follows;

Sulphate of potassa, 1 equivalent,	=88
Sulphate of alum, 3 equivalents, (58×3)	=174
Water, 25 equivalents, (9×25)	225

Chemical equiv. of Sul. alumina and pot.=487.

691. Sulphate of magnesia.

692. Sulphate of alumina. Alum. *Exp.* Anhydrous alum. Homberg's pyrophorus &c. Composition of sulphate of alumina. Law of chemical combination illustrated by this salt. Uses of alum, &c.

The composition of this salt illustrates an important law of chemical combination, viz; that, in the double sulphates, the quantity of oxygen in one of the bases, will be proportioned to the quantity of oxygen in the other base. Now the oxygen in potassa is, in proportion to the oxygen of alumina, as 1 to 3; therefore, there are 3 equivalents of alumina to 1 of potash in alum; thus each base furnishes to the common stock, an equal amount of oxygen.

Alum is an important article of commerce, and is employed in medicine and the arts; it is used in dyeing, calico printing, in paper manufactories and by tallow chandlers to render their tallow more solid. It is not common in nature, but its elements are abundant. Where it is already formed, as at Solfaterra near Naples, it is sufficient to lixivate* the earths, which contain it, and crystalize the liquor.

693. *General remarks.* The sulphates which are formed by the union of sulphuric acid with the fixed alkalies and alkaline earths, are the most important species of this genus. Those sulphates which are formed with oxides having neither earthy nor alkaline properties, and therefore commonly called *metallic oxides*, are scarcely less numerous than these oxides themselves, since all have some affinity, more or less, for sulphuric acid. But it should be remembered, that, in principle, there is no distinction between alkaline, earthy, and metallic salts, since all salts (*with the exception of those of ammonia and the vegetable bases, which we shall hereafter consider,*) are composed of acids and metallic oxides. Thus potassa and soda are now known to be oxides of metals, no less than the oxides of iron and copper; though the two former are usually, called alkalies, and the two latter metallic oxides.

694. *Sulphate of Iron.* Sulphuric acid combines with three oxides of iron; but according to Berzelius there are but the *proto* and the *persulphate*. He regards the *deutosulphate* as a compound of the two others. The *protosulphate*, or sulphate of the protoxide of iron commonly called *copperas*, green vitriol, &c. may be formed by the action of dilute sulphuric acid on metallic iron. Water is decomposed and furnishes oxygen, which uniting with the metal forms the protoxide; hydrogen escapes with effervescence, and sulphuric acid unites with the newly formed oxide. This sulphate is seldom found in nature in a solid state; but is often found, in solution, in water flowing in the neighborhood of mines.

This salt crystalizes in rhombic prisms, is of a beautiful green color, and inky taste. Its color is owing to its water of crystalization of which it contains 45 parts in 100 of its weight. When deprived of this water by

* To leach them, or to form a ley of them.

693. Most important species in this genus of salts. Salts which are not based on metallic oxides.

694. Number of combinations of sulphuric acid with oxides of Iron. Protosulphate of iron, or copperas, &c.

heat, it becomes of a dirty white color. This salt is useful in the arts, particularly in that of dyeing. In combination with nut galls it forms ink.

Persulphate of iron is formed by the action of nitric acid with the protosulphate, or by the action of sulphuric acid upon the red oxide of iron, slightly moistened with water. It is not crystalizable.

695. The *persulphate* (or sulphate of the peroxide of iron) has $1\frac{1}{2}$ an equivalent, or 60 parts of sulphuric acid, with 1 equivalent of peroxide of iron. This furnishes a striking instance of the acid of a salt being in proportion to the oxygen of the base; the more remarkable as the peroxide of iron has its half equivalent of oxygen, and we find it requiring an additional half equivalent of the acid for its saturation.

696. *Sulphate of manganese* appears in transparent crystals of a slight rose tint.

Sulphate of zinc or *white vitriol* reddens blue vegetable colors, though in its composition it is a neutral salt, consisting of one equivalent of acid and one of oxide. It is obtained in granular masses, resembling sugar; but by evaporation may be crystalized in quadrangular prisms. It is employed in medicine, as an astringent, and in certain cases as an emetic.

697. *Sulphate of Copper*. There is no sulphate of the protoxide of copper; for, according to Proust, when this protoxide is heated with sulphuric acid, the result is, a solution of the deutoxide of copper, and a precipitate of metallic copper, which appears as a red powder.—*Thenard*. The bisulphate of copper (sulphate of the deutoxide) is the *blue vitriol* of commerce.

It crystalizes in prisms with an oblique base; its crystals contain in large quantities the water of crystalization, which renders them transparent, and gives them a beautiful blue color. Exposed to the air they become slightly efflorescent, and are covered with a whitish crust. They fuse easily, in their water of crystalization, and become white. This salt has a strong metallic taste, is used in medicine as a caustic, and when taken into the stomach excites nausea. It is soluble in water, but not in alcohol. It is seldom found crystalized in nature; but, by evaporating the water of copper mines,* in which this salt exists in solution, the crystalized *blue vitriol* of commerce is obtained. The same substance is also prepared by roasting copper pyrites with access of air and moisture, the sulphur is acidified, the copper oxidized, and the deuto-sulphate which is formed, is extracted by solution and crystalization.

Anhydrous sulphate of copper consists of

Peroxide of copper, 1 equiv.	=80
Sulphuric acid, 2 do.	=80

Compound equivalent,	=160.
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The crystalized sulphate contains in addition

10 equivalents of water,	=90
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The equiv. of the crystalized sulphate is	=250.
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* Copper ore usually contains some sulphur; copper *pyrites* is the sulphuret of copper.

695. Persulphate of iron.

696. Sulphates of manganese and zinc.

697. Why is there no sulphate of copper? Bi-sulphate of copper. Blue

The sulphate of copper reddens vegetable blue colors; it is therefore called a *super-sulphate*, and sometimes a *bi-persulphate*. Silliman justly remarks,† “The refinements of a significant nomenclature are sometimes embarrassing, requiring frequent changes with the progress of discovery, and presenting names which are inconveniently long; they also compel us to return occasionally to the old proper names, such as alum, common salt, white, green, and blue vitriol.” To this remark we would add, that our Chemists have undoubtedly gone too far in attempting to introduce technical names into common language. Our respect for science would scarcely prevent a smile should we hear one call for the *protoxide of hydrogen* combined with *hydrocarbonous oxide*, instead of water and sugar.

When ammonia is added to a solution of blue vitriol, a precipitate appears, of a greenish blue color; on adding an excess of ammonia, this precipitate is dissolved and forms a liquid of a beautiful blue color, called *celestial blue*; it is the *ammonia ret of copper*. Ammonia affords a valuable test of copper. The sulphate of copper is used in the arts to prepare *blue cinders* used in coloring paper, and *Scheele's green*.

698. *Sulphites*. Salts of this sub-genus are formed by the union of sulphurous acid with salifiable bases. They are distinguished by a disagreeable taste, and an odor like that of burning sulphur. When exposed to air and moisture they absorb oxygen, and pass to the state of sulphates. They are decomposed by the stronger acids, such as the sulphuric, hydrochloric, &c., effervescence takes place, owing to the escape of sulphurous acid, and a sulphate is formed. Nitric acid, by yielding oxygen, changes the sulphites into sulphates.

CHAPTER XXIX.

SALTS OF THE OXACIDS CONTINUED.

GENUS II.—NITRATES.

699. The nitrates may be formed by the action of nitric acid on metals, or their oxides. In the former case, according to the theory of the formation of salts, the metal must first oxidize, before it will become a salt. The nitrates are acted upon by *sulphuric acid*, which disengages nitric acid in the form of dense,

† Elements, Vol. II. p. 282.

vitriol. Composition of the anhydrous sulphate of copper, and the crystallized copper. Properties. Chemical names not adapted to common language. Blue vitriol with ammonia. Uses of sulphate of copper in the arts.

698. Sulphites.

699. Nitrates. Which are most readily decomposed?

white, acid vapors, having the peculiar odor of nitric acid. They are all decomposed by heat, giving out oxygen and becoming *nitrites*. By a strong heat they lose all their acid. They *deflagrate* when heated with charcoal or other combustible substances.

Most of the nitrates are composed of one equivalent of acid, and one of a protoxide; the oxygen of the oxide and acid is, in these cases, in the ratio of 1 to 5, because the proportion of oxygen in the protoxide is 1, and in the nitric acid 5. The oxides of those metals which have the least affinity for oxygen, as gold, palladium, &c. part with their oxygen at a low temperature, and the nitrates formed with them are easily decomposed, while the nitrate of lead and some others, require a red heat for their decomposition.

700. *Nitrate of Potassa*,* *nitre*, *salt petre*, &c. exists in great quantities, in nature. It is not found in large masses, but diffused on the surface of the earth, usually in connection with the nitrates of lime and magnesia, in places where animal substances have suffered decomposition. Efflorescences of this salt, resembling mould, are found upon the damp walls of old cellars and subterranean buildings, especially when these walls are covered with lime mortar. Nitre is manufactured by lixiviating the substances in which it is contained, and evaporating the solution. In the East Indies it is abundant as a natural production; and large quantities are imported from thence into Great Britain and the United States. In Italy and Spain it is found in the dust of the roads; and it is common in the grounds near Lima in South America. It exists in some plants, as the hemlock, sunflower, tobacco, &c.

701. *Properties*. It is a white substance with a cool and sharp taste, and deflagrates when thrown upon burning charcoal. With heat it suffers the *igneous fusion*, as it contains no water of crystallization, though its crystals are not quite free from some *water of interposition*, or water lodged mechanically in their interstices, instead of being chemically combined with their particles. Nitre is used in chemistry as a deoxidizing agent, and to obtain oxygen,† and nitric and sulphuric acids. It is useful in medicine on account of its cooling properties. It is an antiseptic, and is used in the salting of meat, to which it imparts a fine color, rendering the fibre both tender and

* The nitre of the scriptures is the carbonate of soda, called in Greek, *natron*, and in Latin *nitrum*. Thus in Prov. 25: 20, "as vinegar upon nitre, so is he that singeth songs to a heavy heart." Here the effervescence or disturbance caused by the action of the acid vinegar upon the carbonate is evidently alluded to. In Jeremiah 11: 22, we read of washing with nitre; the cleansing or detergent property of the carbonate of soda must be referred to.

† Oxygen being driven from nitre by heat, may be collected over the pneumatic cistern.

700. Nitrate of potassa as found in nature. Manufacture of nitre. In what countries most abundant. Exists in plants.

701. Properties. Action with heat. Uses. Tests. Action with water.

compact. It can be known by its deflagrating on burning coals, and by the disengagement of the fumes of nitric acid, when tested with sulphuric acid. Owing to its rapid combination with water, it forms with ice a valuable freezing mixture.

702. Its action with combustibles constitutes its efficacy as an ingredient in *gun powder*, which is a mixture of 75 parts of *nitre*, 10 of *sulphur*, and 15 of *charcoal*. These are the usual proportions, but they are sometimes varied. The composition of gun powder was discovered by Roger Bacon, a friar, in the fourteenth century. It is supposed that the Chinese were previously acquainted with it. It was first used by the English at the battle of Agincourt in 1415. Gun powder is merely a mechanical mixture, as at common temperatures no chemical action takes place among its parts. But when heated, the oxygen which the nitre yields so readily and abundantly, acts on the carbon and sulphur, producing with the latter a rapid and violent combustion, while the former yields a large proportion of elastic vapor. The volume of gas produced from powder at the moment of explosion, is said to be 1000 times greater than that of the solid powder. As each additional volume of gas exerts a force equal to that of the atmosphere, which is 15 pounds to the square inch, the force of this elastic vapor will be $1000 \times 15 = 15,000$ pounds on a square inch; this according to calculation will project a bullet with a speed of 2000 feet in a second. The products of the detonation of gunpowder, are both gaseous and solid; the former consisting of mixtures of nitrogen, nitric oxide, carbonic acid, sulphuretted and carburetted hydrogen and ammonia. The solid products are some sulphate, and sulphuret of potassa, carbonate of potassa and charcoal.

Various *fulminating powders* are made with nitre, some of which produce a more powerful detonation than gun powder.

703. *Nitrate of Silver* is obtained by dissolving silver in nitric acid. Cast in small moulds, it forms the *lunar caustic** or *lapis infernalis* of medicine. It is highly corrosive, and changes the skin, first yellow, and then black on exposure to the air, (owing to the decomposition of the oxide of silver.) In a very dilute state it is used, with other ingredients, for staining the hair black, and for *indelible ink*, used in marking linen.

An imposition has heretofore been practiced by the venders of the marking ink, by selling at a great price, a vial of what they call *solution*; which is merely a solution of pearlash and water. The article to be marked, is *wet* with this solution, and then dried. The ink is, a colorless liquid, (unless it contains a small portion of India ink;) but the alkali of the pearlash, seizes the nitric acid, and forms nitrate of potash; the oxide of silver being liberated, is precipitated among the fibres of the linen. Exposure to light, partially decomposes the oxide of silver, and the letters become black. When a white garment has been accidentally stained with this ink, the spot may be removed by steeping in diluted nitric acid.

* *Lunar* is derived from the ancient name of silver, *caustic*, from its agency in destroying animal texture. The name *lapis infernalis*, or *infernal stone*, was given in allusion to its strong burning property.

702. Gunpowder. Its composition. Discovery. Cause of its combustible nature. Cause of its explosive property. Force. Products of its detonation. Fulminating powders.

703. Nitrate of silver, how formed? Lunar caustic. Indelible ink. Mode of marking with this ink. Exposure to light.

704. *Nitrites and Hyponitrites.*

When *nitrous acid* is brought in contact with a salifiable base, the result is a *nitrite*, and under certain circumstances a *hyponitrite*. Nitrous acid does not appear to be susceptible of a permanent union with salifiable bases. By exposing the nitrates to a red heat, oxygen is given off and *nitrites* are formed; but by exposure to the air, the latter absorb oxygen, and again become nitrates. The *hyponitrites*, contain a less portion of oxygen than the nitrites. They are decomposed by water even at the ordinary temperature.

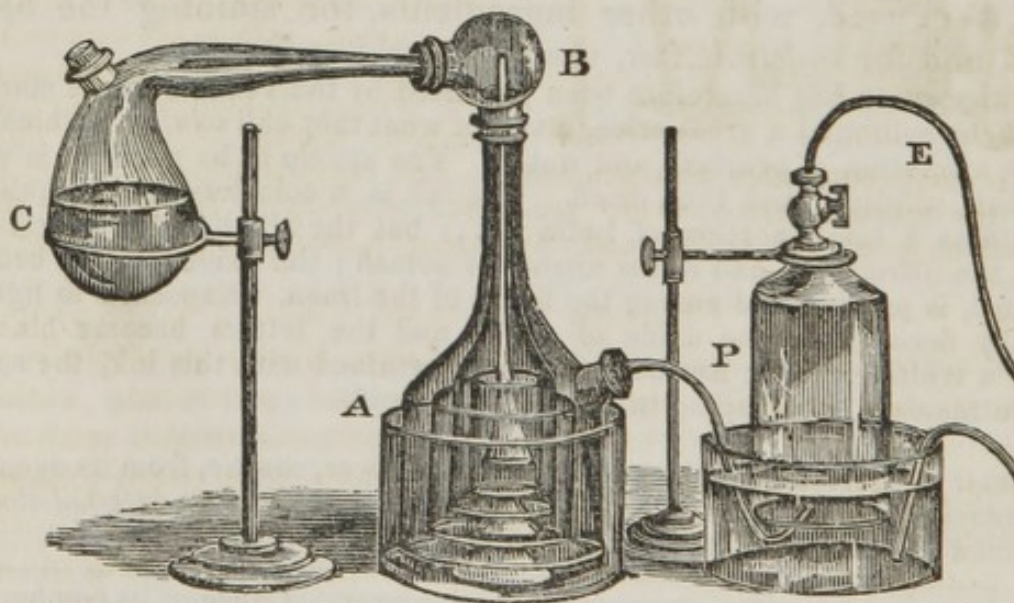
GENUS III.—CHLORATES.

705. These salts (formerly called *Hyperoxymuriates*,) are formed by the combination of bases with chloric acid. They deflagrate with even greater violence than the nitrates, yielding oxygen so readily, that the slightest agitation will produce their explosion. They are soluble in water, and decomposed by heat, giving off oxygen, and becoming metallic chlorides. Most of the chlorates are composed of one equivalent of chloric acid, and one of a protoxide, it follows, therefore, that the oxygen of the latter, to that of the former, is in the ratio of 1 to 5, (chloric acid having 5 proportions of oxygen.) None of the chlorates are found native. They were discovered by Berthollet, in 1786.

706. *Chlorate of potassa*, (*hyperoxymuriate of potash*) is the most important species of the chlorates.

Exp. It may be formed by passing a stream of chlorine gas, (Fig. 119,)

Fig. 119.



704. Nitrites. Hyponitrites.

705. Former name of chlorates. Formation and character. Decomposition.

706. Chlorate of potassa. How formed? *Exp.* Rationale of the process.

through a solution of caustic potash in Woulfe's bottles, or by saturating the gas with a solution of potash. A, represents the outer one of three jars, containing solution of the sulphate of potash; peroxide of manganese being put into a retort C, and some hydrochloric acid added to it, chlorine gas is disengaged, and passes to the globe B, from whence it proceeds into the inner jar. If it be not all absorbed by the liquid in this jar, the superfluous gas will escape into the next jar, and so on, until all the liquid is saturated; any gas which remains in excess, is conducted off by the pipe P, and received in an inverted bell glass. E is a pipe which, when extended, may still further serve for conducting off the superfluous gas, into a suitable receiver.

In this operation, it is supposed that one part of the potassa is deoxidized, and the reduced metal uniting with chlorine forms the chloride of the potassium, which is in solution; and that the oxygen of the potash unites to another portion of the chlorine, producing chloric acid, which, combining with the undecomposed potassa, forms the chlorate of potassa.

Fig. 120.



707. Dr. Hare contrived the apparatus here represented (Fig. 120,) for the purpose of separating the solution of chlorate of potassa from potassa and siliceous earth. A large vessel of sheet tin was fitted to a tin funnel, to support a glass filtering funnel, and furnished with an aperture which serves the purpose of a chimney, by conducting off the smoke of the Argand lamp below. This lamp keeps the water hot, with which the tin vessel is filled. The hot water thus surrounding the solution as it filters, prevents its cooling. A coarse fibrous paper for a filter, is placed within the funnel; the filtering solution of chlorate of potassa, is received in the decanting jar beneath. On being kept undisturbed, the salt crystallizes in beautiful white, rhomboidal scales, resembling mother of pearl. Their

taste is cool, but bitter and nauseous. The crystals are anhydrous, and suffer the igneous fusion, below red heat; at a higher temperature they give off oxygen, with boiling and effervescence, and become *chloride of potassium*.

708. *Properties.* Chlorate of potassa yields a large proportion of pure oxygen gas. For this reason it acts powerfully on combustibles, readily inflaming them and producing violent detonation. Two parts of chlorate of potassa mixed with one of sulphur, and put into a paper, will explode with great violence on being struck with a hammer. When rubbed in a mortar with phosphorus or charcoal, a loud detonation and jets of fire are produced.

707. Dr. Hare's apparatus for purifying chlorate of soda, &c. Crystals of chlorate of potassa. Action of heat upon the crystals.

708. *Properties.* *Exp.*

Fig. 121.



Exp. If a small portion of phosphorus covered by chlorate of potassa (Fig. 121,) be placed in a glass which is then filled with water and sulphuric or nitric acid, poured in through a long glass funnel, the mixture is inflamed, and burns with great brilliancy, with a series of detonations. Sugar mixed with chlorate of potash, deflagrates with the addition of a small quantity of sulphuric acid.

709. Chlorate of potassa is used in the arts, for fire-matches, and attempts have been made to introduce it as an ingredient in gun-powder; but, though it produces a powder of greater impelling force than that which is commonly used, it inflames so easily by slight friction, or shocks, that its manufacture and use are very dangerous, and prevent its being employed for this purpose.

It is composed of

Chloric acid	1 equivalent	=76
Oxide of pot.	1 do.	=48

Chemical equiv., therefore=124

Its ultimate compounds being 6 proportionals of oxygen, 5 in the acid and		
1 in the alkali,	6×8	=48
1 proportion of chlorine		=36
1 do potassium		=40

Compound chemical equiv. =124

710. *Perchlorates* or *oxygenated chlorates*, are formed by the union of perchloric acid with salifiable bases. These salts discovered by Count Stadion, are little known.

GENUS IV.—IODATES.

711. The iodates are produced, either by combining iodic acid directly with bases, or by double decomposition. The composition of iodic acid being similar to chloric acid, in respect to the quantity of oxygen, the iodates, like the chlorates, contain oxygen in the oxide and acid in the proportion of 1 to 5. Like the chlorates, they form deflagrating mixtures with sulphur, and other inflammables. Most of the acids decompose the iodates, by attracting the oxygen from iodic acid. The *iodate of potassa* is the most important species of this genus.

GENUS V.—BROMATES.

712. Like chlorates and iodates, the proportion of the oxide to the acid in the bromates, is in the ratio of 1 to 5, bromic acid

709. Uses of chlorate of potassa. Cause which prevents its being used in gun-powder. Composition.

710. Perchlorates.

711. Remarks on the genus, iodates.

712. Bromates.

containing 5 proportions of oxygen. The properties of bromates appear to be analogous to those of chlorates, and iodates.

GENUS VI.—PHOSPHATES.

713. These salts are not decomposable by heat, but melt at a high temperature. They are extensively diffused in nature. The *phosphate of lime* is most abundant, often forming an important constituent of mountain masses, and existing largely in animal bones. There are phosphates with excess of base called *alkaline phosphates*, *neutral phosphates*, *acidulated phosphates* and *acid phosphates*.

714. *Phosphites* are a combination of phosphorus acid with salifiable bases. When exposed to heat, they disengage phosphuretted hydrogen, and a little phosphorus, while a phosphate colored by the oxide of phosphorus remains. When thrown upon burning coals, they produce a yellow flame. *Hypophosphites* are combinations of hypophosphorus acid with bases. They are too soluble to be crystalized.

GENUS VII.—ARSENIATES.

715. Salts composed of arsenic acid with bases are called *arseniates*.

Arsenites are combinations of arsenious acid with bases. They are distinguished from the arseniates by a green precipitate with sulphate of copper, while the arseniates form with the same compound a bluish *white* precipitate. The arsenite of copper is Scheele's green. The arsenite of potassa is known in medicine as Fowler's solution.

GENUS VIII.—CHROMATES.

716. The salts which result from the union of chromic acid with salifiable bases, are all colored; yellow and red are the prevailing colors, the latter appearing when there is an excess of acid. The *chromate of lead* is a brilliant yellow, known in the arts as *chrome yellow*, it is of a beautiful pink in the state of a subsalt; *chromate of lime* is yellow, and *chromate of potassa*, lemon color; potassa combines with an excess of chromic acid, in which case the salt is of intense orange color; *chromate of silver* is of a rich crimson color; *chromate of copper*, apple green.

