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A

COMPENDIUM

OF THE

COURSE OF CHEMICAL INSTRUCTION

IN THE

MEDICAL DEPARTMENT

OF

The University of Pennsylvania.

BY

ROBERT HARE, M.D.

PROFESSOR OF CHEMISTRY.

PRINTED FOR THE USE OF HIS PUPILS.

SECOND EDITION.

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PREFACE

TO THE FIRST EDITION.

Where a subject cannot be followed by a reader without *study*, it would seem unreasonable to expect that, without some assistance, it should be followed at a lecture.

Under this impression, from the time that I became a lecturer, I applied myself so to improve and multiply the means and methods of experimental illustration, as to render manipulation easier, and the result more interesting and instructive.

But notwithstanding all my efforts, there remained obstacles to be surmounted. However striking might be the experimental illustration of a property or principle, the rationale might be incomprehensible to a majority of my class, unless an opportunity for studying it were afforded them.

Again, some of my contrivances, which greatly facilitated my experiments, were too complex to be understood without a minuteness of explanation, which, even if it were useful and agreeable to some of my hearers, might be useless and irksome to others; and to such minutiæ I have not deemed it expedient to exact attention.

A chemical class, in a medical school, usually consists of individuals, who differ widely with respect to their taste for chemistry, and in opinion as to the extent to which it may be practicable or expedient for them to learn it. There is also much disparity in the opportunities, which they may have enjoyed, of acquiring some knowledge of this science, and of others which are subsidiary to its explanation. Hence a lecturer may expatiate too much, for one portion of his auditors, and yet be too concise for another portion. While to the adept he may often appear trite, to the novice he may as often appear abstruse.

Some pupils, actuated by a laudable curiosity, under circumstances permitting its indulgence, may desire an accurate knowledge of the apparatus, by which my experimental illustrations are facilitated: other pupils may feel themselves justified, perhaps necessitated, not to occupy their time with the acquisition of any knowledge which is not indispensable to graduation.

After some years' experience of the difficulties abovementioned, I came to the conclusion, that the time spent in the lecture room might be rendered much more profitable, if students could be previously apprized of the chain of ideas, or the apparatus and experiments, to be subjected to attention at each lecture; especially as the memory might afterwards be refreshed by the same means. In consequence of this conviction, the minutes of my course of instruction were printed; and subsequently, a work comprising engravings and descriptions of the larger portion of such of my apparatus and experiments, as could in this way be advantageously elucidated. Encouraged by the success of my plan, I am now preparing an edition which will be still more extensive. The work thus expanded, I have entitled "A Compendium of the Course of Chemical Instruction in the Medical School," &c.

There will be much matter in the Compendium, respecting which I shall not question candidates at the examination for degrees. With the *essence* of the larger part, I shall undoubtedly expect them to be acquainted; but other portions have been introduced, that I may not be obliged to dwell upon them in my lectures, and that attention to them may be optional on the part of the students. To designate the portion of the work, respecting which candidates for degrees will not be questioned, I have had it printed in a smaller type, excepting where it was too much blended with subjects of primary importance to be separated. I wish it however to be understood, that I shall expect attention to the parts thus distinguished, so far as they may be necessary to a comprehension of the rest. Thus, although I do not deem it to be a part of my duty to question a pupil on pneumatics, I shall expect him to understand the influence of atmospheric pressure upon chemical phenomena, and in pneumato-chemical operations.

One great and almost self-evident advantage, resulting from my undertaking, I have yet to mention; I allude to the instruction which students may derive from the Compendium, either before or subsequently to their attendance on my lectures, and especially during the period which intervenes between their first and second course.

PREFACE.

In laying before my class the second edition of my Compendium of Chemistry, I have little to add to the ideas presented to the reader in the preceding pages, comprising a copy of the Preface to the first edition.

So numerous and extensive have been the alterations and additions, rendered necessary by the progress of science, that the republication of this work has required more time than I expected. Hence, I have been unable to prepare the whole previously to the commencement of the present session; and am consequently obliged to issue it in numbers.