713. Phosphates.

714. Phosphites. Hypophosphites.

715. Arseniates. Arsenites.

716. Character of the chromates. Chromate of lead. Chromate of lime. Chromate of potassa, &c. Chromates of silver and copper.

GENUS IX.—BORATES.

717. Boracic acid is reckoned among the weak acids; its salts are therefore readily decomposed by the greater attraction of other acids for their bases. The Borates dissolve in alcohol, and burn with a green flame. *Biborate of soda* is imported from the East Indies in a crude state under the name of *tincal*. This is purified in the substance known in the arts as borax. When exposed to heat its crystals lose their water of crystalization, and become fused, forming a vitreous substance called *glass of borax*. It is used in chemistry for the preparation of boracic acid; and in glass making and pottery, as a flux.

GENUS X.—CARBONATES.

718. *Properties*. These salts effervesce with most acids, owing to the rapid disengagement of carbonic acid, for which the bases have but a feeble affinity. The carbonates of the alkalies have an alkaline taste, and change to green the vegetable blue colors; those of the earths are insoluble but become soluble with an excess of carbonic acid. Many of the carbonates are found in nature.

719. *Carbonate of potassa* is not found in nature, but is obtained by lixiviating vegetable ashes, and evaporating the solution to dryness. *Pearlash* or *saleratus* differs from the crude carbonate of potash, only in being freed from impure matter. It is an article much used in domestic operations.

Its action with flour in raising bread, biscuits, &c. depends on the readiness with which it disengages carbonic acid, which becoming entangled among the glutinous particles of the paste, tends to make a light and spongy mass. On its alkaline properties depends its utility in neutralizing the sourness produced by suffering the dough to remain unbaked, until the *vinous* fermentation changes to the *acetous*. Some housewives prefer to let their dough thus sour, as, by adding pearlash, bread and biscuit are rendered more spongy and tender, while the acidity may be wholly corrected. But this process, unless carefully conducted, will give to the bread a darker hue, and the peculiar taste of pearlash. With a little attention, however, very delicate and palatable biscuit may be made without yeast, simply by the action of pearlash and sour cream, or milk mixed and kneaded with the flour, and baked immediately. The common pearlash is uncrystalized, and anhydrous. It exists in white porous masses, potash is harder and of a darker color.

717. Character of the borates. Biborate of soda. Crystals. Glass of borax.

718. Character of the carbonates.

719. Carbonate of potassa, how formed? Pearlash. Its use in domestic economy.

720. *Carbonate of soda*, is obtained by lixiviating the ashes of marine plants. The soda of commerce is an impure carbonate, which may be purified by heat. Though alkaline, it is not highly caustic. Its solution forms beautiful crystals composed of two quadrilateral pyramids. They contain 10 equivalents of water, with 1 of carbonic acid and 1 of soda ; or acid 1 equiv. =22 added to do. soda, 32, added to 10 do. water, 90=144 which is the equivalent of crystalized carbonate of soda.

Bicarbonate of soda is, in its composition analogous to the bicarbonate of potassa. A *sesqui carbonate* is said to exist native on the banks of soda lakes in Africa ; this in commerce is called *trona*. The best variety of the carbonate of soda which is known in commerce is called *barilla* ; an inferior kind is called *kelp*. These substances are much used in the manufacture of glass, soap, in dyeing, bleaching, and in the preparation of artificial soda water.

721. *Carbonate of ammonia*, commonly called *volatile salts of hartshorn* ; is considered as a *sesqui** carbonate, consisting of 1 equivalent of ammonia, with $1\frac{1}{2}$ carbonic acid. It is prepared by heating *hydrochlorate* of ammonia with carbonate of lime ; double decomposition ensues, *hydrochlorate* of lime remains in the retort, and the *sesqui carbonate* of ammonia sublimes.

This salt is the white substance contained in the hartshorn smelling bottles. Its odor is volatile, pungent and stimulating to the nerves. It produces the alkaline effects on blue vegetable colors ; alkaline earths attract its acid and liberate ammonia, while the acids attract ammonia and liberate the carbonic acid gas with effervescence. The *proper carbonate of ammonia* or that with 1 equivalent of acid and 1 of the base, is formed by mingling carbonic acid gas over mercury, with twice its volume of ammonia.

Bicarbonate of Ammonia is prepared by saturating a solution, of the carbonate with carbonic acid gas. The common hartshorn or sesqui carbonate, when exposed to the air, loses ammonia and gains carbonic acid, and appears to be converted into a bicarbonate, becoming almost inodorous and tasteless.

This salt is composed wholly of gases in a condensed state ; the acid consisting of carbon and oxygen, the base of hydrogen and nitrogen ; or

Acid, 1 equiv. carbon 6 added to 2 equiv. oxygen 16=22

Base, 1 equiv. nitrogen 14 added to 3 equiv. hydrogen 3=17

—

The chemical equivalent of this salt is, therefore, 39

As there are *two* equivalents of *acid* and *one* of *base*, the proportions are, carbonic acid 44 added to ammonia 17=61. The carbonate of ammonia is a most valuable medicine. It is much used in chemistry as a re-agent, and, diluted with water, has its useful applications in domestic economy, in removing spots of oil or grease from cloth, &c.

* The term *sesqui* signifies one and a half.

720. From what plants is the carbonate of soda obtained ? Soda of commerce. Crystals. Composition of the crystals. Bicarbonate. Sesqui-carbonate. Barilla and kelp. Their uses.

721. Carbonate of ammonia. Composition. Preparation. Smelling bottles. Properties. The proper carbonate. Bicarbonate. Composition, Uses of carbonate of ammonia,

722. *Carbonate of baryta* may be prepared by double decomposition, by mixing a soluble salt of baryta with any of the alkaline carbonates. It is found native: is an insoluble salt, and of great use in chemistry for preparing the other salts of baryta. It is not readily dissolved by heat.

723. *Carbonate of lime* is an insoluble compound of lime, existing abundantly in nature, in the form of lime-stone, marble, chalk, stalagmites, spar, &c. It is decomposable by fire, and by most of the acids, with effervescence. It is used in chemistry for obtaining pure lime, and carbonic acid, and in the arts for building and statuary. It is much used as a manure for soils, both in the form of lime and carbonate of lime.

The advantage of burning it for this purpose appears to be of no other use than to destroy cohesion, so that it may be easily scattered among the soil; for quick lime soon becomes a carbonate by absorbing carbonic acid from the atmosphere. It was discovered by Dr. Black, in 1756, that lime acquired its caustic properties by the loss of carbonic acid. Though insoluble in water, carbonate of lime dissolves by an excess of carbonic acid: for this reason the spring water of lime stone countries is impregnated with this salt which is found deposited upon the bottom and sides of tea kettles, in which such water is boiled.

724. *Carbonate of magnesia* is prepared by decomposing sulphate of magnesia with carbonate of potassa. It is not found pure in nature, being mixed with lime, silex, &c. *Calcined magnesia* is the carbonate deprived of its magnesia by heat.

Carbonate of iron exists in nature in masses and veins. It is contained in most mineral springs, being held in solution by percarbonic acid.

It may be prepared by decomposing the sulphate of iron by a solution of carbonate of soda or potassa. The precipitate of carbonate of iron readily attracts oxygen from the atmosphere, and the protoxide of iron, becoming a peroxide, parts with carbonic acid, which does not form with it a definite compound. Thus the carbonate of iron known in medicine, is chiefly the peroxide, distinguished by its red color.

Carbonate of copper exists in nature as a beautiful light green mineral, called *malachite*, which is a carbonate of the peroxide of copper. It may be prepared by adding carbonate of potassa to nitrate or sulphate of copper. In an impure state it constitutes the blue pigment known as *verditer*.

Carbonate of lead, whitelead, or ceruse. This substance, so much used in the arts, is rarely found in nature. It is manufactured by introducing a current of carbonic acid gas into a solution of the acetate of lead. Another method is to expose thin plates of sheet lead to the vapor of vinegar, which, by its acid fumes, first oxidizes the lead, and then changes it to a carbonate.

722. Carbonate of baryta.

723. Carbonate of lime, as found in nature. Decomposition. Uses. The utility of burning it for manure. Dr Black's discovery. Solution of carbonate of lime.

724. Carbonate of magnesia. Of iron, lime, copper and lead.

CHAPTER XXX.

ORDER II.—SALTS OF THE HYDRACIDS OR HYDROSALTS.

725. The term *hydracid* is somewhat exceptionable, as it may lead to the error that hydrogen performs the same office in the hydracid, as oxygen does in the oxacid; whereas, it is the element with which hydrogen is united in these acids, that is in reality, the acidifying principle, and analogous to oxygen; thus chlorine and iodine, like oxygen, are supporters of combustion, while hydrogen is a combustible body. Like oxygen, chlorine and iodine on the decomposition of hydrochloric and iodic acids by galvanism go to the positive pole, being, like oxygen, negative in relation to hydrogen.

The acids in which hydrogen is a constituent element, and which form distinct genera of salts with different bases, are the following: *Hydrochloric*, (muriatic acid) *Hydriodic*, *Hydrobromic*, *Hydrofluoric*, *Hydrosulphuric*, (sulphuretted hydrogen,) *Hydrocyanic*, (prussic acid.)

GENUS I.—HYDROCHLORATES.

726. These salts are composed of hydrochloric acid, and metallic oxides. The name, muriatic acid, was first given to the hydrochloric, on the supposition that it was composed of oxygen, and a base called *muriatum*; after the discovery of chlorine, and the consequent change of opinion with respect to the nature of muriatic acid, the name hydrochloric, was given in conformity with the principles, of the new nomenclature. Yet the name muriatic acid, had become so well established, and its compounds, the *muriates* and *oxymuriates*, so well known by these names, that custom has, in a measure, prevailed over the mandates of science, even among chemists themselves. But explanations respecting the nature of these compounds and their changes according to theories now established, are more intelligible by the new nomenclature. For instance, when *hydrogen* or *chlorine* are said to be disengaged by the decomposition of a *muriate*, the nature of the process will not so readily be comprehended as if the term *hydrochlorate* had been used.

725. Difference in the nature of the office performed by the hydrogen and oxygen of these respective acids in the formation of salts. Number of hydracids.

726. Cause of the change of the name muriatic acid, to that of hydrochloric. Why may chemical changes be better understood by using the proper chemical terms?

727. Hydrochlorates are intimately related to the chlorides, as in desiccation, (drying) and crystalization the hydrogen of the hydrochloric acid unites with the oxygen of the oxide forming water, and leaving the chlorine united to the metallic base of the oxygen, in other words, the hydrochlorate has become a chloride. On the other hand, when the chlorides are dissolved in water, the chlorine unites with the hydrogen, and the metal with the oxygen of the water, and the newly formed hydrochloric acid, and metallic oxide combine to form a hydrochlorate. Thus dry common salt is chloride of sodium, but, dissolved in water, it is chlorate of soda. Dry hydrochlorates or muriates, except that of ammonia, are mostly considered as chlorides.

Properties. The hydrochlorates differ from all other salts by forming the white insoluble chloride of silver, when mixed with the nitrate of silver, and by being decomposed at the common temperature by sulphuric acid, with effervescence, and disengagement of white pungent fumes, characteristic of hydrochloric acid. They differ greatly from the nitrates in being little affected by charcoal, sulphur and other combustibles. They melt and volatilize by heat. They are soluble in water. The hydrochlorates which are found in nature are, ammonia, soda, lime, potassa and magnesia.

728. *Hydrochlorate of ammonia*, (the *salammoniac* of commerce) may be prepared by decomposing sulphate of ammonia, with the hydrochlorate of soda. The two gases ammonia and hydrochloric acid exchange bases, and unite, forming the solid hydrochlorate of ammonia, which is obtained pure by sublimation.

Hydrochlorate of soda, is the chief constituent of sea-water; it exists only in solution, for when evaporated it becomes chloride of sodium. *Hydrochlorate of potassa* exists in solution in mineral springs. *Hydrochlorate of baryta* is an important reagent in chemistry. *Hydrochlorate*, of *lime* exists in mineral springs, and often gives common spring water the property called *hardness*, which is indicated by its not combining well with soap. *Hydrochlorate of magnesia* is abundant in sea-water, and often exists in mineral springs. When hydrochlorate of soda is separated from sea-water by crystalization, a liquid remains called *bittern*, consisting mostly of hydrochlorate of magnesia.

GENUS II.—HYDRIODATES.

729. They are formed by the action of hydriodic acid with alkaline earths and metallic oxides; and are supposed to exist only in solution. In drying, the hydrogen of the acid, unites with the oxygen of the oxide forming water; iodic acid then unites with the metal, and an iodide remains. Hydriodic acid

727. Connection of the hydrochlorates and chlorides. Peculiar properties of the hydrochlorates.

728. Hydrochlorate of ammonia. Hydrochlorates of soda, potassa, baryta, lime, and magnesia.

729. Remarks upon the hydriodates.

does not unite with all the metallic oxides; it forms salts with the alkalies and alkaline earths, and with the oxides of zinc, iron, and manganese. The *hydriodates of potassa and soda* are the only salts of this genus which are known to exist in nature. They are formed in the water of mineral and salt springs, in sea-water, sea-weed, the sponge and oyster, and in some other mineral, vegetable and animal substances.

730. *Hydriodate of potassa* is more known than any of the salts of this genus. It may be prepared by adding hydriodic acid to potassa. On being crystalized, the oxygen of the potassa unites with the hydrogen of the acid to form water which evaporates, while the iodic acid unites with the potassium and a solid iodide remains.

GENUS III.—HYDROFLUATES.

731. They are formed of hydrofluoric acid united with bases. The nature of the acid, (see § 298,) is somewhat doubtful. It was formerly supposed to consist of oxygen and fluorine; but is now considered as a hydracid. The analogies of this acid with the hydrochloric, are in some respects remarkable; and these analogies extend to the salts of the two acids. Thus when the hydrofluates are evaporated to dryness, they become *fluorides*, when the latter dissolve in water, they are *hydrofluates*.

Though the hydrofluates give the alkaline test with vegetable colors, they are, according to Berzelius and Thenard, neutral salts; that is, composed of one equivalent of the acid with one of the base. It is not certain that they exist in nature, though the topaz has been called a *double hydrofluat of silica and alumina*; and some other rare minerals have been considered as composed of hydrofluoric acids united to metallic oxides. But these compounds are now regarded as fluorides. *Fluor spar* was known in chemistry as fluat of lime, when its acid was supposed to consist, in part, of oxygen; but it is now regarded as a fluoride of calcium.

732. *Hydrofluat of potassa*. Two definite compounds of hydrofluoric acid and potassa may be formed. The *neutral hydrofluat*, consisting of one equivalent, and the *bihydrofluat*, consisting of two equivalents of the acid to one of the base. The neutral hydrofluat seems improperly named, since it possesses alkaline properties; the bihydrofluat gives the acid test with vegetable colors. The hydrofluoric acid forms also, with soda and ammonia, both neutral and acid salts.

GENUS IV.—HYDROSULPHURETS OR HYDROSULPHATES.

733. The term *hydrosulphuric acid*, which is generally used by

730. Hydriodate of potassa.

731. Remarks upon the hydrofluates. Opinion of Berzelius and Thenard. Fluor Spar.

732. Hydrofluat of potassa.

733. Synonyme of hydrosulphuric acid. Name of the salts of this acid. Properties of the salts. Result of this decomposition.

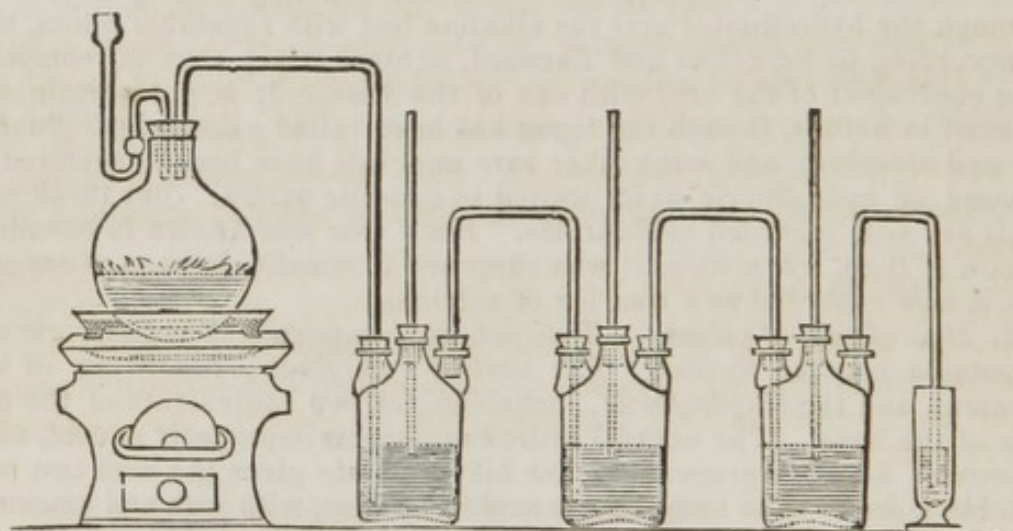
the French Chemists to designate the acid composed of hydrogen and sulphur, is more expressive of its composition than the name *sulphuretted hydrogen*. In the one case, the salts formed with the acid would be properly called, *hydrosulphates*; in the other *hydrosulphurets*. This acid seems not capable of combining with the oxides of many of the proper metals, but forms with the alkaline earths, soluble salts, which have an acid and bitter taste, and disagreeable odor.

The composition of the hydrosulphates is such that if the hydrosulphuric acid and the *oxide* mutually decompose each other, the result is, *water* and a *metallic sulphuret* corresponding to the degree of oxygen contained in the oxide; thus a protoxide will produce a protosulphuret, and a deutoxide, a deutosulphuret.

734. *Hydrosulphuret of ammonia* is formed in nature by the decomposition of animal substances. It is obtained in the laboratory by combining ammoniacal gas with sulphuretted hydrogen gas at a very low temperature; for this purpose, the gases are often mixed in a glass globe surrounded by ice; the salt will be deposited in the form of white scales.

735. The *hydrosulphates* of potassa, soda, baryta, strontia, lime and magnesia may be obtained directly, by causing a current of hydrogen gas to pass into solutions of these bases in water. For this purpose, an apparatus like that represented in figure 122 is used.

Fig. 122.



The matrass (Fig. 122,) placed over a furnace contains *sulphuret of antimony*, the first flask *water*, to wash the gas, and the third flask contains a solution of soda; more flasks may be added, containing solutions of other alkalies or earths. Hydrochloric acid is poured through the branching tube upon the sulphuret of antimony, and a gentle heat applied; hydrochlorate of the protoxide of antimony is formed in the matrass, while the hydrosulphuric acid is disengaged.*

* Thenard "*Traite de Chimie*."

734. Hydrosulphuret of ammonia.

735. Hydrosulphates of potassa, soda, &c. Process for preparing these salts by means of a current of hydrogen.

Fig. 123.



736. *Bisulphuretted hydrogen*, unites with alkalies and alkaline earths forming salts, called *sulphuretted hydrosulphurets*. They absorb oxygen rapidly from the air and are used in eudiometry. Figure 123, represents the eudiometer of Dr. Hope. It consists of a graduated glass tube, sealed at one end, and at the other fitted, into the month of a tubulated glass bottle, so as to be air-tight. The tube is filled with air, the bottle, with the liquid sulphuretted hydrosulphuret. The tube being inverted the air is made to pass into the bottle; the mixture is agitated, and time allowed for the absorption to be completed. The oxygen gas absorbed is replaced by water. The graduation being inspected, the deficit produced by the absorption of oxygen is thus ascertained.

GENUS V.—HYDROCYANATES OR PRUSSIATES,

737. Are formed by combining hydrocyanic acid (prussic acid) with bases. They are distinguished by the formation of a deep-blue precipitate with salts of the peroxide of iron. With salts of the protoxide they give an orange colored precipitate, changing in the air to green and blue.

Hydrocyanate of potassa may be formed directly, by the union of hydrocyanic acid with potassa; or by the decomposition of water by cyanuret of potassium; in the latter case the oxygen of the water forms an oxide with potassium, the hydrogen forming hydrocyanic acid with cyanogen. The acid and oxide combined form the salt. Thus the cyanuret of potassium can only exist in the dry state, as when dissolved in water it becomes a hydrocyanate.

The cyanurets of the other alkaline and earthy bases also become hydrocyanates when in solution; the phenomenon being analogous to that attending similar changes in the chlorides, iodides, bromides and fluorides. On the other hand, the hydrocyanates, when evaporated become cyanurets, parting with hydrogen from the acids, and oxygen from the oxides which unite to form water.

GENUS VI.—HYDROFERROCYANATES,

738. Are sometimes called *triple prussiates*, *ferroprussiates*, and *ferrocyanates*. Hydroferrocyanic acid, consists of hydrogen, iron and cyanogen. It unites with oxides in the same manner as the other hydracids, the hydrogen of the acid being in the exact proportion to form water with the oxygen of the oxide.

736. Bisulphuretted hydrogen. Dr. Hope's eudiometer.

737. Characteristics of the hydrocyanates. Hydrocyanate of potassa. Change of cyanurets by solution. Evaporation of hydrocyanates.

738. Characteristics of the hydroferrocyanates.

It forms soluble salts with the alkalies and alkaline compounds. When evaporated by heat, the hydrogen of the acid goes off with the oxygen of the oxide in aqueous vapor, and a ferrocyanuret remains.

739. *Hydroferrocyanate* of potassa (triple prussiate of potassa) is prepared by digesting potassa with pure ferrocyanate of the peroxide of iron, (prussian blue,) which last parts with its acid, and thereby neutralizes the potassa. It is also formed in the manufacture of prussian blue, when the blood, hoofs and horns of animals are calcined with potassa and iron. It appears in the forms of large, transparent, lemon colored crystals. The crystalized salts consist of cyan. 3. potassium 2. iron 1. Hyd., 3. and Ox., 3 equivalents of each.

740. *Hydroferrocyanate* of the peroxide of iron is the basis of *prussian-blue*. It is formed by mixing the hydroferro cyanate of potassa, with the peroxide of iron; the precipitate is of a deep blue color. The *prussian blue* is prepared by heating animal substances, with potassa and a salt of iron in a large iron crucible. Carbon and nitrogen arising from the decomposition of the animal matter form cyanogen, which, uniting with disengaged hydrogen and a portion of iron, forms *hydroferrocyanic acid*. The acid now combining with iron and potassa forms a salt with a double base, which may be called a *hydroferrocyanate of iron and potassa*.

ORDER III.—HALOID SALTS.

Some late chemists have introduced an order of salts having for one or both of its constituents a compound analogous to sea-salt; the *haloid** acids generally belong to *electro-negative* elements, and the *haloid* bases to the *electro-positive* metals. For example, the *bichloride of mercury* is called a *haloid acid*; its combination with metals forms salts, called *Hydrargot—chlorides*. The *perchloride* of gold forms with metals *aurochlorides*.

SULPHOSALTS.

These are double salts as the oxy-salts are double oxides, they are often called *double sulphurets*, among the genera of this order as the *Hydrosulphurets*, *Hydrosulphocyanurets*, *Carbo-sulphurets*, &c.

* From *hale*, sea-salt, and *eidos*, appearance.

† From the Latin name of mercury *hydrargyrum*.

739. Hydroferrocyanate of potassa.

740. Hydroferrocyanate of the peroxide of iron. Prussian blue. Haloid salts. Sulpho salts.

CONCLUDING REMARKS.

741. We have now completed an outline of inorganic Chemistry. In a subject embracing such a vast variety of combinations, and susceptible of so much amplification, we have found it difficult to keep within the boundary of a simple elementary course of instruction. Yet believing that a few principles well understood are of more advantage to the student, than a mass of unconnected facts, we have endeavored to bring into bold relief the general laws of chemical science, and our choice of facts has often been directed by this view, rather than by their individual importance. For the same reason we have been more careful to explain the rationale of the changes described, than to enter into minute details of manipulations.* We have not attempted to follow the elementary substances through all their metamorphoses in the various arts and manufactures, but have sought examples from the most common and familiar facts to illustrate principles, and on the other hand have endeavored to explain similar facts by a recurrence to principles previously established.

* For a knowledge of these the student is referred to the author's Dictionary of Chemistry, Farraday's "Chemical Manipulations," Gray's "Operative Chemist," Silliman's Elements, Hare's Compendium, Thenard's *Traite de Chemie*, &c.

741. Concluding remarks.

PART III.

ORGANIC CHEMISTRY.

CHAPTER XXXI.

CONSIDERATIONS ON THE SUBJECT OF ORGANIC CHEMISTRY.—VEGETABLE CHEMISTRY.—PROXIMATE PRINCIPLES AND ULTIMATE ELEMENTS.—VEGETABLE ACIDS.

742. *Organic Chemistry treats of animal and vegetable substances, the elements which enter into their composition, and their modes of combination and arrangement. Though organic substances differ greatly from inorganic, they present us with no new elements, but the vital power produces, in plants and animals, changes unlike any of the effects of mere mechanical action. Inorganic substances generally possess some peculiar principle, which distinguishes one from another; as in the acids, where one contains nitrogen, another sulphur, another phosphorus, &c. But organic products, with few exceptions are composed of the same elementary principles, varying only in their proportions. These principles are mostly carbon, oxygen, and hydrogen; nitrogen is less abundant in plants than in animals. Lime, potassa, iron, phosphorus, and some other substances usually exist in organic matter, though but in small proportions.*

743. It is beyond the power of science to explain in what manner the living principle operates in plants and animals, producing in the former, secretions of sap, gum, resin, oil, &c., and in the latter, secretions of a very different nature, as blood, bile, &c. Neither is the chemist able, in organic chemistry, to prove the results of his analysis by synthesis. Although analysis

742. What is Organic Chemistry? Cause of the difference between organic and inorganic substances.

743. Effects of the living principle. Organic compounds cannot be re-composed. Transmutation of matter exhibited in organic substances.

enables him to ascertain the simple elements which exist in gum or sugar, he cannot, by the union of hydrogen, oxygen, and carbon, in the same proportions in which they constitute these apparently simple compounds, form similar ones; but water and carbonic acid, only, result from his combination. If the simplest products of vegetable organization cannot be imitated by man, much less can he produce any action which bears the remotest analogy to that of the mysterious principle of life. Every plant and animal may be considered as a laboratory, in which a presiding genius is carrying on a process of transmutation wholly unintelligible to those who behold the result. Out of the dust of the earth springs a beautiful plant, which drinking in the most offensive vapors, exhales the sweetest fragrance, and glowing with bright, or delicate tints, forms a strong contrast with the dark unsightly soil which gave it birth. The same elements moreover go to form the calyx, petals and pollen of the flower, with its stem, leaves and roots. Where is the chemist who can explain the cause of the various colors, texture and odor of these different organs, all resulting from the same elements, placed in the same circumstances of air, moisture, light and heat?

In the young infant, how rapidly does milk become changed into fleshy fibres, and cellular membranes, giving roundness and beauty of outline to the limbs, while at the same time it is adding hardness to the incipient bones, and firmness to the unstrung muscles!

744. Animal and vegetable substances are all decomposed by a red heat, and most of them at a temperature much below this. When heated in the open air, or with substances which yield oxygen freely, as the *oxide of copper*, for example, they burn, and are converted into water and carbonic acid; but if exposed to heat in vessels from which atmospheric air is excluded, very complicated products ensue. A compound consisting only of carbon, hydrogen, and oxygen, yields water, carbonic acid, carbonic oxide, carburetted hydrogen of various kinds, and probably pure hydrogen. Besides these products, some acetic acid is commonly generated, together with a volatile oil which has a dark color and burnt odor, and is hence called *empyreumatic oil*. A substance containing nitrogen only in addition to carbon, oxygen and hydrogen, yields ammonia, cyanogen, and probably free nitrogen.

745. Organic products are distinguished by the following characteristics:

744. Decomposition of animal and vegetable substances.

745. Characteristics of organic products.

1. They are composed of the same elements.
2. They readily undergo spontaneous decomposition.
3. They cannot be formed by a direct union of these principles.
4. They are all decomposed at a red heat.*

746. Every distinct compound which exists ready formed in organic bodies is called a *proximate* or *immediate principle*, in distinction from the *ultimate* elements, which remain when these principles are reduced to their simplest parts. Thus gum and turpentine are among the *proximate principles* of plants, gelatin and albumen among those of animals. Carbon, oxygen, &c. are the *ultimate elements*.

VEGETABLE CHEMISTRY.

747. The proximate principles of plants are either confined to a particular part, or distributed over the whole, thus *pollenin* is found only in the pollen of flowers, while *sugar* exists in the juices diffused throughout the whole body of many plants. There are various methods of procuring these proximate principles. The sap of the sugar maple, cane and beet yield sugar on being concentrated and evaporated by boiling. *Starch* is made by mechanical division of the potatoe, corn, and some other leguminous plants, and then washing the particles in which it exists, in pure water. On letting the water stand, the starch subsides. *Volatile Oils* are obtained by distillation. More than forty vegetable proximate principles have been discovered.

748. There are still many difficulties in the way of an accurate analysis of vegetable principles, though this subject has within a few years received much attention. The observations of Gay Lussac and Thenard, led them to form the following general conclusions with respect to the constitution of vegetable substances. 1. A vegetable substance is always *acid*, when the oxygen, in relation to hydrogen is in greater proportion than to form water, or in other words when oxygen is in excess.

2. When hydrogen is in excess, or when the oxygen is in relation to it, in a less proportion than is necessary to form water, the body is resinous, oily, or alcoholic.

3. When the oxygen and hydrogen are in the proportions to form water, or neither in excess, the body is neither acid, resinous, oily, &c., but saccharine, as sugar; mucilaginous, as gum, &c.

* Turner.

746. Distinction between proximate principles and ultimate elements.

747. Situation of the proximate principles of plants. Number of vegetable proximate principles.

748. Conclusions of Gay Lussac and Thenard respecting the constitution of vegetable substances.

749. In conformity with these views of the French chemists, a classification of proximate principles has been made by Turner. "These laws," he remarks, "are not rigidly exact, nor do they include the vegetable products containing nitrogen, but for want of a better principle of classification I shall follow M. Thenard in making them to a certain extent the basis of my arrangement."

Division of proximate principles.

1. Vegetable acids.
2. Vegetable alkalies.
3. Oils, resins, alcohol; substances with an excess of hydrogen.
4. Sugar, starch, gum, &c., when hydrogen and oxygen are in proportions to form water.
5. Compounds which are not known to belong to the other divisions, as coloring matter, tannin, &c.

VEGETABLE ACIDS.

750. The vegetable acids are composed of oxygen, hydrogen and carbon; they redden blue vegetable colors, have mostly a sharp taste, and neutralize salifiable bases, forming salts.

The names of these acids are generally derived from the vegetables in which they exist in the greatest quantity. They are decomposed by heat, or by hot nitric acid. The products of their decomposition are carbonic acid and water.

751. *Acetic Acid.* Of all the vegetable acids this is the most extensively used. It exists ready formed in the fruit of the *Phus typhinus* (sumach,) *Sambucus nigra* (elder,) and the sap of many plants, either free or combined with lime, or potassa. It is one of the principal products of the acid fermentation. It gives to vinegar its sourness. Besides acetic acid vinegar contains more or less water, mucilaginous matter, alcohol, and various salts in solution.

In France, vinegar is made by exposing wine to the acid fermentation, in England, malt liquors are used for this purpose, and in the United States, most of the vinegar is made from cider. As oxygen is here the acidifying principle, the cider should be placed where the sun and air may have access, and be furnished with some of the *mother of vinegar*, a mucilaginous, whitish, ropy substance which is usually found at the bottom of strong vinegar. This substance seems equally necessary in hastening the acetous fermentation of cider, as yeast is in promoting the vinous fermentation of bread. The vinegar from wine contains a certain portion of the bitartrate of potassa which may be obtained by evaporation. Vinegar as obtained

749. Turner's classification of proximate principles.

750. General characteristics of vegetable acids. Number. Derivation of the name of these acids. Decomposition, &c.

751. Acetic acid. Vinegar. Making vinegar. Wine vinegar. Distillation. Freezing, &c.

pure by distillation, forms acetic acid. When vinegar is exposed to severe cold, some of its water freezes, and it becomes stronger, or more like pure acetic acid.

752. Acetic acid is also obtained by purifying the *pyroligneous* or empyreumatic acid, which is procured from the carbonization of wood in close vessels. On being distilled, a brown transparent liquid is obtained, having a strong smell of smoke. This pyroligneous acid is beneficial in the preservation of meat, to which it imparts a flavor like that obtained in the common process of smoking.

Pure acetic acid is obtained from the binacetate of copper, (crystalized verdigris,) and from the acetates of potassa and soda. The acetate is distilled with sulphuric acid, which, uniting with the base, disengages acetic acid.

753. *Properties.* Acetic acid is very volatile, has a sour taste, and other acid properties; its odor is refreshing, and hence vinegar is often burnt in sick rooms. Its crystals contain one equivalent of acid with one of water. The strongest acid is a hydrate; it cannot be obtained without a portion of water. According to the late analysis of Leibig, acetic acid is composed of the following elements, Car. 4, Hyd. 4, Ox. 4.*

754. Acetic acid acts readily on ammonia and most of the metallic oxides, forming salts called *acetates*.

Acetate of ammonia is used in medicine under the name of *spirit of minderus*; it is obtained by saturating carbonate of ammonia with acetic acid. The *acetates* of soda and potassa, are employed for obtaining acetic acid. They may be prepared by neutralizing potassa and soda with distilled vinegar. The acetate of potassa exists in the sap of many plants. The acetate of alumina is used by dyers and calico printers; that of *baryta* as a re-agent in Chemistry.

Acetate of Copper furnishes the green paint known as *verdigris*; this may be obtained by exposing metallic copper to the vapor of vinegar; the metal first oxidizes by the action upon it of the oxygen of the air, and the oxide then unites with the acid. There are several definite compounds of copper and acetic acid.

Acetate of lead is made by distilling the carbonate of lead, or litharge in distilled vinegar. It has a sweetish taste, and is known as *sugar of lead*. It is much used in medicine, and in the arts.

OXALIC ACID.

755. So named from the *Oxalis acetosella*, or wood-sorrel,

* The numbers denote equivalents.

752. Pyroligneous acid. Acetic acid obtained by the distillation of acetates.

753. Properties of acetic acid. Its constituent elements.

754. Acetates. Acetate of copper. Acetate of lead.

where it was first discovered by Scheele combined with potassa, forming the salt called *oxalate of potassa*.

Oxalic acid may be obtained by heating nitric acid in a retort with sugar, starch, alcohol or most vegetable acids. It is much used to remove colors occasioned by the oxides or salts of iron. The strong sour taste of this acid is apparent in the different species of sorrel; the bruised green leaves of these plants, on account of the presence of this acid, are efficacious in removing stains, and iron rust from linen. In combination with lime, oxalic acid exists in the leaves of the garden rhubarb. It acts as a poison on the animal system.

Its crystals contain 4 equivalents of water ($9 \times 4 = 36$) with one equivalent of acid 36, their equivalent number is therefore 72. "It is singular," says Silliman, "that this powerful acid in firm crystals should be midway between the two gases carbonic acid and carbonic oxide, and it may even be regarded as composed of 1 equivalent of carbonic acid, 22, and one of carbonic oxide, $14 = 36$. It has the composition of a mineral acid, and it has been proposed to call it the *carbonous* acid which its composition would fully justify."

The combination of oxalic acid with salifiable bases forms salts called *oxalates*, and sold under the name of salts of sorrel and salts of lemon; the latter name however belongs to the nitrates, which we have yet to notice. The *binoxalate* of potassa, called *salt of sorrel* is used to remove stains of iron and ink. One equivalent of the acid gives to the iron forming a soluble *oxalate* of iron, and leaving a soluble oxalate of potassa. The *quadroxalate* of potassa is obtained by digesting the binoxalate with nitric acid, which, uniting with half the base, leaves the other half combined with the whole of the oxalic acid, of which there are now four proportions with one of potassa. If, of 4 parts of this salt, 3 are decomposed, the disengaged potassa can be exactly saturated with the acid which may be obtained by the decomposition of the 1 remaining part.

The nature of the oxalates of potassa beautifully illustrates the law of multiple proportions. Their composition is as follows.

	Equiv. or base.	Equiv. of acid.	Base.	Acid.	Equiv.
Oxalate contains	1	+	1 = 48	+	36 = 84.
Binoxalates	" 1	+	2 = 48	+	72 = 120.
Quadroxalates	" 1	+	4 = 48	+	144 = 192.

TARTARIC ACID.

756. Was first obtained from *cream of tartar*, (*bitartrate of potassa*,) from whence it received its name. It exists in the tama-

755. Name, discovery, &c. of oxalic acid. Method of obtaining it. Uses, &c. Composition of its crystals. Oxalates. Binoxalate of potassa. Quadroxalate of potassa. Composition of the oxalates of potassa.

756. Tartaric acid, derivation of its name, plants in which it exists, &c. Mode of obtaining it. Properties. Pyrotartaric acid. Double salts.

rind, pine apple and many other acidulous fruits, also in balm, sage, and probably sumach.

It is obtained by decomposing the bitartrate of potassa by carbonate of lime. Carbonic acid goes off with effervescence, and one equivalent of the insoluble tartrate of lime is precipitated, while one equivalent of the neutral tartrate remains in solution. The precipitate is washed and then mixed with water containing some sulphuric acid; the latter by uniting with the base of the tartrate, disengages tartaric acid, which when filtered and evaporated is obtained in prismatic crystals.

Tartaric acid possesses strong acid properties. It is used in fevers as a cooling drink. With soda, it forms an effervescing mixture, the *tartrate of soda*.

This acid is remarkable for its tendency to form *double salts* among which are the *tartrate of antimony and potassa*, or the *tartar emetic* of medicine; and the *tartrate of potassa and soda*, or *Rochelle salt*. *Pyrotartaric acid* is the result of destructive distillation of tartaric acid.

757. *Bitartrate of potassa, cream of tartar* exists in the juice of the grape, and is found lining the sides and bottom of wine casks. Owing to the insolubility of this salt in alcohol, it is gradually deposited during the vinous fermentation, especially of the red wines. In a crude state, it is called *wine stone*. This crude tartar is purified by dissolving, filtering, and crystallizing. White crystals are skimmed off the surface of the solution, these are called *cream of tartar*. Its peculiar sour taste is well known, and it has other acid properties. It is valuable in medicine, and is composed of 2 equiv. of acid and 1 of base.

758. *Tartrate of potassa or soluble tartar*, was formerly used in medicine, under the name of *vegetable salt*.

759. *Citric acid* is named from the genus of plants, *Citrus* containing the orange and lemon.

It may be obtained by pouring lemon juice upon chalk, and decomposing the *citrate of lime* thus formed, by sulphuric acid. The sulphate of lime being insoluble, is separated from the liquid citric acid by filtering. Large transparent crystals are obtained by evaporating the liquid.

It is used as a substitute for lemon juice, and for effervescing draughts with the carbonates of soda; the effervescence is caused by the escape of carbonic acid gas, and the liquid is then a solution of *citrate of soda*. Spots caused by iron and ink are removed by citric acid. Its crystals are remarkable for not being affected by the air. When heated, they suffer the watery fusion, the acid decomposes and a peculiar compound called *hydro-citric acid* sublimes. Scheele first ascertained that the sourness of the lemon and lime were owing to the presence of the peculiar acid, now called the citric. This is often combined with malic acid in red fruits. The only *citrate* known to exist in nature is that of lime, which is found in very small quantities in fruits containing citric acid.

760. *Malic acid* is contained in the apple, *Pyrus malus*. It

757. Bitartrate of potassa.

758. Tartrate of potassa.

759. Citric acid, how obtained. Uses. Crystals, &c. Citrate of lime.

760. Malic acid. Malates. Cause of the specific flavor of fruits.

exists in the juices of the cherry, strawberry &c. It may also be obtained by digesting sugar with three times its weight of nitric acid.

Its salts are called *malates*. When sheet lead is steeped in apple juice, *malate of lead* is formed. The malates are usually distinguished from the citrates in being more soluble. Malic, citric and tartaric acids, together with sugar, mucilage and some other principles, give their flavor to fruits, and according as one or the other acids, or sugar prevails, is their specific flavor. In the lemon, citric acid is greatly in excess; in the orange, it is generally neutralized by sugar. In sour apples, malic acid is in excess; in the whortleberry and strawberry malic and citric acids exist in nearly equal quantities, with a large proportion of sugar. In the grape the tartaric acid is in excess. As fruits ripen, they usually contain a larger proportion of sugar.

761. *Benzoic acid* is obtained from *benzoin*, the gum of the *Styrax benzoe*, a plant of the East Indies. It is also found in castor, cinnamon, in some volatile oils, in the flowers of the *Trifolium melilotus*, and other vegetables as well as some animal substances. Its taste is rather sweetish, but it is decidedly acid in its effect on vegetable colors, and with alkalis. Its crystals are white with a silky lustre. It gives to the *paregoric elixir* its taste and peculiar aromatic odor. It burns with a yellow flame. Its salts are called *benzoates*.

762. *Gallic acid* was first discovered by Scheele, in 1786, in gall-nuts, or the excrescences found upon the leaves of a species of oak, supposed to be occasioned by the puncture of an insect whose egg is often found in the center of the nut. The nuts are about the size of a pigeon's egg, of a brown color and uneven surface. They are known in commerce as nut-galls, and are used in domestic coloring to produce slate color and black. Gallic acid, at first supposed to be peculiar to the *gall* nut, is now known to be associated with tannin in the barks of most trees, and in astringent vegetables.

It is an important test with the metals. It precipitates iron deep black, and with tannin forms the basis of ink and black dyes. Ink is a mixture of the *gallate* and *tannate* of iron, and is soluble in the acid which is always present in this fluid; thus, when ink becomes thick, we dissolve it by adding weak

761. Plants which contain benzoic acid. Properties. Salts. Benzoates.

762. Discovery of Gallic acid. Gall nuts. Substances containing gallic acid. Scheele's method of obtaining this acid. Crystals and properties of gallic acid. Ink. Cause of the stains made by tea on knives, &c. Distinction between gallic acid and tannin. Gallates.

vinegar. The black stains caused by tea, on knives and other iron or steel utensils, are owing to the action of gallic acid and tannin, upon iron. Gallic acid is distinguished from tannin by giving no precipitate in a solution of gelatine. The salts of this acid are called *gallates*. The *pergallate* of iron is blue, the gallates of potassa and soda are colorless.

763. *Ellagic* (*ellagique*) acid was so named by the French Chemist Beaconnot, by an invasion of the word *galle* (gall.) Thenard supposes that it forms salts with the alkalies, which he terms *ellagates*; he considers that there is a neutral ellagate of potassa, which is soluble and greens vegetable blues; and an acid ellagate which is white and insoluble. He suggests that the ellagic acid does not exist in the gall-nut, but is formed during the preparation of gallic acid when tannin decomposes by contact with the air.

764. We have now described the most important of the vegetable acids, many of which are indispensable in manufactures and the arts. There are others which are less known; as, *Mucic* or *saccholactic acid* (so called from *mucus*, gum) which was obtained by Scheele, by the action of nitric acid on gum, sugar or milk,* &c. The precipitate is in the form of a white, gritty powder, with feeble acid properties. When decomposed by heat, it yields, besides the usual vegetable products, a white sublimate called *pyromucic acid*. The *saccholactates* have been little studied. This acid belongs both to animal and vegetable compounds.

765. *Pectic acid* derives its name from the Greek *pectis*, coagulum, being remarkable for its tendency to coagulate or to exist in a gelatinous form. It was first obtained by Beaconnot from the pulp of carrots, boiled with potassa; the alkali unites with the pectic acid and forms a gelatinous mass which is the *pectate* of potassa. On adding an acid, the pectate decomposes, giving up its base to the new acid, and disengaging pectic acid in the form of jelly, which is insoluble in cold water.

766. *Indigotic* and carbazotic acids are obtained by the action of nitric acid on indigo. When indigo is boiled in diluted nitric acid, carbonic, prussic and nitrous acids are evolved, and in the liquid, besides carbazotic acid, resinous matter, &c., a peculiar acid is found called by Chevreul the *acid of indigo*.

The *carbazotic acid* appears in yellow crystalline scales. It acts like a strong acid upon metallic oxides, forming salts called carbazotates. The *indigotic acid* changes to carbazotic by the action of strong nitric acid, disengaging carbonic acid and nitrous acid fumes, and producing a small portion of oxalic acid. The change appears to depend on the loss of both carbon and oxygen; the composition of the two acids appear to be as follows: Indigotic acid, Car. 15 equiv. ox. 10, nit. 2. Carbazotic acid, Car. 10, equiv. ox. 10, nit. 2.

The name carbazotic is derived from carbon and azote, the latter being the name by which French chemists usually designate nitrogen.

* The word saccholactic is derived from *saccharum* sugar, and *lacte* milk.

763. Origin of the name *ellagic acid*. Ellagates. Thenard's opinion of the production of ellagic acid.

764. Mucic or Saccholactic acid.

765. Pectic acid.

766. Mode of obtaining indigotic and carbazotic acids. Properties of these acids. Change of the indigotic to the carbazotic acid. Composition of the two acids. Derivation of the name carbazotic.

767. *Succinic acid* is named from *succinum*, amber, from which it is obtained. It was formerly called *salt of amber*. When powdered amber is heated in a retort, the acid sublimes, and is condensed in the receiver. It crystallizes into anhydrous prisms. Its salts are called *succinates*.

Camphoric acid is the product of the action of 14 parts nitric acid, with 1 of camphor, at the temperature of 77° F. Its salts are called *camphorates*.