Being unable to procure the engravings requisite to give to my Lectures on Galvanism and Electromagnetism a degree of illustration corresponding with that afforded to the "Brief Exposition of Mechanical Electricity," I have had printed a revised and amended abstract from my lectures on those branches as previously published. This abstract will be handed to the class in due time.

The next number will comprise from one to two hundred pages of the Compendium.

I am under the impression that it will not be in my power to issue the Appendix before the end of this session. For information respecting the alterations which I have deemed it expedient to make in arrangement, classification, and nomenclature, I refer to the Preface to the Brief Exposition of Mechanical Electricity: also to pages 97, 125, and 200, and to my Letter on the Berzelian Nomenclature, which occupies the first pages of the Appendix, and will be delivered herewith. It will be seen, that in this edition I have employed type of three sizes, in order to indicate to the student the relative claims of the contained matter upon his attention.

DEFINITION OF CHEMISTRY.

It is natural for a person whose attention may be directed to chemistry, to inquire, of what does it treat, or how is it to be defined, or distinguished from other sciences? I subjoin various definitions from some of the most celebrated modern writers on chemistry.

Agreeably to the definition given in the first page of the Compendium, chemistry treats of those phenomena and operations of nature which arise from reaction between inorganic particles.

Thomson defines chemistry to be "the science which treats of those events or changes, in natural bodies, which are not accompanied by sensible motions."

Henry conceives that "it may be defined, the science which investigates the composition of material substances, and the permanent changes of constitution, which their mutual actions produce."

According to Murray, "it is the science which investigates the combinations of matter, and the laws of those general forces, by which these combinations are established and subverted."

Brande alleges "that it is the object of chemistry, to investigate all changes in the constitution of matter, whether effected by heat, mixture, or other means."

According to Ure, "chemistry may be defined that science, the object of which is to discover and explain the changes of composition that occur among the integrant and constituent parts of different bodies."

The definition given by Berzelius is as follows:—"Chemistry is the science which makes known the composition of bodies, and the manner in which they comport with each other."

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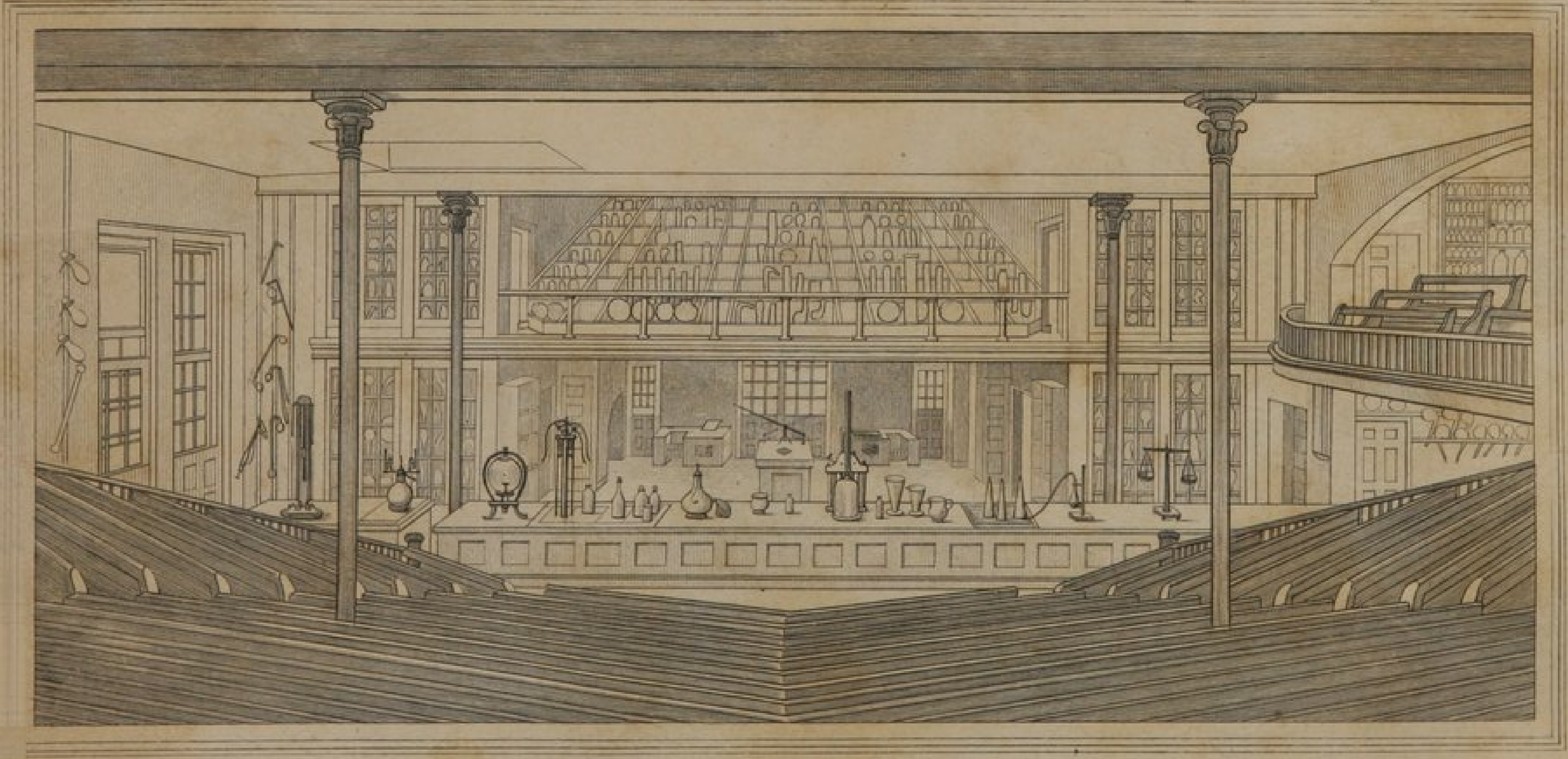
Dimensions of the Lecture room & Laboratory 60 feet square — adjoining offices 35 by 25 ft.