768. *Moric* or *moroxylic acid* is found combined with lime in the *morus alba* or white mulberry. *Kinic acid* exists in combination with lime in the cinchona. (Peruvian bark.) *Meconic acid* is combined with morphine in opium. *Zumic acid*, from *zume*, yeast, was discovered by Beaconnot in vegetable substances which have passed through the acetous fermentation; from more recent observation it appears not to be essentially different from acetic acid.

Hydrocyanic or *prussic acid*, exists in many plants, as bitter almond, peach leaves and blossoms, &c.

Rheumic acid was formerly supposed to exist as a distinct acid in the garden rhubarb. (Rheum). It is now considered as identical with the oxalic acid. *Boletic acid* is a peculiar substance discovered by Beaconnot in mushrooms, called familiarly *touch wood*,—in Botany *Boletus igniarius*. *Suberic acid* is procured from the cork plant. (*Quercus suber*.)

We might extend our list of vegetable acids; but it is highly probable that future discoveries may greatly reduce their number, by showing many of those which are now considered different to be the same, modified by peculiar circumstances; on the other hand, it is very possible that acids may be discovered whose existence is now unknown.

CHAPTER XXXII.

VEGETABLE ALKALIES, OILS, RESINS, &c.

769. By the name vegetable *salifiable* bases, or *alkalies*, is designated the proximate principles of certain vegetable substances, which united with acids, saturate them in a greater or less degree, and form with them combinations, which may, properly, be called salts.

The discovery of these vegetable bases was made by M. Sertuerner, in 1805, in some experiments upon opium. But his publication of the discovery, attracted little attention, until some new communications of the author awakened chemists to the nature and importance of the subject. Such researches have now been made, as prove that the property possessed by many vegetable substances, of acting powerfully on the animal economy,

767. Succinic acid. Camphoric acid.

768. Moric acid. Kinic acid. Meconic acid. Zumic acid. Hydrocyanic or prussic acid. Rheumic acid. Boletic acid. Number and distinctive characters of vegetable acids not entirely settled.

769. Description of vegetable alkalies. Their discovery by Sertuerner. Chemists awakened to the importance of the discovery.

is owing to the presence of peculiar active principles, and that to obtain those, separate from a mass of useless, or mere counteracting matter, is a great desideratum in medicine.

770. For example; the Peruvian bark, *cinchona*, had long been in high repute for its medicinal powers; but it was evident that, combined with the energetic principle of the bark, were others, such, for instance, as tannin and woody fibre, which could not aid in producing the desired specific effect, that to crowd the weak stomach with useless or hurtful substances in order to introduce a medicinal one, was contrary to the dictates of common sense as well as the principles of science. With this important and definite object in view, two French chemists, Pelletier and Caventou, commenced a series of experiments with *cinchona*, which resulted in the discovery of its active medicinal principle. This they called *quinine*. A small quantity of this concentrated alkali produces powerful effects on the human system, particularly in intermitting fevers, and other diseases.

771. The vegetable alkalies are not found free in nature, but exist in plants, combined with acids forming natural salts, more or less soluble in water. In order to obtain the alkaline principle, the vegetable substance is digested in water, and the salt being thus dissolved, some powerful salifiable base, as ammonia or potassa is added. This uniting with the acid, leaves the alkali free; the latter being insoluble in water may be obtained by precipitation.

Properties. Vegetable alkalies are soluble in hot alcohol, and crystalize on cooling. They are solid, bitter or acid, inodorous, change blue vegetable colors green, and are heavier than water. When decomposed by fire, they yield ammonia; this is formed by the carbon and nitrogen,* which, with hydrogen and oxygen, constitute their ultimate elements. They form combinations with sulphur, and are soluble in chlorine and iodine. When salts with vegetable bases are decomposed by the voltaic pile, the alkali appears at the negative, and the acid at the positive pole.

772. *Morphia* or *morphine*, so called from Morpheus, (known in heathen mythology as the God of sleep) is the narcotic principle of opium, in which it exists combined with meconic acid. Opium is the dried juice of the poppy, and besides *meconic acid*, contains various principles, as *narcotine*, gum, resin, lignia, oil, and caoutchouc or gum elastic. *Morphia* in most cases, acts on the animal system as a violent poison; but did it meet with no acids in the stomach, it would be inert on account of its insoluble nature;

* Nitrogen was formerly considered as a distinctive character of animal matter; it is now known to exist in many vegetable compounds, though more sparingly than in animal.

770. Combination of the medicinal principle of the Peruvian bark, with useless or hurtful matter. Discovery of quinine.

771. Method of obtaining the alkaline principle of plants. Properties of vegetable alkalies.

772. *Morphia*, with what acid combined. Various principles of opium. Antidotes to the poison of *morphia*. Uses. Acetate.

thus experiments have given different results, as the stomach of the animals into which it has been introduced have contained more or less acid.

When morphia has been taken in too large quantity, a solution of ammonia may decompose the soluble salt, formed by it with the acetic and other acids in the stomach, and the vegetable alkali will thus be precipitated in an insoluble state. Ammonia and other alkalies are recommended in cases where laudanum or any preparation of opium is taken in excess; they decompose the meconate of morphia, which is the active principle and produce an insoluble precipitate of morphia. Infusions of coffee and nut-galls counteract the effects of morphia, by forming with it insoluble compounds.

When properly used, morphia is a highly valuable medicine; it is said to "produce the soothing effects of opium, without causing the feverish excitement, heat, and headache which so often accompany the use of that drug." The acetate of morphia is very soluble, and the most active of the salts of this alkali. The constituent elements of morphia are, Car. 34, Hyd. 18, Nit. 1, Ox. 6, =284.

773. *Meconic acid*, so called from the Greek *mekon*, poppy, is sour and bitter; it reddens vegetable colors and gives a red tint to the persalts of iron and an emerald green to sulphate of copper. It seems inactive with respect to the animal system. The meconate of morphia, therefore, must owe its energetic action to the increased solubility of morphine in the state of a salt.

774. *Narcotine* is an independent principle which, though not alkaline we shall here notice on account of its association with meconic acid and morphia. The powerful effects of opium have been attributed to narcotine. Acids mitigate its power; and this appears to explain the use of vinegar in counteracting some of the effects of opium, and also the comparative mildness of the *black drop*, in which the narcotine is in solution in vinegar, nitric or tartaric acid."

775. The medicinal property of the *Peruvian bark* is found to reside in two alkalies, the *cinchonia* and the *quinia* or *quinine*; the former exists in the pale bark, quinia in the yellow bark; while both are contained in the red bark. These two vegetable alkalies are found to bear to each other much the same relation as potassa and soda relatively sustain; they exist in combination with *kinic acid*. Quinine is mostly used in the form of a sulphate. According to the latest analyses, these two alkalies are constituted as follows, *Cinchonia*, Car. 20, Hyd. 13, Nit. Ox. $1\frac{1}{2}$ =158. *Quinia*, Car. 20, Hyd. 1, Nit. Ox. 2=162.*

776. *Strychnia* is an intensely bitter alkali obtained from the *Strychnos nux-vomica*, and exists in the Upas tree of Java; it is a deadly poison.

Brucia was discovered in the *Brucia antidysenterica*; it has since been found in the plants which yield Strychnia, and resembles that alkali in its poisonous properties, but is less active.

Sanguinaria has been discovered in the *sanguinaria canadensis* or blood root. The medicinal virtues of the blood root are said to exist in this alkaline principle.

* For explanations of *chemical signs* see the Author's Dictionary of Chemistry.

773. Meconic acid.

774. Narcotine.

775. Medicinal properties of the Peruvian bark, &c. Constituent elements of cinchonia and quinine.

776. Strychnia. Brucia. Sanguinaria. Veratria. Emetia. Codeia. Cania. Parilla.

Veratria is the medicinal principle in the white hellebore, *Veratrum album*, and the *Colchicum autumnale* or meadow saffron, plants which have a peculiar acid nature caused by the union of the alkaline principle with gallic acid.

Emetia is the alkaline principle which gives ipecacuanha its emetic properties.

Codeia was discovered in 1832 by Robiquet in the hydrochlorate of morphia. *Conia* is the active principle of the *Conium maculatum*. *Parilla* is found in sarsaparilla.

777. Almost every plant distinguished for energetic action will probably be found to owe its powers to some peculiar alkaline principle. Thus in the *Atropia belladonna* or deadly night shade, has been discovered *atropia*, which, with acids forms salts of a peculiar kind, giving off from their watery solutions vapors which produce giddiness, violent headache, and dilatation of the pupil of the eye. From the black henbane, *Hyoscyamus niger*, is obtained an alkali called *Hyosciamia*. From the Digitalis or fox glove, is obtained digitalia which seems to possess the concentrated medicinal virtues of the plant; and from the Datura Stramonium, is obtained the alkali daturia. These vegetable alkalies were at first distinguished by the termination *ine*, as *quinine*, *morphine*, *emetine*, &c. But the termination in *a*, is generally adopted, as being in conformity with the names of other alkaline substances, potassa, soda, magnesia, &c.

Vegetable substances which contain Hydrogen in excess.

778. Substances which contain an excess of hydrogen are generally oily, resinous, alcoholic or etherial; being also abundant in carbon, they are very fusible and combustible. When heated in a retort many of them volatilize without any change in their constitution, others decompose, producing large portions of oil and a carbonous residuum. When exposed to a high temperature in a porcelain tube, they all suffer ultimate decomposition, produce carburetted hydrogen gas, carbon, and oxide of carbon. Most of these substances are insoluble, or nearly so, in water, but very soluble in alcohol.

OILS.

779. *Oils* are of two kinds, *fixed* or *fat oils*, which are not volatile, and give a permanently greasy stain to paper: and *volatile* or *essential oils*, which, when dropped on paper, may be dissipated or volatilized by a gentle heat.

Fixed Oils.

780. *Fixed Oils* are chiefly obtained from the seeds of plants,

777. Peculiar alkaline principles of plants. *Atropia*. *Hyosciamia*. *Digitalia*. *Daturia*.

778. Nature of vegetable substances which contain hydrogen in excess. Effects of heat upon these substances.

779. Two kinds of oils.

and mostly from the dicotyledonous kinds; as the almond and various kinds of nuts, linseed, &c. The oil of olives or common sweet oil, is extracted from the pulp which surrounds the olive nut. These oils are usually procured by subjecting to great pressure the crushed seed or pulp, gently heated, it may also be procured by the action of boiling water upon the pulverized oily seeds.

Properties. The fixed oils, with few exceptions, are fluid at the common temperature. They usually swim on water, but sink in alcohol. They combine with alkalies or metallic oxides, forming soaps which are soluble or insoluble according to the nature of the oxide. When exposed to the action of the atmosphere they absorb oxygen, become thick and rancid, and redden vegetable blues. Such as dry so hard as not to stain paper are called *siccative* or drying oils; linseed oil is of this kind, and hence its use in painting. Drying oils, mixed with lamp black, form printer's ink. During the drying process large portions of oxygen are absorbed. This absorption is sometimes so rapid, and causes the disengagement of so much free caloric, that light, porous, combustible matters, such as lamp black, hemp, cotton and the like may be kindled by it. "Substances of this kind moistened with linseed oil, have been known to take fire or produce spontaneous combustion within 24 hours, a circumstance which has been repeatedly the cause of extensive fires in ware houses and cotton manufactories." (Turner.)

Though fixed oils do not unite with water, they may be suspended in it by the aid of sugar or mucilage, forming an *emulsion*. Sulphur and phosphorus aided by heat, dissolve in the fixed oils; and the solution with sulphur may be crystalized on cooling. Iodine and chlorine absorb a portion of the hydrogen of the fixed oils, and form hydriodic and hydrochloric acids. Potassium and sodium have little action upon these oils; though in time they absorb a small portion of their oxygen, and when oxidated thus form with them a soapy compound. Sulphuric acid thickens the fixed oils; strong nitric acid acts so forcibly upon them as sometimes to produce combustion. Oxide of lead or litharge, heated with oil produces a drying liquid used as *oil varnish*; olive oil, with the same oxide, forms the *diachylon plaster*. Oils aid in the oxidation of metals; oiled copper soon becomes green, showing the presence of the carbonate of copper.

Soaps of various kinds are formed by the union of oils with alkalies. *Volatile liniment* is a mixture of ammonia and olive oil. Common domestic *soap* is made of animal oil or fat combined with alkali; but the finer kinds of soap are often made with vegetable oils.

781. The principal fixed oils are *linseed* oil, obtained from flax-seed, and used with litharge for paints, varnishes and printer's ink; *olive oil*, from the fruit of the olive tree; (the purest kind being used for the table, the inferior for soap and for lights); *almond oil* used in medicine; mustard seed and sunflower seed oils are cheap and much used by leather dressers; *oil of bean* from the seeds of an East Indian plant is used for absorbing the volatile oils of aromatic plants. The perfumed oil is dissolved in alcohol, and water is added to the mixture; the alcohol uniting with the water, disengages the

780. Fixed oils, from whence obtained, &c. *Properties.* Drying oils. Effects sometimes produced by the rapid absorption of oxygen, by these oils. *Emulsion.* Action of sulphur, phosphorus, iodine and other substances with the fixed oils. Effect of oils with metals. Soaps, volatile liniment, &c.

781. Principal fixed oils.

volatile oil which floats on the top, and may be collected for the perfumer. *Palm oil* is used in warm countries for food, and exported for medicinal purposes, and to form the finer kinds of soap. *Cocoa butter* is not liquid at the common temperature, it has the flavor of chocolate. *Castor oil* from the *Ricinus communis* is very valuable in medicine. It does not congeal, but at a temperature much below zero.

782. The volatile oils are the aromatic principles of plants which sometimes are confined to the flower, leaves, bark, or root, and sometimes diffused through the whole: but seldom contained in the cotyledons of seeds which furnish most of the essential oils. These oils may be obtained by distilling the plant with water.

The operation of distilling plants is as simple as that of making fruit preserves, and might furnish an agreeable and feminine employment. Every lady may manufacture *rose-water* of a much better quality than that which is generally sold. A small distilling apparatus may be placed over a portable furnace, with a quantity of water and rose petals in the boiler; the aromatic principle of the rose passes over with the distilled water into the recipient. This product should be returned to the boiler and a new portion of the rose petals added, and a stronger product is next obtained. The operation must be repeated, several times, before the water will become strongly impregnated with aromatic properties. The *essential oil of the rose* will appear when the water is cool, in very minute quantities on the surface. But the proportion of oil in this flower is so small that great quantities of its petals are requisite for obtaining a very little oil. As the rose petals drop off, they may be collected and dried, or preserved by putting them into a large vessel and sprinkling them with salt. The salt will not come over with the product of distillation, nor disengage its elements. Other aromatic plants may be distilled in a similar manner. In India the oil, or *attar of roses*, is obtained by filling large casks with rose petals, covering them with water, and placing them in the sun, after a few days, particles of oil appear floating on the surface. These are collected and put into the small bottles, which are sold in the shops. In some cases, as in the rose, jessamine and lily of the valley, the water which passes into the recipient in distillation will be strongly impregnated with the aroma of the plant, while no oil may appear on its surface when cold. Thus, rose-water, though not visibly containing any oil, owes its aromatic property to a very small portion of essential oil, dissolved by the water, in the distilling process.

783. Essential oils much diluted with alcohol, are called *essences*; twenty or thirty drops of essence do not usually contain more than two or three drops of the essential oil; in medicine, therefore, it is important to distinguish between the two, as over-doses of the volatile or essential oils will produce convulsions, and even death. The strong odor of flowers in a confined room is unhealthy, on account of exhalation of volatile oils.

Properties. These oils are generally more energetic than the fixed oils; they are odoriferous, with a hot aromatic taste.

782. Situation of the volatile oils in plants. How obtained? Manufacture of rose-water. Attar of roses.

783. Essences. Properties of volatile oils. Principal volatile oils, &c.

They are colorless, yellow, green or blue, very volatile and inflammable; they readily absorb oxygen from the air, and become thick. They do not easily combine with salifiable bases. With nitric acid they often inflame and burn brilliantly. The most important of the volatile oils are those of turpentine, cloves, nutmeg, lavender, cinnamon, peppermint, annise, and chamomile.

784. The oil of *turpentine* is procured by distilling turpentine. When purified it is called *spirits of turpentine*. *Camphor* may properly be ranked with the essential oils, as it is odorous, inflammable and volatile. The camphor of commerce is chiefly extracted from the *Laurus camphora*, which grows in Japan and the East Indies. The camphor is obtained in the form of green, porous masses. *Crude camphor* is purified by sublimation. Its odor is strong, but agreeable and refreshing, and its taste acid and pungent. It is soluble in alcohol and ether. It burns brilliantly in oxygen gas, producing camphoric and carbonic acids. It is lighter than water, its specific gravity being 0.980. It is insoluble in water. When a few drops of a solution of camphor in spirits is put into a tumbler of water, the water and spirits unite and camphor is precipitated. Proust obtained a crystalline product from thyme, and some other labiate flowers, which he supposes differs little from camphor. Camphoric acid which results from the action of nitric acid on camphor, unites with salifiable bases forming salts called *camphorates*. *Coumarin* is a peculiar, odoriferous, volatile principle derived from the *Coumarouna odorata* or Tonka bean.

RESINS,

785. Are the thick juices of certain plants, and are often found combined with essential oils, which give them their peculiar taste and odor, and render them soft. The resins are non-conductors of electricity, but become negatively electrified, on being rubbed. Exposed to the action of fire, they burn with a yellow flame and much smoke. They are insoluble in water, but soluble in alcohol, oils, and solutions of potassa and soda. With the two latter they form a kind of soap. They are not decomposed by air. Nitric acid rapidly decomposes them, much gas is disengaged, and a compound results which resembles tannin.

786. The resin of pine has been analyzed by Gay Lussac and Thenard, 100 parts of which were found to contain Carbon, 75.944; Hydrogen, 10.719; Oxygen, 13.337.

The juice of the different kinds of pine, called *turpentine*, consists chiefly of resin combined with the volatile oil of turpentine. The resinous products of the different species of cone-bearing trees are distinguished by various names. *Common turpentine* is obtained by making incisions in the pine trees, and hardening the juice which flows out by exposure to the air and sun. *Burgundy pitch* is from the Norway spruce and larch. *Tar* is melted out from the resinous trees by a smothered fire resembling a coal pit. *Lac* is a

784. Oil of turpentine. Camphor. Coumarin.

785. Cause of the peculiar taste of the resins. Properties of resins. Composition.

786. Resinous products of the pine. Lac. Copal. Amber.

red concretion caused by the puncture of an insect upon the branches of the banyan, fig, and *Rhamnus jugaba* of the East Indies. It consists mostly of resin with coloring matter and wax. *Shell lac* contains more resin and less coloring matter than *Stick lac*. Shell-lac, in India, is cast into beads, and other ornaments; it is used for red sealing wax. Stick-lac is used in dyeing. *Copal* is a brilliant, transparent resin which is chiefly used for varnishing. It is brought from South America and the East Indies. It is susceptible of becoming highly electrified by friction. *Amber* resembles copal in appearance; it is supposed to be of vegetable origin, though found in sand. It is sometimes found in beds of bituminous coal, and enveloping vegetable substances. It often contains insects in good preservation. It was in this substance that electrical phenomena were first observed; its ancient Greek name was *electron*. It consists of a volatile oil, *succinic acid*, resin, and a bituminous principle.

787. *Balsams* are resins containing so much essential oil as to render them fluid, or nearly so. They are not proximate principles, but rather consist of several of these principles united; as resin, benzoic acid, essential oil. They are divided into *liquid*, of which the *balsam of copaiba* and *styrax* are examples, and *solid*, as *benzoin* and *dragon's blood*; the latter is used in making red varnish.

788. *Gum resins* contain gum, resin, wax, volatile oil, and extractive matter. They are not therefore distinct proximate principles. The gum-resins are valuable in medicine. Among the most important are *myrrh*, *aloes*, *assafoetida*, *gamboge* and *guaiacum*.

789. *Caoutchouc*, *Indian rubber*, or gum elastic is the concrete juice of the *Urceola elastica*, and *Jatropha elastica*, plants of South America. It is said to have been prepared from the dried juice of the milk weed, (*asclepias*.) It is white, when not blackened by smoke as is common in its preparation; it is soft, flexible, very tenacious and elastic. It melts readily and burns with a bright flame, leaving little residuum. It is insoluble in water, alcohol, alkalies and acids. The volatile oils are its proper solvents. The purified Naphtha from coal tar dissolves it, and being a cheap article may be profitably employed in Indian rubber manufactories. It must contain some nitrogen since by destructive distillation it yields ammonia.

Creosote exists in tar and pyroligneous acid; it is an oily fluid, with an odor of smoke.

790. *Wax* is extensively diffused in nature. It is found as a varnish on the surface of the leaves of plants, in the pollen of flowers, and in many trees. The wax of bees appears not to be wholly of vegetable origin, being composed also of some animal secretion. Huber found that bees which were fed solely on sugar, produced wax in as great quantities, as those which had access to flowers. The berries of the *Myrica cerifera* or *bayberry*, contain large portions of wax; it is aromatic, of a pale green color, and is sometimes mixed with tallow to render candles more firm; it has been called *bayberry tallow*. Wax is usually more or less colored, and may be bleached by exposure to the sun and air, and by the action of chlorine. Thus

787. Balsams.

788. Gum resins.

789. Caoutchouc or Indian rubber.

790. Wax. Wax of the *myrica cerifera*, &c. Properties of wax. Constituent principles of wax, composition,

bees wax which is yellow and has an aromatic smell, becomes, by bleaching very white and destitute of odor. Wax melts at 154° F., it is insoluble in water, dissolves in warm ether and alcohol, but precipitates when cold. It is easily dissolved by the fixed and volatile oils. It has been found to consist of two principles, one of which called *cerin* is soluble, the other called *myricin* is insoluble in alcohol. The composition of bees' wax according to Gay Lussac and Thenard, is in 100 parts; Car. 81.784. Nit. 12.672. Ox. 5.544. According to Liebig, Car. 20, Hyd. 20, O.

CHAPTER XXXIII.

ALCOHOL, ETHER, &c.

ALCOHOL,

791. Is a colorless, volatile liquid, of a strong odor and a burning taste. It is the intoxicating ingredient in all kinds of spirits, wine, cider and beer. It does not exist ready formed in plants, but is the product of vinous fermentation. Fermented liquids have been known from the remotest periods of history; *distilled* liquors were first prepared by an Arabian alchemist in the 10th century, though they were little known, until several hundred years after.

792. On account of its volatile nature, alcohol is readily obtained by distilling fermented liquors. Pure alcohol is called *rectified spirit*, and when supposed to be entirely free from water, *absolute alcohol*. The purity of alcohol is in an inverse proportion to its density. Common alcohol has a specific gravity of about 86, but when freed from water of 82. Thus the specific gravity of spirits is a test of their purity, which is determined by the *hydrometer*.* Alcohol boils at a temperature as low as 176° F. It produces cold during evaporation. No degree of cold has yet been known, with certainty, to freeze alcohol. When half water it freezes at 60° below zero. On account of the property of alcohol to remain liquid at the extreme degree of cold where mercury freezes, it is used in thermometers designed to measure intense cold.

793. As alcohol burns without smoke or residuum, the *spirit lamp* is much used in laboratories. Attempts have been made to introduce alcohol into common use, in the place of oil, for lamps, but its use has been found dangerous, owing to its great inflammability; if accidentally spilled when burning, its whole surface will burst forth into instant flame. The products of

* See the author's Familiar Lectures on Natural Philosophy, page 165.

791. Physical properties of alcohol, &c. Distilled liquors first known.

792. Mode of obtaining alcohol. Rectified spirit and absolute alcohol. Specific gravity. Its boiling point. Effect of its evaporation on surrounding bodies. Freezing point of alcohol. How useful in thermometers?

793. Spirit lamp. Products of the combustion of alcohol. Its use in light-houses, &c.

its combustion are water and carbonic acid. The flame of alcohol directed upon lime or chalk produces a most vivid light, and is therefore much used in light-houses. It may be inflamed by the electric spark.

794. Alcohol dissolves most of the vegetable principles, as the essential oils, resins, balsams, and most of the vegetable alkalies and acids, but not many of the animal oils. It dissolves potassa, soda, and ammonia, but not the earths or metallic oxides. Phosphorus, sulphur, and iodine are sparingly soluble in Alcohol. Chlorine produces with it an oily substance, accompanied with hydrochloric and carbonic acids. This oily matter seems to be a combination of chlorine and percarburetted hydrogen. When equal parts of alcohol and water are mixed, there is an elevation of temperature, and consequent expansion of the liquids; this mixture constitutes *proof spirit*.

795. When alcohol is heated in a porcelain tube, the products of the decomposition are carburetted hydrogen, carbonic oxide and water. According to the analysis of the younger De Saussure, the ultimate elements of alcohol are

Carbon	2	Equiv.=12	parts in 100	52.17
Oxygen	1	" = 8	" "	34.79
Hydrogen	3	" = 3	" "	13.04
Equiv. of alcohol	23			100.00

These elements are in the proportion to form olefiant gas and water; there are 2 equivalents of carbon, 1 of oxygen and 3 of hydrogen. Olefiant gas requires 2 equivalents of carbon+2 of hydrogen. Water requires 1 equivalent of oxygen+1 of hydrogen. According to Liebig's formula the constituents of alcohol are Car. 4, Hyd. 5, Ox.+ Hyd. Ox.=46.

796. It was formerly asserted that alcohol did not exist ready formed in wine, but was generated by heat, during the distilling process. Mr. Brande determined this question by obtaining alcohol from wine without the aid of heat. He precipitated the acid, and extracted coloring matter by the sub-acetate of lead, and then absorbed the water from the alcohol by dry carbonate of potassa. Pure alcohol rose on the surface. The strong wines, Maderia, Sherry, Port, &c. contain from 18 to 25 per cent of alcohol, and cider, ale and porter from 4 to 10 per cent.

797. The action of the *acids* on alcohol produces *ether*. Alcohol also, like water, forms with certain bodies, definite *crystalline* compounds, called *alcoates*.*

When the anhydrous chlorides of calcium, manganese and zinc, or the nitrates of lime and magnesia are heated with anhydrous alcohol, the compound on cooling will assume a crystalline form. A very small quantity of water would prevent the crystallization. The crystals are deliquescent, soluble both in water, and alcohol, and readily fuse in their water of crystallization.

* As crystals containing water are called *hydrates*.

794. Solvent powers of alcohol. Use of Spirit.

795. Products of the decomposition of alcohol. The elements composing alcohol are in the proportion to form olefiant gas and water.

796. The question settled with respect to the existence of alcohol ready formed in wine.

797. Action of acids with alcohol. Alcoates. How formed?

798. Alcohol, on account of its great solvent power, and other peculiar properties, is an agent of great importance in medicine and the arts; but however indispensable, when taken in any considerable quantities into the animal system it has a poisonous and fatal tendency; and this, under whatever disguises it may be presented.

ETHER,

799. Is an inflammable, volatile liquid, formed by the action of alcohol with various acids. The ethers are composed of three classes, the 1st containing those which are composed of oxygen, carbon and hydrogen; 2d those whose acids contain hydrogen instead of oxygen, and 3d when the oxacid is united with alcohol.

800. *Sulphuric ether* was long the only ether known. It is much used in medicine and the laboratory.

It is formed by heating strong sulphuric acid with an equal weight of rectified alcohol in a glass retort; ether rises in a recipient surrounded by ice-cold water. The operation is continued until white vapors appear in the retort; after this, sulphurous acid gas, with a peculiar yellowish liquid, called ethereal oil, and the sweet oil of wine (*sulphovinic acid*,) begin to pass over; longer continuance of the heat produces olefiant gas. The ether thus obtained is impure; it is rectified by adding potassa, which absorbs the sulphurous acid and the ethereal oil.

801. *Theory*. It was long believed that sulphuric acid transformed alcohol into ether, by taking from it a certain quantity of water; and the composition of ether seemed to favor the theory. At present, the decomposition of sulphuric acid during the process for obtaining ether is admitted, and also that alcohol consists of 1 part of olefiant gas and 1 of water; and ether of 2 of olefiant gas and 1 of water.

802. *Physical Properties*. Sulphuric ether is without color, has a strong and fragrant odor, and a hot and sharp taste. According to Gay Lussac it does not transmit the electric fluid. It reflects light strongly, is perfectly limpid and fluid. Its specific gravity when purest is about 0.70; It is very volatile, boiling at 96° F. under atmospheric pressure; and at 20° below zero in a vacuum absorbs caloric so rapidly from surrounding bodies as to freeze water, and even mercury. It freezes at -46°. Its vapor has a density of about 2.58, air being 100. It flows through a capillary tube nearly four times as fast as water, and eight times as fast as alcohol, but does not rise so high by capillary attraction as either of the other two fluids. It is

798. Use of alcohol, and its effects on the animal system.

799. Ether.

800. Sulphuric ether. Preparation.

801. Theory.

802. Physical properties.

highly inflammable, burning with a blue flame ; its vapor forms a mixture with the oxygen gas, which explodes by an electric spark or on the approach of flame.

803. " When a coil of platinum wire is heated to redness, and then suspended above the surface of ether contained in an open vessel, the wire instantly begins to glow and continues in this state until all the ether is consumed. During this slow combustion, pungent acid fumes are emitted, which, if received in a separate vessel, condense into a colorless liquid possessed of acid properties. Mr. Daniell, who prepared a large quantity of it, was at first inclined to regard it as a sour acid which, in reference to the mode of obtaining it, he called *lampic acid* ; but he has since ascertained that the acidity is owing to the acetic acid, which is combined with some compound of carbon and hydrogen different both from ether and alcohol. Alcohol when similarly burned likewise yields acetic acid."—*Davy*.

804. *Chemical properties*. Ether is somewhat less powerful as a solvent than alcohol, though most of the substances which dissolve in the latter, are dissolved in the former. It has no action upon the fixed alkalies, but unites with ammonia. It dissolves Indian rubber with great facility. When exposed to the light it gradually absorbs oxygen, and becomes sour, which is supposed to be occasioned by the formation of acetic acid. Ether is very inflammable, burning with a blue flame ; a lump of sugar filled with ether thrown into a vessel of boiling water, forms a burning fountain, by lighting it with a taper. Chlorine with ether produces spontaneous combustion and explosion.

805. *Hydrochloric ether* is obtained by distilling a mixture of equal parts of hydrochloric acid and alcohol in a glass retort connected with Woulfe's apparatus. The first flask contains water, the others are empty and surrounded with ice. This ether is composed of equal volumes of hydrochloric acid and olefiant gas, united without condensation, as its specific gravity is equal to the sum of the specific gravity of the two gases ; viz. hydrochloric acid having the specific gravity of $1.278 \times$ to alcohol having the specific gravity of $972 = 2.250$, which is very near the specific gravity of hydrochloric ether, when compared with atmospheric air. It is even more volatile than sulphuric ether : boils by the heat of the hand, producing by its evaporation a sensation of coldness. It burns with a green flame, disengaging hydrochloric acid gas. From its composition it is apparent that it contains no oxygen gas.

806. *Hydriodic ether* is obtained by distilling hydriodic acid and alcohol. When poured on hot charcoal it gives off the purple vapors peculiar to iodine.

807. *Nitric ether* is made by distilling equal weights of alcohol and nitric acid : but the mutual action of the two substances is so violent as to render the process dangerous. The alcohol must be added in small quantities.

803. Substance named by M. Daniell *lampic acid*.

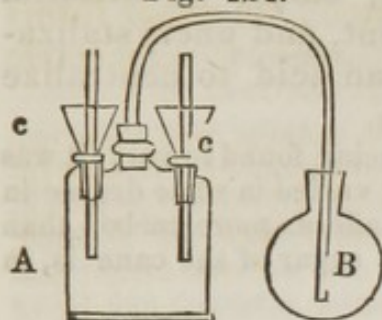
804. Chemical properties.

805. Hydrochloric ether.

806. Hydriodic ether.

807. Nitric ether. Properties. Sweet spirit of nitre. Ultimate elements. Acetic ether, &c.

Fig. 124.



A, (Fig. 124,) represents a Woulfe's bottle; B, a receiver; c, c, glass funnels ground to their necks, and glass rods ground to the funnels; the acid being in one funnel and the alcohol in the other.

Nitrous ether is of a yellowish color, has a strong odor, and burning taste. It is more volatile than sulphuric ether. With alcohol it forms the *sweet spirit* of nitre, which is valuable in medicine. Its ultimate elements are Car. 4, Hyd. 5, Ox+Nit. Ox. 3.

Acetic ether is formed in a manner analogous to the ether already described. It inflames on the approach of a burning substance, reproducing acetic acid. It has an agreeable odor, dissolves in alcohol, and forms a stimulating medicine.

Oconanthic ether gives to wines their peculiar odor; it is obtained by the decomposition of wine and produces intoxication when inspired. *Pyroxylic spirit* is a kind of ether formed by heating wood.

There are other ethers formed with alcohol and the vegetable acids; or the benzoic, citric, oxalic, &c.

CHAPTER XXXIV.

SUGAR, STARCH, GUM, &c.

SUGAR.

808. Under the head of sugar are included those substances which have a sweet taste, and when brought in contact with water, and a very small proportion of yeast, produce alcohol, by means of the vinous fermentation. This proximate principle is extensively diffused throughout the vegetable kingdom. Plants which contain it are called saccharine. Sugar is crystalizable either more or less perfectly, sweet, inodorous and very soluble in water, alcohol and other liquids. Pure sugar is hard, firm, and not acted upon by the air. Sugar, by friction, is phosphorescent in the dark. Sulphuric acid decomposes it and disengaging charcoal, forms water, and acetic, or some other vegetable acid. When nitric acid is mixed with sugar, both substances decompose, and oxalic acid is formed. Owing to the quantity of carbon in sugar it is very inflammable, and gives off a peculiar odor in burning.* It forms but feeble

* The carbonaceous, acetic and other vapors which exhale from burning sugar, possess medicinal powers; and the practice of sprinkling sugar in the domestic warming pan, when used for warming the beds of those who are suffering under rheumatic affections or sudden colds, is founded on more substantial reasons than "old wives' whims."

combinations with metallic oxides; lime, baryta or strontia boiled with sugar make it bitter, astringent, and uncrystallizable. By adding a sufficient quantity of an acid to neutralize the oxide, the sugar resumes its properties.

809. The results in the decomposition of sugar being found to vary, it was at length discovered that its constituent principles varied in some degree in different vegetables; thus the sugar of the cane affords more carbon than that of the grape. According to Gay Lussac the sugar of the cane is, in weight, composed of

Carbon	42.47
Oxygen	50.63
Hydrogen	6.90

100.00

According to Liebig; Car. 12, Hyd. 11, Ox. 12=179

Sugar of the grape was found to consist of

Carbon	36.71
Oxygen	56.51
Hydrogen	6.78

100.00

The specific gravity of sugar is about 1.6.

810. The sugar cane is the *arundo saccharifera* of botanists. This plant furnishes the greater part of the sugar of commerce. Although sugar was manufactured in India in the days of Alexander the Great, who is said to have brought the knowledge of it to Macedon, yet it was scarcely used in Europe, except in medicine, until the discovery of the West Indies, where the most extensive sugar manufactories now exist.

Sugar is obtained from the expressed juice of the sugar cane, by slow boiling, during which process the aqueous particles evaporate. Lime water is then added to the liquor when boiling, to neutralize the oxalic, and other vegetable acids, and to separate extractive matters and other impurities, which, uniting with the lime, rise and form a thick scum on the surface; the liquor below, is drawn off, by means of a syphon, into large shallow vessels, where an imperfect crystalization takes place.

811. From the sap of the sugar-maple tree *Acer saccharinum*, is manufactured, to a considerable extent, a valuable domestic sugar in many of the northern United States.

Incisions are made in the trees at that season of the year when the sap runs most abundantly; this is in early spring, with the first warm beams of the sun. The sap of the maple is about one sixth as rich as the juice of the cane; four pounds of maple sap yielding one pound of sugar. When suitably evaporated, by boiling in large kettles, and permitted to cool, it forms a granular solid mass. This may be purified so as to resemble loaf sugar, in whiteness and fineness; but is generally used in a less refined state. The maple juice boiled down to a consistence somewhat less than common West

809. Constituent principles of sugar, &c. Gay Lussac's and Liebig's analysis.

810. Sugar cane. Manufacture of sugar.

811. Maple Sugar. Manufacture of Maple Sugar.

India molasses is used for similar purposes ; and when evaporated to a thick syrup, resembling liquid honey, it is sometimes used for the table, as a substitute for sweetmeats.

812. The beet root is found to be rich in sugar. In France, are many large manufactories of this article. Count Chaptal, a peer of France, a theoretical, and practical Chemist, and farmer, says, "from twelve years experience I have learned in the first place that the sugar extracted from beets differs from that of the sugar cane neither in color, taste, nor crystallization ; and in the second place that the manufacture of this kind of sugar can compete, advantageously with that of the sugar cane.*

813. Many other succulent roots, besides the beet, furnish sugar, as the onion, parsnip and carrot.

Sugar of grapes, of figs and other ripe fruits contains more or less of the peculiar flavor of the fruit derived from other principles. It does not crystalize in regular forms, and it is less sweet than the sugar from the cane. *Sugar of mushrooms* crystallizes in four-sided prisms ; its taste is not pleasant. *Sugar of starch* is made by forming a paste with starch and water and allowing it to stand for some time. Sulphuric acid converts starch into sugar. De Saussure found the weight of sugar formed was considerably more than that of the starch employed, from whence he inferred that a portion of the water becomes solidified, that the sugar of starch was consequently only a combination of sugar with hydrogen and oxygen in the necessary proportions to form water, and that the sulphuric acid had no other influence than to increase the fluidity of the aqueous solution of starch.

814. *Manna* (from a Syrian word *mano* a gift, being the food given by God to the Israelites), exists in the sap of the ash, *Fraxinus ornus*, in the celery and beet plant. It is sweet and crystalizable like sugar, but it owes its sweetness to a distinct principle called *mannite*. This principle differs from sugar in not fermenting with water and yeast, of course it produces no alcohol.

Honey is composed of two kinds of sugar, the one liquid and uncrystalizable, the other analogous to the sugar of grapes and crystalizable ; these, with mucilage, and an aromatic principle, constitute all the varieties of honey. By mixing honey with alcohol, the liquid sugar may be obtained by pressing the solution through a strainer, while the crystalizable principle remains solid. Honey is prepared in the stomach of the bee, from the viscous juice and sugar which this insect collects from the nectaries of flowers ; after remaining a time in this laboratory it is deposited in the cavities of the honey comb. Honey varies in quality according to the different

* See Chaptal's "agricultural Chemistry," for a detailed account of the mode of cultivating the beet root, and conducting the beet sugar manufacture.

812. Sugar of beets. Chaptal's opinions upon the manufacture of beet sugar.

813. Other roots which furnish sugar. Sugar of grapes, figs, &c. Sugar of mushrooms. Sugar of starch.

814. Manna. Honey. Sugar of liquorice.

plants which furnish the materials. That which is obtained from the flowers of the tobacco, stramonium, and others of the same natural family, is poisonous. The honey of Mount Hymettus and Mount Ida in Greece was celebrated in ancient times for its beauty and excellence. The honey furnished by labiate plants, as the thyme, balm, &c., is of the best kind. Honey is used as food and medicine. When united with the vinegar it forms *oxymel*. Thus the common preparation of squills is called the *oxymel of squills*.* Dissolved in water, honey ferments, and forms a liquor called *hydromel* or *metheglen*, a pleasant but intoxicating beverage.

Sugar of liquorice. The substance called liquorice is from the root of a plant, the *Glycyrrhiza glabra*; its sweet principle seems to be of a peculiar kind. It resembles amber in its appearance and inflammability.

815. *Starch*, is one of the most abundant proximate principles in nature, existing in the stems, leaves, roots and seeds of plants. When pure it is a white powder, insipid, inodorous, insoluble in cold water, alcohol and ether, but soluble in boiling water. This solution on cooling takes the form of a jelly, in which state it is used by the laundress for starching linen. Hot sulphuric acid transforms starch into sugar, capable of yielding alcohol by fermentation. Nitric acid changes it into malic and oxalic acids. Iodine furnishes the best test for starch, forming with it compounds of a blue color. The principle deduced from this fact is applied in the arts to discover whether goods owe their fineness to the texture of the material or to a finish of starch; in the latter case, a drop of the solution of iodine produces a blue spot.

816. According to Gay Lussac and Thenard, starch is composed of

43.55	parts of Carbon.
49.68	" " Oxygen.
6.77	" " Hydrogen.

Starch is usually obtained by grating or bruising the substances which contain it, and washing the product with pure water. Its specific gravity being greater than that of water, the starch is soon deposited in the form of a white mass, which, when dry, is a soft powder. If a piece of dough or wheat flour be enclosed in a linen bag, and pressed with the hand while a current of cold water is poured on, the starch or farina will be washed out mechanically and subside at the bottom of the vessel, while the *gluten* of the flour is left pure in the bag, and saccharine matter and mucilage are in solution. Heat produces with starch peculiar effects; thus, when dry starch is heated a little above 112°, it becomes soluble in cold water, and its odor resembles that of baked bread. The action of boiling water on starch, as prepared for starching muslin, produces a similar change of properties. By continued heat, and careful evaporation a transparent mass is obtained, so-

* That is, oxymel combined with the juices of a bulbous plant, the *Scilla maritima* or squills.

815. Abundance of starch in vegetables. Properties. Action of other bodies upon it.

816. Constituent elements of starch. Modes of obtaining starch. Action of heat and of boiling water upon starch.

able in cold water, and resembling horn, this is called *amidine**. Starch when exposed to a greater heat than sufficient to produce amidine is converted into a substance called *gum*, and in this state is used by calico printers.

817. We have seen that the constitution of starch differs little from that of sugar, and that the former may be easily converted into the latter. This change takes place in the germination of seeds, in the process of malting barley, and in vegetables that have been frozen under certain circumstances: thus apples, which have been exposed to the air during severe frosts, acquire a peculiar sweetish taste.

818. Of the various kinds of starch, those which are obtained from the flour of different kinds of grain, from the potato, and green Indian corn are used in the laundry for starching linen and muslin. The Indian arrow-root, (*Maranta arundinacea*,) Sago (from the pith of the *Cycas circinalis*,) Tapioca, and *Cassava* (from the root of a plant,) have the properties of pure starch. They are all highly nutritious and valuable as food for the sick.

GUM AND MUCILAGE.

819. Gum is an abundant product of vegetables. It is uncrystalizable, colorless, inodorous, insoluble in alcohol, and soluble in water with which it forms a gelatinous compound called *mucilage*. It cannot be made to pass through the vinous fermentation. Nitric acid changes it to *mucic* acid. Gum or mucilage is found in all the parts of herbaceous plants, in many roots, and in all fruits. Many trees, particularly those whose fruit is of the *drupe*† kind, secrete large portions of gum.

820. The principal gums are.

1. *Common gum*, obtained from the peach, plumb, cherry tree, &c. 2. *Gum Arabic*, which flows naturally from the acacia or mimosa of Egypt, Arabia and other warm countries; this, with water, forms a clear, transparent mucilage. 3. *Gum senegal* resembles Gum Arabic except that it is exported in much larger pieces. 4. *Gum tragacanth*, from the *Astragalus tragacantha*, a shrub of Syria, and of the islands of the Levant. These are all useful in medicine and the arts; and in some countries they are used as food.

* So called by the French Chemists from *amidon*, the French name for starch.

† Having a kernel enclosed within a pulpy substance, as the cherry, plum, and peach.

817. Conversion of starch into sugar.

818. Uses of starch.

819. General properties of gum, &c.

820. The principal gums. Uses of these gums.

821. Flax-seed, the fruit and seeds of the quince, the bark of the slippery elm, and the different species of mallows, all afford *mucilage* when boiled in water. When evaporated to the thickness of syrup the gum is precipitated by alcohol. *Mucilage* may be considered as an aqueous solution of gum, existing naturally in ripe fruits, and the leaves and roots of some plants, and formed by dissolving gum in water. Mucilage soon becomes sour on exposure to the air, owing to the formation of acetic acid; and in time this change takes place without access of air, which must be owing to the new arrangement of its constituent principles. 100 parts of gum arabic have been found to consist of.

42.23	parts of Carbon.
50.84	" " Oxygen.
6.93	" " Hydrogen.

100.00.

Vegetable jelly, such as is obtained from the currant, quince grape, &c., is mucilage combined with different vegetable acids.

WOOD, LIGNIA, OR WOODY FIBRE.

822. This is the basis or skeleton of vegetable substances, and the most abundant of all the proximate or vegetable principles forming about 96 per cent of the different kinds of wood. The woody or hard substance of plants contains, in its interstices the sap, and other peculiar principles, as the volatile oils, gums, resins, sugar, &c. This substance is found in every part of the plant, the root, the stem, leaf, fruit and even the flower. In the dry state it may be seen in the shells of almonds and many other nuts, even the soft petals of the rose, when deprived of their essential oils, mucilage and other extractive matter, will be found reduced to this hard insoluble substance.

Lignia, for chemical purposes, is usually obtained from saw-dust, because wood thus minutely divided, is in a favorable state to be acted upon by the agents which are required to purify it of all foreign matter. Saw-dust is first digested in alcohol, to dissolve the resinous part, afterwards in water which dissolves some salts and extractive matter, then with weak muriatic acid, which attacks salts that are insoluble in water, particularly the carbonate and phosphate of lime. *Lignia* is white, insipid, inodorous, and specifically heavier than water.