CHEMICAL LABORATORY AND LECTURE ROOM

in the Medical Department of the University of Pennsylvania

COMPENDIUM
OF
CHEMISTRY,
&c.

OF THE REACTION BETWEEN MASSES OR ATOMS OF MATTER, AS THE CAUSE OF THE PHENOMENA AND OPERATIONS OF THE PHYSICAL WORLD.

The phenomena and operations of the material world appear to be dependent on certain properties in the particles or masses of matter which enable them to exercise a reciprocal influence.

Without this reciprocal action, which I would prefer to call reaction,* every particle or mass would be as if no other existed, and could itself have no efficient existence. The reciprocal action or reaction, thus inferred to exist, may be distinguished as taking place between masses, between a mass and particles, and between particles only.

Reaction between masses† is sublimely exemplified in the solar system, by that attraction between the sun and planets, by which they are made to revolve in their orbits.

Reaction between a mass and particles, is exemplified by the reflection, refraction, or polarization of light; as by the moon, the rainbow, the Iceland spar.

Reaction between particles is exemplified by a fire, or the explosion of gunpowder.

DEFINITION OF NATURAL PHILOSOPHY, CHEMISTRY, AND PHYSIOLOGY.

Natural Philosophy, in its most extensive sense, treats of physical reaction generally. In its more limited and usual acceptation, it treats of those phenomena and ope-

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* In Mechanics, action is said to produce reaction: but in the case of an innate property, which mutually causes different portions of matter to be self-attractive, or repellent, it is impossible to distinguish the agent from the reagent. From our first acquaintance with any bodies so situated, they may be said mutually to react, or to exercise reaction.

† By the word mass, I mean a congeries of particles capable of producing some effect collectively, to which severally they would be incompetent.

rations of nature, which arise from reaction between masses, or between a mass and particles.

Chemistry treats of the phenomena and operations of nature, which arise from reaction between the particles of inorganic matter.

Physiology treats of the phenomena and operations, which arise from the reaction of the masses or atoms, of organic or living bodies.

REACTION BETWEEN PARTICLES, OR CHEMICAL REACTION,

Is distinguished into repulsive reaction, or repulsion, and attractive reaction, or attraction.

ON REPULSIVE REACTION, OR REPULSION.