Sulphuric acid decomposes *lignia*; changing it first into a gum-like substance, which, on being boiled, becomes sugar. According to Beaconnot all substances which contain *lignia*, as saw-dust, straw, bark, and linen,

821. Mucilage. Composition of gum arabic. Vegetable jelly.

822. Abundance of woody fibre, &c. *Lignia* for chemical purposes, how obtained? Properties, &c. Products of the decomposition of wood, by heating in close vessels. Bread made from saw-dust, &c.

may be converted to sugar. In heating wood in close vessels, acetic (pyro-ligneous) acid and volatile products are obtained. Among these, is *pyroxylic spirit*. It is found that bread may be made from saw-dust, bark, rags, &c., by converting these substances into lignia. The latter, when heated in an oven, smells like meal or flour of Indian corn. It ferments with leaven, and affords a spongy, nutritious bread. The same flour of wood, when boiled, affords a jelly like that of starch.

COMPOUNDS WHICH ARE NOT CONSIDERED AS BELONGING TO THE
PRECEDING DIVISIONS OF VEGETABLE PRINCIPLES ; AS
COLORING MATTER, TANNIN, GLUTEN, &c.

823. *Coloring matter*. Vegetable coloring matter is found attached to some proximate principle, as mucilage, farina, resin or extractive matter ; and its solubility depends on the nature of the principle with which it is associated. Coloring matter cannot, therefore, be considered as itself a proximate principle. Color is a secondary property, dependant on the peculiar arrangement of atoms, and of course affected by chemical changes. Thus, we have seen in the course of our experiments, color of bodies changing with new combinations ; a colorless acid transforming the blue infusions of flowers to a brilliant red, and a colorless alkali changing the same blue infusion, to a green color. The process of dyeing, depends on chemical principles, but the details of the subject belong to the *arts* rather than to science.

The coloring matter resides in various parts of plants. In some, it is in the flower, in others, in the bark, or the leaves, wood, or root. It is soluble by various agents according to the nature of the proximate principle with which it is associated ; thus some colors are obtained by means of alcohol, others by water, others by acids, and others by the essential oils. Most vegetable colors are decomposed by exposing to the sun, and all by the agency of chlorine.

824. Several of the metallic oxides, and especially alumina and the oxides of iron and tin form with coloring matter insoluble compounds, to which the name of *lakes* is applied. Lakes are commonly obtained by mixing alum or pure muriate of tin with a colored solution, and thus, by means of an alkali, precipitating the oxide, which unites with the color at the moment of separation. In this property is founded many of the processes in dyeing and calico-printing. *The art of the dyer consists in giving a uniform and permanent color to cloth.*

823. Coloring matter not a proximate principle, &c. Situation of the coloring matter in plants. Means of obtaining these colors. Decomposition of vegetable colors.

824. Compounds with coloring matter, called lakes, &c. Setting of colors. The use of a mordant. Substantive and adjective colors. Substances which change the hue of coloring matter, &c.

The setting of colors depends on a chemical affinity between the dye, and the material with which it unites. To produce this affinity the agency of a *third* substance is often required, which is called a *basis* or *mordant*.* This unites the coloring matter to the cloth by means of an affinity for both. The most important bases or mordants used in dyeing, are alumina, and the oxides of tin and iron; but many others are useful, as alum, copperas, sugar of lead, muriate of tin, blue vitriol, &c.

Colors that adhere to the cloth without the intervention of bases are called *substantive* colors, while those which only form a transient union with cloth, unless fixed by a third substance, are called *adjective* colors.

Besides bases to fix the coloring matter, various chemical agents are employed to alter the shade or hue of colors; thus the hydrochlorate of tin changes the crimson of cochineal to a brilliant scarlet. Alum changes the dull red of madder to a bright crimson. The attraction both of coloring matter and mordants for wool and silk, is much greater than for cotton; thus we find the most brilliant and permanent hues in woollen and silken stuffs. All the hues obtained in dyeing, may be produced by four primary colors, *blue, red, yellow, and black*.

825. *Blue*. The only vegetable substance used for dyeing blue is *indigo*. This is obtained from several species of the *Indigofera*, and has been found in small quantities, in some other plants. The indigo plant is a product of warm climates.

The leaves are fermented with water in large tubs; the liquor becomes acid, and covered with irised pellicles. It is then drained, and mixed with lime water. A deposit is formed, which when washed, and dried, is the indigo of commerce. In order to obtain perfectly pure indigo, it should be heated in a closely covered silver crucible. It soon volatilizes and deposits purple crystals.

Pure indigo has neither taste nor odor; its color is a rich blue, with a shade of purple. It does not dissolve in water, alcohol, or ether. Strong sulphuric acid dissolves it, forming a sulphate of indigo, which is employed for giving the color called Saxony blue. Where indigo is deoxygenated it loses its fine color, becomes yellow, and is easily dissolved in slightly alkaline water; if this solution be agitated in contact with the atmosphere, the indigo acquires oxygen, and becomes blue.

The dyer's *blue-vat* is made by mixing indigo with an equal weight of green sulphate of iron, twice its weight of lime, and boiling the mixture in water†. The protoxide of iron precipitated by lime, gradually deoxydizes the indigo, and a yellow solution is obtained. Cloth wet in this liquid, and exposed to the air, becomes green, and then blue by the union of the deoxydized indigo with the oxygen of the air; and the blue indigo being now chemically united with the fibre of the cloth, a permanent color is obtained.

A white substance called *indogene* has been obtained by depriving indigo of its oxygen; it rapidly changes to blue on exposure to the oxygen of the air.

* From *mordeo* to bite, corrode or fasten upon.

† In the domestic blue dye the ammonia of urine is the solvent of indigo.

825. Indigo, how obtained from the plant? Properties of indigo. Effects of deoxygenating indigo. Blue-vat of the dyer, &c. Effect of air upon cloth wet in a solution of deoxydized indigo.

826. *Red.* Among the red coloring matters are *Madder*, *Cochineal*, *Archil* or *Litmus*, *Logwood*, *Brazil Wood* and *Safflower*.

Madder is the root of the *Rubia tinctorum*. It is used in dyeing the *Turkey-red*, and by the aid of proper mordants, may produce not only the various hues of red; but purple and black. This is seen when calico stamped with different mordants is wet in the madder dye. The coloring matter of madder is supposed to have been obtained in a pure state by some of the French chemists in the form of brilliant red, needle-shaped crystals.

Cochineal, though found on the leaves and branches of the cactus plant, is an animal substance, deposited by an insect which feeds upon it. It is a fugitive dye when mixed with water only; but becomes fixed by alumina, or the oxide of tin. Its natural crimson color is changed to scarlet by the permuriate of tin, or the *bitartrate* of potassa, (cream of tartar.) *Carmine* is made of cochineal and alumina.

Litmus, *archil*, or *turnsol* is prepared from the *Lichen roccella*, a plant which grows in the Canary, and Cape de Verd islands. The color of the lichen is red; but in preparing litmus by means of fermentation with an alkaline substance, it receives a blue tint. This preparation is affected by the weakest acids, and is, therefore much used as a chemical test. Paper tinted with litmus is called litmus paper, and furnishes a convenient mode of using this as a chemical test. Litmus paper, when reddened with an acid, becomes blue in an alkaline solution.

Logwood is a heavy compact wood from the *Haematoxylum* campechianum*, a plant which grows in South America. Its coloring matter has been obtained in crystals called *hematine*. Logwood affords a red, fugitive color, but is chiefly used for black dyes, which are fixed or set with iron; copperas (sulphate of iron) is chiefly used for this purpose.

Brazil Wood is from the *Caesalpinia echinata* a large tree of Brazil.

Safflower is the dried flower of the *Carthamus tinctorius*, an unusual plant of the countries bordering on the Mediterranean. This is the exotic compound flower of our gardens, known by the name, *Saffron*, although the *crocus* is the true Saffron. The flowers of the *Carthamus* or false saffron are yellow; but according to Thenard, repeated washing dissolves the yellow coloring matter, leaving the red which was combined with it. This article gives a variety of shades of red, from that of the damask rose to the cherry. They are fugitive colors though very brilliant. *Rouge* is prepared from this substance.

827. *Yellow.* Of yellow dyes the principal are the *American walnut*, *tumeric*, *fustic*, *saffron*, *sumach*, and *quercitron*. These like the red dyes are all adjective colors.

The bark of the *walnut*, and the *butternut* afford a yellow dye, which, with iron becomes brown. *Turmeric* is the root of an East Indian plant, the *Cucurma longa*. Paper stained with an infusion of this dye is called turmeric or cucurma paper; it is stained brown by an alkali, for which reason it is used as a chemical test. *Fustic* is obtained from the West Indies; it is the wood of the *Morus tinctoria*. *Saffron* is from the *Crocus sativus*. With water and alcohol it forms a bright yellow, which sulphuric

* This name is from the Greek *haima*, blood, in reference to the red color of the wood.

826. Red Colors. Madder. Cochineal. Carmine. Litmus. Logwood. Brazil Wood. Safflower. Rouge.

827. Yellow dyes.

acid changes blue, then lilac, and nitric acid gives it a green shade. *Sumach*. The bark of the different species of the *Rhus*, furnishes a yellow dye. This was formerly exported in large quantities from America to England. *Quercitron* is the bark of the common black oak of this country. A decoction of this bark, gives a bright yellow dye with a basis of alumina; with oxide of tin all the shades of yellow from pale brown to deep orange. With indigo it forms a green color, and with oxide of iron a drab color. *Annotta*, improperly called *otter*, is obtained from the seeds of a plant of Cayenne, the *Bixa orellana*; it is sometimes used to heighten the color of cheese, and is much used in domestic dyeing.

Carthamus tinctorius so common in our gardens furnishes a fine though fading straw color. It is probable* that the foreign species of *carthamus* from which saffron is obtained, differs from the saffron of our gardens.

828. *Black dyes*, as writing ink, &c. consist of the salts of iron with gallic acid and tannin; astringent barks, such as maple, oak, &c. afford these two substances; secretions of such barks with copperas (sulphate of iron,) will therefore color black. Gall-nuts are often used instead of bark to furnish gallic acid and tannin.

There are various mineral dyes as *orpiment*, the chromates, and Prussian blue; the latter is partly mineral, and partly, an animal compound. There are various modes of applying the colors in dyeing cloth of different kinds. In general, the cloth is passed through a decoction of the coloring matter, and then of the mordant; the latter seems to perform the same office in preserving a union between the coloring matter and the texture of the cloth, as the alkali which affects a combination between oil and water. In calico printing "The mordant thickened with gum or flour, is applied to the cloth by means of blocks or engraved copper cylinders. The cloth is then passed through a decoction of the color which adheres only to the spots impregnated with the mordant, and is easily discharged, by washing. To preserve certain parts white, they are occasionally covered with wax, tallow or pipe clay, and sometimes the color is discharged from particular parts by chlorine."—*Sill.*

TANNIN.

829. To the proximate principle called *tannin*, vegetables owe their astringent properties. This principle exists in large proportions in the bark of certain trees, in the gall-nut, and in the leaves of the tea-plant.

The most remarkable property of tannin is that of forming with many animal substances, particularly gelatine, a tough insoluble and imputrescent compound. Thus the skins of animals, which are mostly composed of gelatine, by being soaked in the *tan-vat*, (a decoction of astringent bark,) are converted into leather, which is not only necessary to the comfort, and health of man, but in various ways contributes to his con-

828. Mineral dyes. Various modes of applying colors, &c.

829. Cause of the astringent properties of plants, &c. Action of tannin with gelatine. Leather. Action of tannin on the salts of iron.

venience, and is of extensive use in the arts of civilized life. Another important property of tannin is its action on the salts of iron, which it precipitates, producing in combination with gallic acid, ink and black dyes.

830. Pure tannin is obtained with difficulty owing to its tendency to form combinations with the principles with which it is associated. It may be precipitated from an infusion of nut-galls by various re-agents; as sulphuric and muriatic acids, carbonate of potassa, and muriate of tin. The precipitate of tannin is combined with other matters, which are separated by various complicated methods. Some gallic acid and extractive matter will often be found after the most careful preparation. Proust recommends preparing tannin by precipitating it from an infusion of nut-galls, by muriate of tin, washing the precipitate, and passing over it a current of sulphuric hydrogen, filtering and evaporating the liquor. Tannin tolerably pure may be obtained by precipitating it from an infusion of nut-galls, with lime-water. Pure tannin is without color, very soluble in water, but insoluble in perfectly pure alcohol. The acids, except the acetic, precipitates it from its solution in water. Tannin is most abundant in the inner layers of the bark of hemlock, oak, chestnut and birch.

831. *Artificial tannin*, a substance resembling tannin may be produced by the action of diluted nitric acid on oil, or indigo; or by the diluted sulphuric acid with the resins, or charcoal. A solution is thus obtained which, when evaporated to dryness, produces a brown, fusible substance, soluble in water, and insoluble in alcohol, and which exhibits, with a salt of iron, and a solution of gelatine the same changes as natural tannin. Lagrange asserts that tannin changes into gallic acid by the absorption of oxygen.

GLUTEN, YEAST, VEGETABLE ALBUMEN.

32. *Gluten* is obtained in the process for the separating the fecula or starch from wheat flower by washing; the albumen and sugar lodged in the interstices of the gluten are dissolved and carried off with the fecula; the gluten is pure when it no longer disturbs the transparency of water by washing. It is of a grayish white color, soft, viscous, very tenacious, and elastic. When dried it becomes brown, and has a glossy brittleness. Exposed to the moist air it swells, putrifies and diffuses an odor, like that of cheese. It does not dissolve in cold water or alcohol; warm water destroys its tenacity and elasticity, but without dissolving it. It is soluble in most of the vegetable, and some of the mineral acids. Charcoal, sulphuric and nitric acids act upon it, as upon most animal substances.

833. Taddei, an Italian Chemist does not regard gluten as a proximate principle, but as formed of two such principles, which he calls *gliadine*,•

* From the Greek *ghia*, gluten.

830. Extraction of pure tannin. Properties of pure tannin.

831. Artificial tannin.

832. Manner of obtaining gluten. Its properties, &c.

833. Gliadine and zimome. Test for zimome and albumen in flour.

and *zimome*.* Berzelius, however, supposes the gliadine to be modified gluten, and the zimome to be albumen. The Italian Chemist, in his researches, discovered that the powder of gum guaicum afforded a delicate test for the zimome; as, when rubbed in a mortar with this substance in a moist state, it strikes a fine blue color. This test is found equally good to shew when flour contains the due proportion of albumen or gluten; it is kneaded into the flour, which, if good, assumes a blue color. But if the flower be bad, owing to the spontaneous decomposition of gluten, the blue tint is scarcely visible.

834. Gluten appears to promote fermentation. The action of yeast has been ascribed to its presence. It is favorable to animal nutrition. Thus bread is emphatically called the "staff of life." The different kinds of grain contain a large proportion of gluten, but wheat more than any other. The gluten in wheat flour, on account of its elastic, and viscous nature, is favorable to the formation of light bread. The carbonic acid gas which is disengaged during the fermentation, being detained by the gluten, expands it, and causes the pores which appear in light, wheaten bread. Rye bread can never be made so light as wheat, because rye contains little gluten; and Indian meal without intermixture with some other substance can scarcely be *raised* at all by yeast.

835. Potatoes contain no gluten, but much farina, and may be mixed with wheat flower in making bread; but, if added in too large proportion, the bread will be heavy, because, for want of sufficient gluten to retain the gas of fermentation, the latter passes off in the atmosphere; and if, as supposed, gluten assists fermentation, there will be the less gas disengaged. This substance was discovered by Beccaria an Italian chemist, who, from its analogy to *glue*, both in its viscid properties, and its tendency to putrefy, like animal substances, called it *gluten*.

836. Yeast is a viscous, frothy substance which rises to the surface of fermenting liquors.† When liquor is fermenting, the yeast rises to the surface, with the gas it generates; but, afterwards, becomes specifically heavier than the liquor, and sinks.

The yeast of breweries, and distilleries is best for raising bread. But when this cannot be obtained yeast may be prepared by adding a small quantity of ferment to a decoction of hops, made of proper consistency with rye or wheat flour. Boiling water, or heat, equivalent to it, destroys the fer-

* From *zume*, a ferment or yeast.

† Vulgarly called *emptins*, as when beer is drawn off, it is found at the bottom, or in the *emptyings* of the cask.

834. Gluten favorable to fermentation, &c. Rye flour and Indian meal contain little gluten.

835. Effect of mixing potatoes with wheat flour in making bread. Discovery of gluten and derivation of the name.

836. Yeast, &c. Domestic yeast. Dried yeast. Effect of heat on yeast.

menting power of yeast. The cause of its action in producing fermentation has not been discovered. By distillation yeast affords carbon, hydrogen, and some nitrogen; it resembles gluten in its composition.

837. *Vegetable Albumen*, a substance resembling animal albumen, and especially in its property of coagulating with heat, has been discovered in the almond, and some other oily seeds. It contains nitrogen, and when exposed to the moist air, undergoes the putrefactive fermentation, emitting an offensive odor like that of old cheese, and disengaging ammonia. Vegetable albumen and gluten appear to form a connecting link between vegetable and animal substances.

838. There are many vegetable principles which have not yet received a classification, owing to their not having been sufficiently studied, or to some obscurity in the nature of their constitution.

Asparagin has been discovered in the juice of the asparagus, with an acid called *espartic*; which, by decomposition, affords ammonia, proving that it contains nitrogen; it exhibits neither acid nor alkaline properties, it is found in the juice of liquorice, and the *Althea officinalis* or marsh-mallows. *Fungin* is that portion of the fleshy part of the mushroom which remains after removing every thing soluble, by digesting in alcohol and alkaline water; it is very nutritious, has a smell like bread, but appears to resemble animal matter, in its composition. *Legumin* is extracted from the pulp of peas; its solution gives, with sulphate of lime, a dense coagulum, which is supposed to explain why peas boiled in hard water, or that containing a salt of lime, become hard; peas and beans are found to consist of 18.40 per cent of legumin with 42.58 of starch, 8 of water, 4 of nitric acid, and 8 animalized matter, &c. *Ulmin* was discovered by Vauquelin in the brown matter which exudes from the elm, (*Ulmus*), Braconnot found it in turf and mould; it has been regarded by some Chemists as an acid, and called *ulmic acid*; ammonia and oxygen change gallic acid into alumina.

Caffein is a white, crystalline matter extracted from coffee; Pelletier regarded it as a salifiable base, but it neither affects blue vegetable colors, nor combines with acids. *Bassorin* was first extracted from gum Bassora, a substance resembling gum tragacanth, and imported from Bassora in Asia; it has been found in assafoetida, and some other resinous plants. *Cathartin* is a substance which has been obtained from *senna* and is supposed to contain the cathartic principle of that plant. *Suberin* is a name applied by Chevreul to the cellular tissue of the cork tree (*Quercus Suber*), which he supposes to be a proximate principle; the cells of this substance are filled with astringent, coloring, and resinous matter; the latter, Chevreul called *cerine*. By the action of nitric acid, suberin changes to suberic acid. *Lupulin* is obtained from the membranous scales of the pistillate flower of the hop. It is very bitter, and soluble in water and alcohol.

Piperin is procured from black pepper (*piper nigrum*); it has some of the stimulating properties of pepper; these being found to reside in a volatile oil. *Oliville* extracted by Pelletier from the gum of the olive tree, has a bitter and aromatic taste. *Rhubarbarin* is a name given to an extract of

837. Vegetable albumen.

838. Asparagin. Fungin. Legumin. Ulmin. Caffein. Bassorin. Cathartin. Suberin. Lupulin. Piperin. Oliville. Rheubarbarin and Rein. Sarcocoll. Pollenin and Medullin. Colocynthis. Polycroite. Nicotin. Dahline and Inulin.

the medicinal rhubarb, supposed to contain its active principle. *Sarcocoll*, from a plant of Ethiopia and Persia called the *Penæa sarcocolla*, is imported in small grains, resembling gum arabic. It forms mucilage with water; it differs from gum in being soluble in alcohol, and by being precipitated by tannin from its aqueous solution. It has a sweetish taste, resembling that of liquorice. *Pollenin*. The pollen of tulips was found by Professor John, to constitute a peculiar principle, of a very insoluble nature, highly combustible, burning with a rapid darting flame. It has been used in theatres for artificial lightning. The same chemist discovered a peculiar substance in the pith or *medulla* of the Sunflower, which he called *medullin*. This substance yields ammonia by destructive distillation. *Colocynthin*, is a name given by Vauquelin, to a bitter, resinous extract from the colocynth in which the medicinal properties of the plant reside.

Polycroite is obtained from the flowers of the saffron (*Crocus sativus*.) It is the coloring matter of the saffron; it is named from *polus*, many, and *kroma* color, on account of its producing different colors with acids. Nitric acid gives it a green color, which disappears on diluting it with water. Sulphuric acid, at first, changes it blue, which color gradually passes to violet. *Nicotin* is a peculiar principle obtained by Vauquelin from tobacco (*Nicotiana tabacum*.) It has the smell and taste of the plant, is volatile and poisonous. Professor Silliman says, "The empyreumatic oil of tobacco, disengaged in smoking, is doubtless nicotin modified and perhaps rendered more noxious by the heat."* *Dahline* exists in the tubercles of the Dahlia. It resembles starch in most of its properties. Dahline exists with inulin in the Jerusalem artichoke, both substances are varieties of fecula or starch, and are therefore nutritious. The Dahlia root, if as easily cultivated as the potatoe, might, therefore form a valuable aliment.

839. *Chlorophile* is a name given to the green coloring matter of plants, formerly called *green fecula of plants*; it is obtained by coagulating the green juice of plants with heat, and purifying the coagulum with water and alcohol; it is a deep-green, resinous substance; from some late discoveries it appears that the resin may be removed by ether, after which, according to some chemists, the coloring matter will be left pure.† *Bitter principle*, a term formerly applied to a supposed peculiar substance which caused the bitterness of plants; but it is found that different principles in different plants produce this effect; thus the bitter principle of the hop is owing to lupulin, that of opium to morphia, &c. *Extractive matter*, a term formerly supposed to refer to a peculiar principle; but it is vague and indefinite, since no such distinct principle has ever been obtained. When vegetable substances are macerated in water, there usually remains, after removing the proximate principle, something which seems to belong to none of these principles; and this has been called *extractive matter*, a convenient term, which expresses a mixture of different principles, or the residuum of vegetable infusions and decoctions.

* "As a source of refreshment and pleasure to man, tobacco ought to be universally proscribed; it should be retained only as a means of destroying insects and vermin, and as a medicine, which, in its internal use is so violent and dangerous, that the proper occasions for employing it must be "few and far between."—*Sil. El. of Chem. Vol. 2. p. 509.*

† What can those chemists mean who talk about a pure coloring matter, since color is itself a mere secondary property of matter, and cannot exist separate from a colored body? Can they expect to obtain a substance of which they can say, 'this is *pure color*?' or, "pure coloring matter?"

839. Chlorophile. Bitter principle. Extractive matter.

CHAPTER XXXV.

FERMENTATION.