A PRIORI PROOFS THAT THERE MUST BE A MATTER, IN WHICH REPULSION EXISTS AS AN INHERENT PROPERTY.

Matter may be defined to be that which has properties. We know nothing of matter directly. It is only with its properties that we have a direct acquaintance. It is upon our perception of matter, through the powers or properties by which it affects our senses, that we become confident in its existence.

The existence of repulsion and attraction is as evident as that of the matter which, in obedience to their successive predominancy, may be seen either to cohere, as in solids, with great tenacity, or to fly apart with explosive violence in the state of a vapour. The existence of repulsion and attraction being proved, it must be admitted that they are properties of matter; since the existence of a property, independently of matter, is inconceivable. Yet being of a nature to counteract each other, the repellent and attractive powers cannot coexist in particles of the same kind, and consequently must belong to particles of different kinds. There must therefore be a matter endowed with repulsion, distinct from that which is endowed with attraction.

I conceive that the phenomena of chemistry demonstrate that there are at least the three following properties, which, from their obvious incompatibility, cannot belong to the same elementary particles.

An innate property of reciprocal attraction.

An innate property of counteracting attraction directly, by imparting reciprocal repulsion.

And an innate property of imparting an attraction, variable in its force, and limited and contingent in its duration.

I presume that there must be at least three different kinds of matter, to each of which, one of the properties thus specified innately appertains.

The permanent and unvarying attractive power is exemplified by gravitation, and as modified by circumstances, by tenacity, or cohesion.

It resides undoubtedly in every kind of matter endowed with weight, and consequently in all that is considered as material by the mass of mankind.

It must likewise act between each of those imponderable principles which I am about to mention, and all other matter, whether ponderable or imponderable.

The property of imparting reciprocal repulsion to ponderable matter, is supposed by chemists generally to reside in certain imponderable material reciprocally repulsive particles, constituting the cause of heat, called caloric.

The power of indirectly counteracting inherent attraction, and substituting for it a contingent and variable attraction, appears to belong to electricity. Light also appears to exercise a modifying influence.

Thus have we reason to infer the existence of at least three imponderable principles—caloric, light, and electricity—each consisting of particles reciprocally repulsive, yet attractive of other matter, and probably more or less attractive of each other.

OF CALORIC.

EXPERIMENTAL PROOFS OF THE EXISTENCE OF A MATERIAL CAUSE OF CALORIFIC REPULSION.

It has been ascertained that ice melts, and water freezes, at the same temperature, of 32° of Fahrenheit's thermometer. If at this temperature, which is called the freezing point, ice, in a divided state, as in that of snow for instance, be mingled with an equal weight of water at 172°, the ice will be melted, and the resulting temperature will be 32°; but if equal weights of water be mingled, at those temperatures, the mixture will be at the mean heat of 102°.

It follows that a portion of heat becomes latent in the aqueous particles during the liquefaction of the ice, sufficient to raise an equal weight of liquid water one hundred and forty degrees. In this case the ice is supposed to combine with material calorific particles, innately endowed with a power of reciprocal repulsion, and likewise with that of combining with ponderable matter. Hence liquid water is considered as a combination of ponderable particles, endowed with a reciprocally attractive power, and imponderable particles endowed with a reciprocally repellent power, so, that in obedience to the power last mentioned, the compound atoms instead of cohering, as in the solid state, move freely among each other, forming consequently a liquid.

In all cases of liquefaction, or fusion, which have been examined, analogous results have been observed; whence it is generally believed that whenever a solid is converted into a liquid, its particles unite with a portion of the material cause of heat, which becomes latent as in the case of ice in melting. The evidence is equally strong in favour of the inference that in passing from the liquid to the aeriform state, ponderable matter combines with, and renders latent even a larger quantity of heat in proportion to its weight, than in cases of liquefaction.

When, by means of a thermometer, we observe the rise of temperature in water exposed to a regular heat, as when placed in a cup upon a stove, it is found that nearly equal increments of heat are acquired in equal times, until the boiling point is attained. Subsequently the cup being open, so as to allow the steam to escape freely, no further rise of temperature will be found to ensue; but in lieu of it, steam will be evolved, more or less copiously, in proportion to the activity of the fire—Since from the time the water boils it ceases to grow hotter, it may be fairly presumed that the steam generated during the ebullition, although of a temperature no higher than 212°, contains in a latent state, the caloric which meanwhile enters the liquid. This presumption is fully justified by the fact, that if any given weight of steam be received in a quantity of cool water ten times heavier, it will cause in it a rise of temperature of nearly one hundred degrees.

The heat, which would raise ten parts of water to 100 degrees, if it were concentrated into one of those parts, would raise it to 1000 degrees nearly, which is about equal to a red heat. It follows, therefore, that as much heat is absorbed in producing steam, as would render the water, of which it consists, red hot, if prevented from assuming the aeriform state.

These facts and deductions induce chemists generally to believe, that the cause of calorific repulsion is material—that it consists of a fluid, of which the particles are self-repellent, while they attract other matter—that by the union of this fluid with other matter, a repulsive property is imparted, which counteracts cohesion, so as to cause, successively, expansion, fusion, and the aeriform state. And further, that it is by the afflux of the calorific matter, that the sensation of heat is produced, while that of cold results from its efflux.

OF THE TERM CALORIC.

If we place a small heap of fulminating mercury upon the face of a hammer, and strike it duly with another hammer, an explosion will ensue so violent as to indent the steel. This explosion, agreeably to the premises, can only be explained, by supposing the evolution of a great quantity of the material cause of heat. Were an equal quantity of red hot sand, to be suddenly quenched with water, the effect would be comparatively feeble. We may therefore infer that the fulminating powder, though cold, contains more of the cause of heat, than a like quantity of red hot sand. Hence it would follow from using the word heat in the sense, both of cause and effect, that there is more heat in a cold body, than in a hot one; which is in language a contradiction. On this account it was considered proper, by the chemists of the Lavoisierian school, to use a new word, *caloric*, to designate the material cause of calorific repulsion.

1. EXPERIMENTAL ILLUSTRATION.

A portion of fulminating mercury is exploded between two hammers.

ORDER TO BE PURSUED IN TREATING OF CALORIC.

On expansion. On the influence of atmospheric and other pressure, in opposing calorific expansion. On vaporization. On capacities for caloric and specific heat. On the communication of caloric. Of the means of producing heat, or rendering caloric sensible. Of the means of producing cold, or rendering caloric latent. On the states in which caloric exists in nature.

OF EXPANSION.

OF THE EXPANSION OF SOLIDS—OF LIQUIDS—AND OF ELASTIC FLUIDS, ON THE OPPONENT AGENCY OF ATMOSPHERIC AND OTHER PRESSURE.

EXPANSION OF SOLIDS.

A ring and plug, which, when cold, fit each other, cease to do so when either is heated: and a tire, when *red hot*, is made to embrace a wheel, otherwise too large for it.

2. *The Influence of Temperature on the length of a Metallic Wire may be rendered very evident by means of the instrument of which the opposite figure is a representation.*

WW represents a wire, beneath which is a spirit lamp, consisting of a long, narrow, triangular vessel of sheet copper, open along the upper angle, so as to receive and support a strip of thick cotton cloth, or a succession of wicks. By the action of the screw at S, the wire is tightened; and by its influence on the levers, the index, I, is raised. The spirit lamp is then lighted, and the wire enveloped with flame. It is of course heated and expanded; and, allowing more liberty to the levers, the index, upheld by them, falls.

By the action of the screw the wire may be again tightened, and the application of the lamp being continued, will again, by a further expansion, cause the depression of the index; so that the experiment may be repeated several times in succession.

Since this figure was drawn, I have substituted for the alcohol lamp, the more manageable flame of hydrogen gas, emitted from a row of apertures in a pipe supplied by an apparatus, for the generation of that gas.

If while the index is depressed, by the expansion, ice or cold water be applied to the wire, a contraction immediately follows, so as to raise the index to its original position.