840. By fermentation is understood, a spontaneous change which takes place in substances; their elements disunite, combine in other proportions, and give rise to compounds, differing wholly from any which had originally existed in the fermenting mass. There are various kinds of fermentation; as the *panary* which produces bread, the *saccharine* which affords sugar, the *vinous* in which sugar is converted into alcohol, the *acetous* which results in vinegar, and the *putrefactive* which results in the entire dissolution of organic matter.

841. *Panary** or *bread fermentation*. It is evident that bread, or even raised dough, differs essentially from a mixture of flour and water which has not undergone a process of fermentation. Besides the porous and spongy texture which distinguishes the former, it has a peculiar pungent odor, so that on opening a mass of thoroughly raised dough, a peculiar effluvia issues, scarcely less penetrating than that of ammonia. Dough is not only enlarged in bulk by fermentation, but, when subjected to the heat of the oven, it swells to a still greater bulk, and appears in the form of light bread; while dough that has not passed through the fermenting process does not rise in the oven, and would, if baked, present a compact, heavy, insipid and indigestible mass.

842. It is to gluten that flour owes its property of forming a paste with water. Paste is merely a viscous and elastic tissue of gluten, the cells of which are filled with starch, mucilage, sugar, &c. This being understood, we can readily conceive, that to gluten, paste owes its property of becoming light when mixed with yeast. The yeast acting upon the farina or starch of the flour converts it into a gummy, sugar-like substance. This *saccharine* fermentation is the *first* stage in the process. The change of sugar into alcohol and carbonic acid next takes place, and this *vinous* fermentation is the *second* stage. If the process is suffered to go on, alcohol is converted into active acid or vinegar, and this *acetous* fermentation works a *third* stage.

* From the Latin *panis*, bread.

840. What is meant by fermentation? Different kinds of fermentation.
 841. Changes effected in flour by means of the panary fermentation.
 842. Importance of gluten in flour. Stages in panary fermentation.
 Cause of the porous texture of bread.

At the second or vinous stage of fermentation, a large portion of carbonic acid is disengaged. This in seeking to escape becomes fixed in the cellular tissue of the gluten, which being tenacious and elastic extends itself, forming a series of membranous partitions filled with gas, and thus swelling out the mass. When exposed to heat, as in baking, the gas expands still more, and the baked loaf becomes specifically much lighter than before.

843. It is very necessary in making bread to observe; 1st. That the yeast should be mixed thoroughly with the dough; otherwise the bread will be heavy in certain portions. 2d. The dough will rise light in proportion to the quantity of gluten, contained in the flour; for this reason wheat flour makes better bread than any other. 3d. Substances which contain no gluten cannot be raised with yeast. Thus the flour of Indian corn, cannot by itself make light bread, but may be advantageously mixed, in certain proportions with wheat or rye; and potatoes though they are nutritious on account of the farina which they contain, can never be used for bread, except with the flour of the glutinous grains. When bread has been suffered to sour, or pass through the acetous fermentation, the acetous acid which is generated may be neutralized by a solution of pearlash, or some other carbonated alkali; in this case, the further disengagement of carbonic acid gas, by the union of its base with acetic acid will render the bread still lighter, though if the alkali is too freely used, it will acquire an alkaline taste, and a yellowish color.

844. *Saccharine fermentation* produces sugar in bodies where it did not previously exist. It accompanies the germination of many buds, is produced in heating starch with sulphuric acid, and in the action of yeast, or gluten upon farina. When starch, which has been coagulated by boiling water, is kept moist, during some time, a spontaneous change takes place, and sugar is produced. The germination of the buds of barley, in the *malting* process is an example of the saccharine fermentation.

Vinous or Alcoholic Fermentation.

845. Fermentation takes place when sugar, or farina, the latter being readily changed to sugar, together with water, and a small portion of yeast, is exposed to a temperature from 60° to 80° F. The liquor soon begins to exhibit marks of action; bubbles of carbonic acid, attracting around them small portions of the yeast, form a froth on the surface; the liquor, after a time, deposits the interposed substances, which disturbed it, and becomes clear. The sugar having disappeared, it is proba-

843. Considerations important in respect to the making of bread.

844. What is saccharine fermentation, and when does it take place?

845. Production of the vinous fermentation. Phenomena attending this fermentation. Experiment to illustrate the process of vinous fermentation. Change of sugar to alcohol.

ble that it has been converted into alcohol and carbonic acid ; especially as the weight of the two latter is found to be about equal to the weight of the sugar.

This process may be examined, by way of experiment, by placing about five parts of sugar, with twenty parts of water, and a very little yeast in a glass flask with a bent tube, the extremity of which opens under an inverted jar, full of water or mercury, and exposing the whole to the proper temperature. The carbonic acid gas which is disengaged may thus be collected, and its weight, together with that of the alcohol which is now formed in the flask, may be readily ascertained. The quantity of yeast decomposed is so small as not to be brought into the account ; the only part the yeast performs is that of exciting the fermentation ; the agency of atmospheric air is of no importance, as the operation proceeds equally well without it.

According to Gay Lussac sugar may be transformed into alcohol, by taking from the former 1 volume of oxygen gas and 1 volume of the vapor of carbon, constituting, by their union, one volume of carbonic acid gas.

846. Many vegetable juices containing sugar, acids, mucilage and starch, undergo the vinous fermentation without yeast, owing to the presence of gluten, which seems, in many respects, analogous to it. Cider is thus obtained by the fermentation of the juice of the apple, wine from that of the grape, currant, gooseberry, &c.

In the malting of barley, the grain, after being soaked, is spread upon a floor. When the fermentation begins, and the seed germinates, the process is interrupted by heat, and the barley remains in a saccharine state ; it is now called malt. When malt is fermented with an infusion of hops, the liquid is called beer, ale, or porter, in all of which, alcohol is produced during the fermentation. Ale and beer are more liable to sour than wine, on account of the mucilage and other principles which the former derive from malt. Alcohol may be obtained by distilling both the liquors produced by the vinous fermentation of saccharine fruits, and those which result from the fermented decoction of hops and malt.

Acetous Fermentation.

847. The vinous fermentation readily passes to the *acetous*, or that in which acetic acid is generated. The acid appears to result from a change in the constituent principles of the alcohol. That this change takes place, seems evident from the disappearance of the alcohol, and the simultaneous production of acetic acid in an equal proportion to the alcohol which had previously existed. Pure alcohol, mixed with yeast and exposed to a warm temperature, will undergo the acetous fermentation. The nature of the chemical action which thus changes alcohol

846. Vinous fermentation produced by gluten. Malt, &c.

847. Cause of the change from the vinous to the acetous fermentation. In what case pure alcohol may be made to undergo the acetous fermentation. Distinction between the formation of acetic acid, and the acetous fermentation.

into acetic acid is yet considered doubtful. It is necessary to distinguish between the mere *formation of acetic acid*, and the acetous fermentation. Most vegetable substances yield acetic acid when they undergo spontaneous decomposition. Mucilaginous substances, even when excluded from the air, gradually become sour. But these processes appear essentially different from the proper acetous fermentation, when there is a visible movement in the liquid, with absorption of oxygen, and disengagement of carbonic acid.

848. The acetous fermentation is attended by the following circumstances. When a vinous liquor is exposed to the atmosphere, at a certain temperature, it yields a portion of its carbon to the oxygen of the air, from whence results carbonic acid gas, and a slight disengagement of caloric; the liquid becomes turbid owing to the formation of a filamentous matter, which, after much agitation, subsides in a jelly-like mass; the alcohol is decomposed, becomes transparent, and is found changed to vinegar or acetic acid. The alcohol has been supposed to pass to the state of acetic acid, by yielding a portion of its hydrogen and carbon to the oxygen of the air, forming carbonic acid and water, and leaving its remaining carbon, hydrogen and oxygen in the exact proportion for forming acetic acid. But according to the experiments of De Saussure, the volume of carbonic acid gas formed, is such as to show that all the oxygen absorbed from the air unites with the carbon of the alcohol, while the hydrogen must be disposed of in some other way than by combining with oxygen to form water, as is supposed upon the former theory.

Putrefactive Fermentation.

849. While organized beings possess life, the elements of which they are composed, remain combined according to the laws of the vital principle, which are often contrary to those of affinity; but when life is extinct, the laws of affinity prevail, and former combinations are broken up in the effort of the elements to unite according to their chemical attractions. This movement of the particles of bodies is called *putrefaction*, or the *putrid fermentation*. It is more rapid in animals than in vegetables; and more rapid in vegetable substances, in proportion as their constitution resembles that of animal matter. A damp and stagnant air, and warm temperature, hasten the progress of this fermentation. When vegetables deprived of their living principle, are thus situated, they become converted into a black matter, called mould, disengaging at the same time a little oil, acetic acid, water, nitrogen, carburetted hydrogen, and carbonic acid. Animal matter under the same circumstances besides most of these products, gives ammonia, some nitric acid, and hydro-cyanic acid. All the gases which are disengaged carry with them a little decomposed animal matter, which gives them

848. Circumstances which attend the acetous fermentation.

849. Change which ensues in organic beings when life ceases, &c. Phenomena of the putrefactive fermentation. Products of this fermentation. Miasma of marshes, &c.

a very offensive odor. The noxious miasma of marshes are supposed to be a gaseous principle, arising from the putrefactions of vegetable matter, but they have never been obtained in an insulated state, and it is not even known that they are a distinct principle of matter.

850. The dark mould arising from putrefactive fermentation enriches soils, and fits them for the production, and nourishment of new plants. Thus, in the vegetable kingdom, we everywhere behold decay followed by renewed life. Why then should man fear to commit his organic frame to the dissolution of the sepulchre, and the watchful eye of that Omniscient Power to whom every atom is known, and who can as easily re-assemble the dispersed elements, as he could at first have made man of the dust of the earth? And why should infidel man speculate upon the ability of the Almighty to raise the dead, because the atoms which composed these bodies, have successively held a place in other material forms? Having seen the powers which chemistry develops, shall we dare restrict the power of The GREAT CHEMIST OF THE UNIVERSE, to preserve amid the "wreck of matter" one minute atom, *one little germ* which may constitute our personal identity, and to form from this, that "celestial body" which is to be fashioned like unto His glorious body, immortal and incorruptible!"*

CHAPTER XXXVI.

ANIMAL CHEMISTRY, OR ANIMAL ORGANIC BODIES.

851. Animals, like vegetables, are composed of different parts; these parts, of different animal substances; and these substances, of different *proximate principles*. The object of animal chemistry, is to examine into the nature of those proximate principles, and their associations in the various solids and liquids of animals.

We do not find in the analysis of the proximate, animal principles, any new *ultimate elements*. These proximate principles differ from the vegetable principles, in containing more nitrogen, in a stronger tendency towards putrefactive fermentation, and in giving off offensive odors during this process.

* For an account of the chemical phenomena attending the *germination*, *growth*, *respiration*, &c. of plants, the student is referred to the author's "Familiar Lectures on Botany," where these subjects are discussed at large.

850. Reflections on the new life which results from putrefactive fermentation.

851. Composition of animals. The object of animal chemistry. Difference between the proximate animal principles and the vegetable principles.

852. By *destructive distillation*, or exposing animal substances to heat in close vessels, we obtain their ultimate elements. These, in some cases, as in animal oil, are the same as we obtain in the destructive distillation of vegetable matter; but, in the former, nitrogen in greater quantity is generally obtained and sometimes a little phosphorus and sulphur. The ultimate elements of animal matter may be, in general terms, stated as nitrogen, hydrogen, carbon and oxygen.

853. Animal substances are formed by the various operations of a living principle, as respiration, circulation, nutrition, secretion, &c. The proximate animal principles are less numerous than the vegetable. They may be divided into, 1st. *Neutral principles, or those that are neither fat nor acid*; 2d. *Animal acids*; 3d. *Animal substances which are fat, without being acid*; and 4th. *Saline and earthy matters*.

854. The first division includes fibrin, albumen, gelatine, &c. These principles contain a large proportion of carbon: hydrogen is in proportion to take up all their oxygen to form water, and all their nitrogen to form ammonia. But in destructive distillation, these elements are obtained under a variety of combinations; as some water, carbonic gas, carbonic oxide, carbonate and hydro-cyanate of ammonia, a thick, black and foetid oil, carburetted hydrogen, nitrogen, and the carbonaceous matter which remains in the retort. This animal carbon is more effectual as a clarifying agent than vegetable charcoal, and is less easily consumed, on account of its containing some phosphates and perhaps oxides of iron and manganese.

855. Fibrin is that part of *animal muscle* which gives the power of motion, by alternate contraction and relaxation. It constitutes the greater part of muscular flesh, and appears to be that substance immediately acted upon by the nervous matter, which is supposed to communicate directly with the sensorium or brain, from whence emanate the impulses which produce voluntary motion. Fibrin constitutes a large proportion of the blood, and exists in other animal fluids.

856. Pure fibrin is without taste or odor, of a yellowish color, and semi-transparent. Fibrin may be obtained by beating blood, recently obtained from the veins, with a bundle of twigs; it attaches itself to the sticks under the form of long, reddish filaments, which become colorless by repeated washing with cold water. According to Gay Lussac and Thenard it is

852. Destructive distillation. Ultimate elements of animal matter.

853. Animal substances cannot be recomposed. Four classes of proximate animal principles.

854. Substances included in the first class, &c.

855. What is fibrin?

856. Properties of fibrin, &c. How obtained? Constituent elements of fibrin, &c. Proteine.

composed of 53.360 parts of Carbon; 19.934 parts of Nitrogen; 19.685 parts of Oxygen; 7.021 parts of Hydrogen.—100.000. These proportions when reduced to *equivalents*, have been thus stated by Dr. Hare. Carbon 18 equiv.=108. Nitrogen 3 equiv.=42. Oxygen 5 equiv.=40. Hydrogen 14 equiv.=14.—Equiv. of fibrin=104.

Mulder, a German chemist, obtained by the decomposition of fibrin a substance which he called *proteine*, a name derived from the Greek, signifying *to take the first rank*. This is considered by Leibig as the chief constituent of the blood, and of fibrin and other animal tissues which are formed from the blood. The formula of relative properties given for *proteine* by Leibig is, Car. 48, Hyd. 36, Nit. 6, Ox. 14.

857. *Animal albumen*. The purest form in which it is known to exist, is in the *white of eggs*,* though here, it is united with water, soda, and sulphur. The free soda contained in the albumen of the egg is sufficient to green, slightly, blue vegetable infusions. Albumen exists in most of the animal solids and fluids. It is the germ of all animal matter; the starting point of all tissues, as cartilage, bones, hair, shell &c; and it exists in the skin, membranes, and muscles. In a liquid state, it exists in chyle, and blood, in the coagulable part of milk or that which becomes cheese, and forms a part of various other animal fluids.

It is heavier than water, and perfectly soluble. Its peculiar property is that of *coagulating* by heat, alcohol, and strong acids.

858. It is the property of coagulating, which renders albumen useful in clarifying liquors. Thus blood, which contains a large portion of albumen, is used to clarify the syrup, in the manufacture of sugar. And the use of the white of eggs to clarify liquor for jellies and preserves, is common in culinary operations. In these cases, the albumen, mixed in a very small proportion with the liquors, coagulates by heat and entangles in its substance all the sediment, or undissolved particles, which it carries to the surface of the liquid where they form a scum which may easily be removed. When albumen is used to clarify wine and cider, it is coagulated, by the vegetable acids and by alcohol, without heat.

The constituent elements of albumen and fibrin have been found by Leibig and others to be the same, and in the same proportions. With potassa, and soda, albumen forms a soap-like compound from which it is precipitated by acids in a coagulated state. Phosphoric acid does not precipitate albumen, but it is precipitated by pyro-phosphoric acid, also by metallic salts, tannin, and corrosive sublimate; for the latter it is a very delicate test,

* The word *albumen* was first applied only to distinguish the white of the eggs.

857. Purest form of albumen. Its extensive existence in animals, and animal matter. Peculiar property of albumen.

858. Use of albumen in clarifying liquors, &c. Albumen compared with fibrin. Substances which precipitate albumen. Change which takes place in an egg when placed in boiling water, &c. Opinions as to the cause of the coagulating of albumen, &c. Putrefactive tendency of albumen in a fluid state, &c. Sulphur in albumen. Test of the presence of albumen in animal fluids. An antidote to metallic poisons.

causing a visible white precipitate in a fluid containing a very small proportion of that poison. When coagulated by heat albumen becomes insoluble in water. If an egg taken from its shell, be put into boiling water, the white does not dissolve or mix with the water, because it almost instantly, begins to coagulate. In about three minutes it is boiled sufficiently for the table. Eggs may be thus boiled more delicately for the sick than with the shells on; in the latter case the outer portion of the white may become too much hardened, while the inner part is under done. Fresh eggs being full, do not cook as soon in the shell, as those twenty or thirty days old, which have a small vacuum at one end, owing to the escape of moisture through the pores of the shell. In six or seven minutes boiling, the albumen of the egg becomes solidified, and continued boiling would but serve to increase its hardness up to a certain point. From the insoluble nature of albumen, after being hardened by heat, we may infer that hard-boiled eggs, are indigestible food. Cheese, which is chiefly albumen hardened by pressure and desiccation, is of the same nature, and should not be eaten in large quantities.

There are different views as to the cause of the coagulation of albumen. Fourcroy attributed it to oxygenation. "But, says Thenard, "albumen coagulates as readily without as with access of air, and in alcohol as well as by heat, we must therefore refer this change to cohesion." The affinity between water and albumen appears slight, and is diminished by heat, until quite destroyed, the cohesive principle prevails, and albumen becomes a solid mass. The union of the water of fluid albumen with alcohol, would produce heat, and this would still further promote the decomposition of the albumen. The same cause operates when the strong acids are added to albumen: viz, the attraction of those acids for water, and the increase of temperature which takes place as these two fluids unite.

Fluid albumen readily putrefies; this may be observed in the case of an egg taken from the shell, when suffered to stand a few days, exposed to the air at a warm temperature. Even eggs protected by the shell require to be kept in salt, lime, or powdered charcoal, in order to preserve them for any great length of time. Coagulated albumen putrefies with difficulty; it therefore follows that hard-boiled eggs may be preserved much longer than eggs which have not been boiled.

Albumen contains some sulphur; thus when blood is suffered to evaporate in a silver vessel, the vessel becomes tarnished by sulphuret of silver; and the same may be observed of silver spoons with which eggs have been eaten. Putrid albumen also gives off the odor of sulphuretted hydrogen.

Galvanism furnishes an excellent test of the presence of albumen in animal fluids. When liquid albumen is exposed to the galvanic circuit, pure soda appears in the negative cup, and the albumen coagulates in the positive. This effect has been attributed to the decomposition of muriate of soda; the muriatic acid being thus left free, coagulates the albumen. On account of the insoluble precipitate which albumen forms with metallic salts and chlorides, by uniting with their acids, it is recommended as an antidote to poisons of this nature, especially corrosive sublimate and mercurial salts.

859. *Gelatine or Animal Jelly* constitutes the greater part of

859. What parts of animals contain gelatine? How obtained. Glue. Paper maker's size. Isinglass. Calve's foot jelly, &c. Portable soup, &c. Gelatine with alcohol, sulphuric acid, &c.

the skin of animals ; it is also contained in membranes, muscles, tendons, ligaments and cartilages, and even in bones and horns.

It may be obtained by boiling these substances in water. The gelatine dissolves, forming a transparent solution, which, when evaporated to a certain degree and cooled, *gelatinizes* or forms a semi-transparent, tremulous solid, as is seen in the jelly made by boiling calves' feet ; this is a hydrate, containing a large portion of water, in which it readily melts with a slight degree of heat. By continued evaporation it hardens, loses its transparency, and acquires a vitreous appearance. *Glue* is gelatine thus prepared, and is procured by boiling the skins and hoofs of animals. The size used by paper-makers is glue much diluted ; it is used to give the paper a smooth surface, and prevent ink from spreading. Paper without sizing is sometimes called *bibulous* or blotting paper, because it readily absorbs moisture.

*Isinglass** which is used for blanc-monge and jellies, is gelatine obtained from the sounds of fishes. It is usually pure and white, and being evaporated to a very dry state, is a concentrated gelatine, requiring but a small portion, dissolved in boiling water, to form a gelatinous mass when cool. *Calves'-foot-jelly* is made by boiling the feet of calves, straining and evaporating the liquor, and adding sugar, wine, lemon and spices, to give it an agreeable flavor. *Hartshorn shavings*, or small shavings of the horns of the hart, yield gelatine, which is considered as peculiarly nutritive for the sick. When gelatine is distilled, hydrogen and nitrogen unite and form ammonia ; which was formerly considered as a peculiar product of the hartshorn, and received the name by which it is generally known.

Portable soup may be made by boiling meat, or even bones for a sufficient length of time, straining and evaporating the liquor, and then drying it in thin cakes, by a slow, gentle heat. These cakes will keep for years, and form a very concentrated nourishment. As there is a great deal of gelatine in bones, it should be made an object in domestic economy to preserve the bones of roast meat for soup. There is a richness of flavor in soup prepared from such bones, that cannot be given to that made from joints of meat that have not been thus cooked. Soup is less used in domestic economy than it should be, considering that, on account of the gelatine it contains, it is one of the most nutritious kinds of food, and that those joints of meat which are the least expensive† furnish the greatest proportion of gelatine. By means of the strong heat which may be applied in *Papin's digester*, bones are readily dissolved, and their nutritious qualities thus extracted.

Gelatine is insoluble in alcohol, but dissolves in most of the diluted acids. Sulphuric acid converts it into a kind of sugar. Common vinegar, with a gentle heat, dissolves isinglass, forming with it a cement for glass and china. Gelatine does not, like fibrin and albumen, form with alkalies soapy compounds which may be precipitated by acids ; but it dissolves with hot caustic alkali, and forms a brownish viscid substance, without those properties. Gelatine differs from albumen in not readily precipitating metallic solutions.

860. Gelatine is remarkable for its *property* of combining with *tannin* ; by this means, the skins of animals are hardened, and converted into leather. The skins being freed from hair, fat,

* Fish glue or *ichthyocol*.

† There are what the butchers call *hock-bones*, or the lower joints of the legs of neat cattle which, being abundant in cartilage and tendons, are rich in gelatine.

860. Action of gelatine with tannin. Skins converted into leather. Elements of gelatine compared with those of fibrin and albumen.

&c. by various processes are little else than gelatine, bound together by fibrous matter. Thus prepared, they are laid in vats, or solutions of tannin. The latter, gradually leaving the water, forms with the gelatine a firm and insoluble union. By means of various improvements, which have been the fruits of chemical discovery, the process for tanning leather has been shortened, from two or three years, to a few months, or even weeks. Gelatine contains less carbon and nitrogen than either fibrin or albumen, and more oxygen and hydrogen.