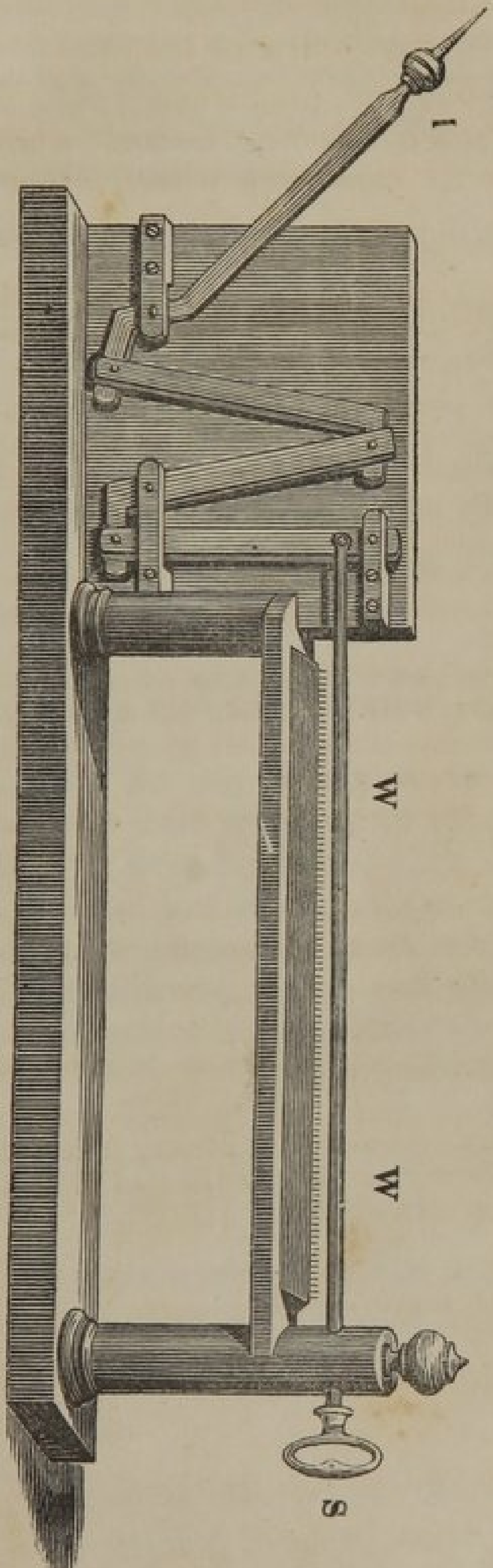
METALS ARE THE MOST EXPANSIBLE SOLIDS, BUT SOME ARE MORE EXPANSIBLE THAN OTHERS.

The following table, abstracted by Turner, from that furnished by Lavoisier, will show the increase of bulk obtained by glass and various metals, in rising in temperature from 32° to 212°.

Names of Substances.	*Elongation when heated from 32° to 212°.*
Glass tube without lead, a mean of three specimens	1-1115 of its length.
English flint glass,	1-1248
Copper,	1-581
Brass—mean of two specimens,	1-532
Soft iron forged,	1-819
Iron wire,	1-812
Untempered steel,	1-927
Tempered steel,	1-807
Lead,	1-351
Tin of India,	1-516
Tin of Falmouth,	1-462
Silver,	1-524
Gold—mean of three specimens,	1-602
Platinum, determined by Borda,	1-1167

Instrument for demonstrating the Power of Caloric in expanding a Metallic Rod.

(C. p. 6.)



Pyrometers have been made of platinum, in one of which, changes, arising from temperature in the length of a cylinder of this metal, are made sensible by the motion of a lever associated with it, and which acts as an index. In the other, a bulb is formed of the platina, and the degree of the heat is inferred from the quantity of air expelled.

The use of this air pyrometer is burdened by the necessity of measurement and calculation to ascertain the result. This might be very much facilitated by the use of a sliding rod and air-gage. The retraction of the rod might be made to compensate the expulsion of air, while divisions well made on it would indicate the quantity.

3. EXPERIMENTAL ILLUSTRATION OF THE DIFFERENT EXPANSIBILITY OF METALS.

That the expansibility of one metal may exceed that of another, may be rendered apparent by soldering together, face to face, two thin strips, one iron, the other brass. On exposure to heat, the compound strip, thus constituted, assumes the shape of an arch. The brass, which is the more expansible metal, forms the *outer*, and of course, *larger* curve.