Osmazome,

861. Was found by Thenard in the muscular flesh of animals, and in mushrooms. It is obtained by dissolving small pieces of animal muscle in cold water; on boiling the liquor, the albumen rises to the surface, from whence it is removed; the remaining liquor is filtered, evaporated to a syrup, and heated with strong alcohol, which dissolves the osmazome, and precipitates muriate of soda and potassa. On evaporating the alcoholic solution, pure osmazome is obtained. It is of a yellowish brownish color, with an agreeable taste and odor. It is to this substance, according to Thenard, that soup owes its flavor, 1 part of osmazome being combined with 7 parts of gelatine.

Sugar of Milk.

862. By evaporating *whey* the saccharine principle of milk is obtained. It is insoluble in strong alcohol, which gives a test for the sugar of milk, when used, as it sometimes is, for adulterating the sugar of the cane. It is less sweet than vegetable sugar, and does not suffer the vinous fermentation with water and yeast. According to analysis of this animal sugar, it contains no nitrogen, but carbon, oxygen, and hydrogen in very nearly the proportions of other sugar.

Second Class of Animal Substances, or Animal Acids.

863. By the term animal acids we mean such acids only as are the sole result of animal organization, and found only in the animal kingdom.

We shall give but few examples of these acids, as their study belongs rather to medical, than chemical science.

Lactic acid was discovered by Scheele in sour whey. According to Berzelius, it exists in blood. It is a thick, uncrystalizable liquid, soluble in water, and alcohol, and combines with bases, forming soluble salts. But the existence of this acid is regarded as uncertain. It has been suggested by Berzelius that it may be acetic acid, united to animal matter; or perhaps identical with zumic acid. *Formic acid* from *formica*, an ant, is extracted from ants; its specific gravity is greater than that of acetic acid, which it resembles in its properties. *Saccholactic or mucic acid*, is obtained by heat-

861. Mode of obtaining osmazome. Properties, &c.

862. How is sugar of milk obtained? Alcohol a test. Sugar of milk compared with vegetable sugar.

863. What is meant by the term animal acids. Lactic acid. Formic acid. Saccholactic acid. Caseic acid. Butyric, capric, and caproic acids. Sebacic acid. Stearic acid, &c. Choleic and cerebrie acids.

ing the sugar of milk with nitric acid; but as it is now known to exist in gums, and many other vegetable substances, it can no longer be regarded, exclusively, as an animal acid. *Caseic acid* gives to old cheese its peculiar odor; it is of a yellow color, with a taste like cheese; nitric acid converts it to oxalic acid. It gives ammonia by distillation, and is precipitated white, by a secretion of nut-galls. It forms with ammonia an uncrystalizable salt.

Butyric acid was discovered by Chevreul in butter. It inflames on the near approach of a burning body, does not solidify at 15° below zero. *Capric acid* has been obtained from butter made of cow's milk; and *caproic acid* from butter made of goat's milk. *Sebacic acid* was discovered by Thenard in the recipient after the distillation of hog's lard. It contains no nitrogen. It combines with alkalis, forming salts called *sebates*. *Stearic*, *Margaric*, *Oleic*, and some other acids discovered by Chevreul in a series of experiments on animal fat substances will be noticed in treating of that class of bodies. *Choleic acid* is the chief constituent of *bile*, in which it exists with soda, forming a saponaceous compound. *Cerebric acid*, combined with soda, forms the chief constituent of the fat found in the brain.

Third Class of Animal Substances; Animal Oils, or Fat Substances.

864. Bodies of this class melt at a low temperature, are insipid, very inflammable, insoluble in water, and give by distillation foetid oil, and a carbonaceous residuum. When their vapor is made to pass through a heated tube, carburetted hydrogen is disengaged. They contain no nitrogen, and but a small proportion of oxygen, and form soap with alkalis. These bodies are known under various names, as fat, oil, suet, lard, tallow and butter. They vary amongst themselves in hardness, and some other properties. When an animal substance is boiled, the fat, being specifically lighter than water, floats, and may easily be removed. In some cases, as in what is called by housekeepers the *trying* of lard, the fat being incorporated with a fibrous texture, requires to be for some hours exposed to a moderate heat, and then strained, in order to separate it from the fibrin.

865. *Train or fish Oil*, is obtained from the blubber of the whale. It is the common lamp oil, and is used in making oil gas. It is often so impure, as to give an offensive odor in burning. On account of the quantity of carbonaceous matter which settles upon the wick in burning impure oil, it is unsuitable for argand or astral lamps. The wick becoming encrusted with animal charcoal, its little capillary tubes which pumped up the oil and thus fed the flame, are prevented from performing their office, and the lamp goes out. This mortification to housewives, might be spared, if care were taken to procure good winter strained oil, to keep the lamps clean, and to tip the wick occasionally with spirits of turpentine, in order to render it more inflammable. Train oil is composed of

864. General properties of the third class of animal substances.

865. Train oil, its use, properties, &c. Why unsuitable for astral lamps, &c. Composition of train oil.

Carbon,	13	Equiv.=72	per cent.	68.87
Oxygen,	2	"	=16	" 16.10
Hydrogen.	17	"	=17	" 15.03
Chem. Equiv.	"	105		100.00

866. *Spermaceti* is obtained from the head of the sperm whale. It is found in an oily matter contained within a bony cavity of the head, and not in the brain of the whale. It is put into bags, and subjected to pressure: the part which is fluid and can be strained out at a low temperature, is called *winter strained oil*; this will resist the ordinary cold of winter without congealing, and burns in lamps without incrusting the wick. After the oil has been pressed out of the spermaceti, it is melted, strained, and washed with a weak solution of potassa; this is the *spermaceti* of commerce. It is softer and more brittle than white wax, and chiefly used for candles. It dissolves with boiling alcohol, and on cooling is deposited in the form of brilliant scales, called by Chevreul, *cetine*. This is pure spermaceti. Cetine forms a soap with potassa, which, when decomposed by an acid, gives rise to a substance, called *ethal*, from a combination of the first syllables of ether and alcohol, to both of which it has some resemblance.

867. *Stearin and Elain*. It was discovered by Chevreul that animal fat, and the fixed vegetable oils are not pure proximate principles, but consist of one substance which is hard at common temperatures, and another which is fluid. The former he called *stearin* from the Greek *stear*, suet; the latter *elain* from *elaion*, oil. Beef-suet, lard, and butter maintain their solidity at common temperatures, because they contain a greater proportion of stearin than of elain; while oil, in which elain exists more abundantly, is fluid except at very low temperatures.

These principles were obtained by Chevreul by dissolving pork-fat in boiling alcohol; after standing some time, the liquor was decanted, and to the undissolved fat was then added a new portion of boiling alcohol. The process was repeated until the whole was dissolved. Each portion of alcohol, on cooling, deposited *stearin* in white needle shaped crystals, while elain, which remained in solution, was obtained pure by evaporating the alcohol. Elain resembles olive oil in appearance; it is considered valuable for oiling the wheels of watches, and other delicate machinery, as it remains fluid at a very low temperature, and does not unite with the oxygen of the air to become an acid.

All fat substances contain stearin and elain, and are firm or soft, in proportion as one or the other prevails. Thus hog's-lard contains stearin 38 parts, and elain 62; while olive oil contains stearin 28 parts, and elain 72.

Their ultimate elements, are

	Stearin.	Elain.
Carbon	79.030	78.776
Hydrogen	11.422	11.770
Oxygen	9.548	9.454

868. When fat substances are heated with an alkali, a remarkable change appears to take place in the arrangement of the

866. Spermaceti. Winter strained oil. Spermaceti of commerce. Cetine. Ethal.

867. Discoveries of Chevreul with respect to animal fat, &c. Manner in which stearin and elain were obtained. Use made of elain in the arts. Proportions of stearin and elain. Ultimate elements of stearin and elain.

proximate principles. Stearin and elain are decomposed, and their elements arrange themselves in several new compounds, called *margaritic*, *stearic* and *oleic* acids and *glycerine*. The process of forming soap consists in the union of the acids with the alkalies employed, forming *margarate*, *stearate* and *oleate* of potassa or soda.

According to Chevreul, to whom science is indebted for these discoveries, *saponification is the change which fat substances undergo in the arrangement of their elements, by the action of the alkali*. Those elements, having combined, in proportions to form acids, unite with the alkali which is presented to them, and form *salts*, which are soluble in water, and capable of combining with it in all proportions. Thus soap is not, as was formerly considered, a direct combination of oil and alkali, but a mixture of various salts resulting from the union of acids and alkali. The nature of the compounds formed, differ in different kinds of soap. That which is made with the fat of pork, beef, &c., contains more stearate than that which is made with human fat, the latter consisting chiefly of margarate and oleate.

Soap is hard in proportion to the quantity of margarate or stearate it contains, and soft when the oleate prevails. Much also depends upon the nature of the alkaline base; as soda tends to render soap hard, and potassa soft. Thus the *stearate of soda* will form the *hardest* soap, and the *oleate of potassa* the *softest*. The hardness of soap is also increased by exposure to the air, or evaporation from any cause.

869. *Glycerine* is the sweet principle of oils: it is formed by the action of metallic oxides, upon fat substances, or in other words, during saponification. It may be obtained in the form of sweet, uncrystalizable syrup.

Adipocire (from *adeps*, fat, and *cera*, wax) is a white, pearly substance resembling spermaceti, formed from human bodies when subjected to slow decomposition, under water, or in wet places.

Fourcroy whose attention was first directed to the subject, regarded this matter as an ammoniacal soap with excess of fat.* Chevreul by a minute analysis has found that it consists of some ammonia, potassa and lime united with much margaritic acid, (to which it owes its peculiar whiteness,) and a little oleic acid.

It may be obtained by keeping animal muscle, for some months in a running stream; or, more rapidly, by digesting the muscle in nitric acid, and then exposing it to the action of water.

* The phenomenon was first observed on opening the graves in the cemetery of the Innocents at Paris in 1782. The superstitious regarded it as a miraculous testimony to the holy lives of the persons whose bodies were thus changed to a pearly white.

868. Effect of alkalies upon fat substances. In what consists the process of forming soap, or saponification? Cause of the hardness or softness of soap.

869. *Glycerine*. *Adipocire*.

Fourth Class of Animal Substances ; or saline and earthy matters and the soft or solid parts of animals.

870. All the humors, and many of the soft and solid parts of animals contain a certain quantity of saline and earthy matter. The phosphate of lime, muriate of soda and carbonate of soda are found to be most common.

No law of animal existence is more admirable than that by which food is converted into blood. First the food dissolving in the stomach, becomes a pulpy matter, called *chyme* ; the latter either passes into the intestines, or becomes a milky liquid called *chyle*. The chyle forms *blood*, and the blood is converted into the various liquid secretions and solid parts of the body.

871. By *secretion* is understood a process, in which any particular organ, by decomposing blood, forms a substance peculiar to that organ. It is thus that all animal fluids, except the chyle and blood are formed. Most of the fluids of secretion remain in the body, and then fulfil some peculiar office.

872. The *bile* is a bitter, yellowish-green secretion, formed in the liver, from venous blood. By mixing with the chyme in the stomach, it acts an important part in converting it into chyle, and is also a necessary stimulus to the bowels. Human bile consists of choleic acid, a bitter *resin*, *albumen*, *soda*, *some of the salts of soda*, as the sulphate, phosphate and muriate, *oxide of iron*, and a large proportion, (about 90 per cent) of *water*. In diseased persons the proportion of resin is less, and that of albumen greater, than in those who are in health. A peculiar substance, called *picromel*,* has been discovered in human bile, in that of the ox and some other animals ; and it is supposed to exist in all. It is of consistence of turpentine, of a bitter taste, and without odor.

873. *Gastric juice* is a secretion of the stomach, and the principal agent in digestion. It has a saline taste, and does not give either the acid or alkaline test with vegetable colors. Though apparently a mild, neutral liquid, it possesses a remarkable solvent power. It dissolves the food introduced into the stomach and changes it into the pulpy substance, chyme. Experiments made with the gastric juice taken from the stomach of an animal killed while fasting, have proved that this liquid is capable of dissolving very insoluble substances ;—and it is known that after death, or in excessive fasting, the gastric juice turns its active energies upon, and seizes the coats of the stomach itself.

* From the Greek *picros*, bitter, and *mele*, honey, so called from its peculiar taste.

870. Saline and earthy matter found in animal substances. Change of food into blood. Chyme and chyle, &c.

871. Secretion. 872. Bile. Picromel. 873. Gastric juice.

874. *Lymph* is a colorless, saltish liquid, secreted in a set of vessels, called *lymphatic*, which have their origin in the extremities of the arteries, and extend over the surface of the cellular membrane. The liquid formed in them, lubricates the various cavities of the body, exists in blisters, and is secreted, in large quantities, in cases of dropsy.

875. *Synovia* is a viscous fluid, secreted in the capsules of the joints, preserving their health and freedom of motion, and protecting them from injury.

876. *Saliva* is an inodorous, tasteless fluid, secreted from the blood, by different glands around the mouth, and discharged into it through various ducts. Mixing with food it softens and dissolves it, and thus serves an important purpose in digesting. It lubricates the organs of speech, and thus enables them to perform their office with greater ease. In the analysis of this proximate principle, are found salts of various kinds, (chiefly hydrochlorate of potassa,) *mucus*, *albumen*, and a very large proportion of water. From the mucus existing in saliva, according to Thenard is deposited the *tartar* which incrusts the teeth.

877. *Blood* is that part which, by its various transformations, gives rise to every part of the animal organism. Its color in the arteries is a lively red, and in the veins a deep purple. In respiration, the dark venous blood enters the lungs, and being there exposed through a thin porous membrane to the action of the air, it absorbs oxygen inhaled by the lungs from the atmosphere, and becomes of a bright red color.

Blood consists of a liquid through which are diffused small globules, which contain fibrin, the coloring matter and iron. The liquid portion consists of water holding in solution fibrin, albumen and salts. When blood is suffered to stand undisturbed it separates into a red coagulum called the *clot*, (*crassamentum*,) and a thin yellowish fluid called the *serum*. More than $\frac{3}{4}$ th. of the blood is water.

878. The *brain*, *skin*, *glands*, *tendons*, *muscles* and *bones*;—*hair*, *wool*, *nails*, *teeth*, *shells*, &c., with various other substances constituting either the bodies of animals, or resulting from their organization, have been subjected to chemical analysis and though found to differ among themselves in their proximate principles, yet they consist of a small number of the ultimate elements into which Chemistry has resolved all matter, whether of the inorganic or organic kingdoms.

879. The late investigations of Dr. Leibig of Germany in Organic Chemistry, have thrown much light upon some subjects, hitherto but little under-

874. Lymph. 875. Synovia. 876. Saliva. 877. Blood. Color of arterial and venous blood. Parts of blood. 878. Brain, skin, &c. 879. Dr. Leibig's investigations in organic chemistry.

stood. He has simplified the analysis of organic bodies, and established formulæ, and equations, upon principles of arithmetical calculation. He has attempted to ascertain and express in simple numbers those chemical forces, which, acting at insensible distances, produce in organic bodies the peculiar changes to which they are subject, and in a degree give laws to vitality.

The higher phenomena of mental existence he does not profess to trace to their proximate, and still less to their ultimate causes; these he justly refers to an immaterial agency, having nothing in common with the vital force.

880. Dr. Leibig justly condemns the efforts of philosophers to penetrate the relations of the soul to animal life; but while we can never learn what life is, we may discover the laws of vitality, with the chemical or mechanical causes which disturb, promote, or destroy it. We are also able in many cases to trace the influence of the spiritual nature within, in its effects upon the condition of the organic frame; but the mysterious tenant of the building is invisible to our senses, and shrouded from our observation.

881. Dr. Leibig's views of Organic Chemistry applied to physiology, may be briefly stated as follows:

Vital force, or vitality, which is the spring of both vegetable and animal life, is a *force* which causes growth, and is capable of reproduction, or of supply of matter consumed. It is a *force*, which may be as in the seed of a plant, in a *state of rest*.

882. The growth and developement of *vegetables* depend on the *elimination of oxygen*, which is separated from the other component parts of their nourishment.

In animal life on the contrary, there is a continued *absorption of oxygen* from the air, and its combination with the animal body. While no part of an organized body can serve as food for vegetables until by the process of putrefaction and decay, it has assumed the form of inorganic matter; the animal organism requires for its support and developement highly organized atoms, and therefore the food of animals consists of parts of *organisms*.

883. The nervous system within the animal organism, is the source of the motion and force necessary to sustain the vital process.

Assimilation, or the process of formation and growth, or in other words, the passage of matter from a state of motion, to that of rest, goes on in the same way in animals and vegetables; in both, *it is carried on without consciousness*. Though intellect adds to vitality a peculiar source of energy, or of disturbance, the soul has no more to do with the developement of the germ of animal life in the egg of a fowl, than in that of vegetable life in the seed of a plant.

884. The first condition of animal life being the assimilation or nourishment, the second is absorption of oxygen from the atmosphere, as all vital activity arises from the mutual action of oxygen and the elements of food. In the processes of nutrition and reproduction, matter passes from the state of motion to that of rest; under the influence of the nervous system, this matter again enters into a state of motion. The ultimate causes of these different conditions of the vital force, are chemical forces; the cause of a state of rest is a resistance determined by a *force of attraction*, which acts between the smallest particles of matter, or otherwise by chemical affinity.

As in a closed galvanic circuit, a *metal* in contact with an acid undergoes *certain changes*, producing what is called a *current of electricity*, so, in the animal body, in consequence of changes undergone by matter previously constituting a part of the organism, certain phenomena of motion and activity are perceived, and to them we give the name of *life* or *vitality*.

880. Laws of vitality. Chemical or mechanical causes. 881. Organic chemistry applied to physiology. 882. Growth of animal and vegetable life.

883. Assimilation. 884. Vital activity.

885. The great amount of oxygen introduced through the lungs, and through the pores of the skin into the animal system, is disposed of by combining with carbon and hydrogen, which are furnished by supplies of food. It is considered that an adult person receives daily into his system 32½ ounces of oxygen, and that 13 and 9-16 ounces of carbon, unite with that to form carbonic acid gas, which escapes through the skin and lungs.

Since no part of the oxygen taken into the system is given off in any other form but that of a compound of carbon or hydrogen, and since these are supplied by food, it follows that the amount of nourishment required for the support of the animal body, must be in a direct ratio to the quantity of oxygen taken into the system.

886. The consumption of oxygen in equal times may be expressed by the number of respirations; it is clear that the quantity of nourishment required must vary with the force and number of respirations. The number of respirations is smaller in a state of rest than during exercise. The quantity of food necessary in both conditions must vary in the same ratio. An excess of food is incompatible with deficiency in respired oxygen, that is with sufficient exercise. The quantity of oxygen which an animal takes into the lungs, not only depends upon the number of respirations, but is affected by the temperature and density of the atmosphere. Air being expanded by heat, and contracted by cold, it follows that at different temperatures equal volumes of air must contain unequal weights of oxygen.

In an equal number of respirations we consume more oxygen at the level of the sea, than on a mountain, where the air is less dense. It is a wise provision of Providence, that the articles of food in different climates, are very unequal in the proportion of carbon they contain. The fruits, on which the natives of southern countries usually subsist, do not contain more than 12 per cent of carbon, while the bacon and train oil, used by the inhabitants of the polar regions, contain from 66 to 80 per cent of carbon.

These facts being established mankind should seek to conform to the laws of their organic nature, and proportion their food to the climate in which they live, and the degree of exercise they take.

887. Animal heat is caused by the mutual action of the combustible hydrogen and carbon of food and oxygen, or the great supporter of combustion; these combining, are conveyed by the circulation of the blood to every part of the body. The carbon of the food which is converted into carbonic acid within the body must give out as much heat as if it had been burnt directly in the air, or in oxygen gas; but in the one case the combustion is rapid, in the other slow.

The amount of heat liberated must increase or diminish with the quantity of oxygen introduced in equal times by respiration. Those animals which respire most frequently and consequently consume most oxygen, possess a higher temperature than others, which with a body of equal size to be heated, take into the system less oxygen. Thus the temperature of a child is 102°, that of an adult 99°.

888. A deficiency of food, and a want of power to convert the food into a part of the organism, both equally cause a want of resistance. The flame goes out because the oil is consumed; and it is the oxygen that has consumed it.

889. There are various causes by which force or motion may be produced. A bent spring, a current of air, the fall of water, fire applied to a

885. Disposition of oxygen. Amount of oxygen introduced into the system.

886. Consumption of oxygen. Number of respirations. Quantity of food.

Situations which air contains the most oxygen. Properties of carbon in food.

887. Cause of animal heat. Effect of increased respiration on animal heat.

888. Result of deficiency of food. 889. Physical motion. Animal motion

boiler, the solution of metal in an acid, all these different causes of motion may be made to produce the same effect. But in the animal body we recognize as the ultimate cause of all force only one cause, the *chemical action* which the elements of the food, and the oxygen of the air mutually exercise on each other. The only *known* ultimate cause of vital force, either in animals or plants is a chemical process.

890. *Theory of respiration.* During the passage of the *venous blood* through the lungs, oxygen is absorbed from the atmosphere, and the blood changes its color. For every volume of oxygen absorbed, an equal volume of carbonic acid is given out. The red globules of blood contain a *compound of iron*, which is found in no other constituent of the body. It appears that this is necessary to animal life from the great affinity of iron for oxygen, the globules readily become oxidised; they are now in a condition to combine with the carbonic acid which they meet with in travelling through the capillary vessels, and become the carbonate of protoxide of iron.

It is in the capillary system that the functions of secretion, nutrition, absorption, and calorification are performed. This seems to be the great work shop of the animal system, the globules having returned from the lungs towards the heart richly charged with oxygen, mingle with the arterial blood, and return to the lungs with a new supply of surplus carbonic acid which impedes the vital functions, and is emitted by the exhalation of the breath.

Before taking a final leave of our subject, we would call the attention of the young to the effects which the study of the useful and noble science of Chemistry should have upon their *own minds*. Chemists are sometimes, most strangely led to confound the soul with matter; the laws of nature, with the providence of God. This unhappy result is owing either to a littleness of mind, which cannot rise from effects beyond their secondary causes, or a pride of intellect which disdains to ascribe Supreme power to an unknown being. The phenomena of nature exhibit to the enlightened and humble Christian, an all wise and powerful Divinity who presides over, and governs all. The regular sequences of natural phenomena, so far from indicating the non-existence of a Deity, prove themselves to be the *laws* to which *He* has, wisely, subjected all material substances. The skeptic indeed talks of the *laws of nature*; but how absurd to suppose the existence of laws, without a *lawgiver*!

We have shown, in a great variety of applications, the utility of Chemistry considered in its economical relations;—but, in taking leave of our subject, we would refer to considerations of a higher and nobler nature.—We would bid adieu to our science, not merely as to an agent subservient to material wants, but as a noble pursuit, in which, in addition to the pure and elevated enjoyment arising from the acquisition of knowledge, our souls have been raised to higher thoughts of God, and a better understanding of His operations.

890. *Theory of respiration.* Change in the blood effected by the absorption of oxygen. Process by which the changes in the blood is effected. Capillary system.

THE END.

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