SUPPOSED EXCEPTION TO THE LAW, THAT SOLIDS EXPAND BY HEAT, IN THE CASE OF CLAY; WHICH CONTRACTS IN THE FIRE.

The phenomena do not justify us in considering the contraction of clay from heat, as an exception to the general law. In the first instance, clay shrinks by losing water, of which the last portions are difficult to expel. In the next place, a chemical union takes place between the principal ingredients, silica and alumina, which is rendered more complete in proportion to the duration and intensity of the fire. It may be presumed that the vitreous compound which would result from a complete fusion and combination of the constituents, would be as expansible as other vitreous substances.

4. EXPERIMENTAL ILLUSTRATION.

The contraction produced by heat in cylinders of clay, shown by means of the ingenious, but inaccurate pyrometer of Wedgewood.

OF THE EXPANSION OF LIQUIDS OR NON-ELASTIC FLUIDS.

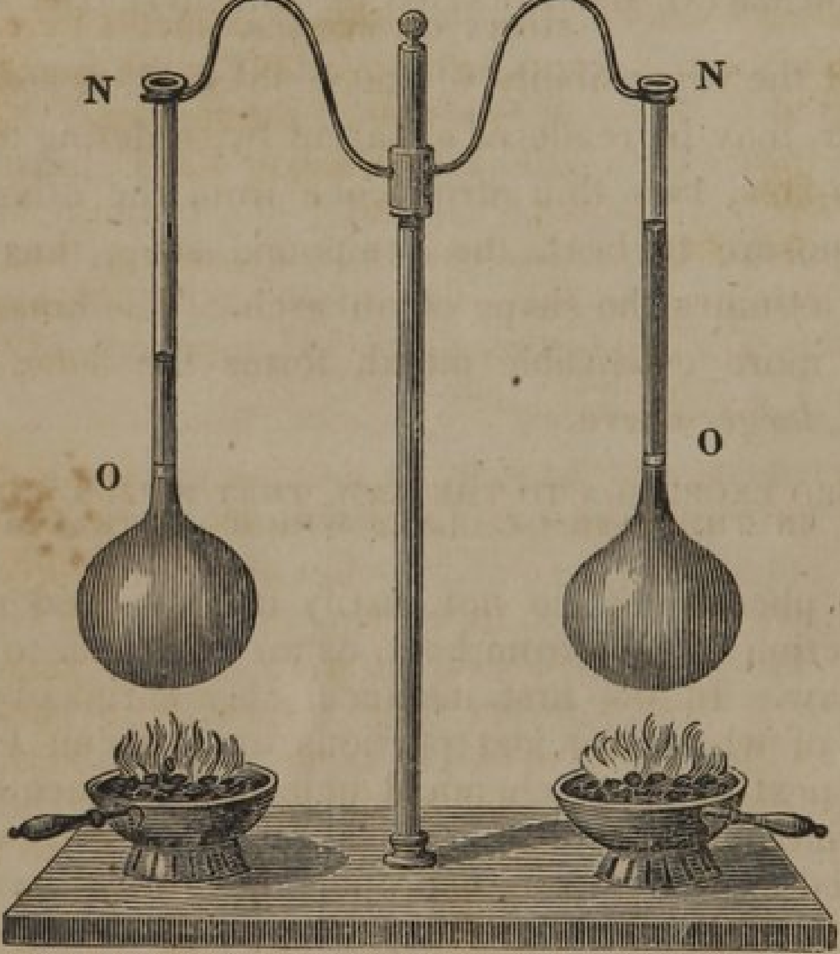
The word fluid applies to every mass that will flow, or distribute itself equally, in obedience to its own weight or self-repulsion.

Ponderable fluids are either elastic or non-elastic.

Latterly the term *liquid* has been employed to designate those fluids which are, like water, alcohol, and oil, devoid of elasticity; a property which, in due time, I shall define and illustrate.

5. EXPANSION OF LIQUIDS.

Liquids are expanded when their Temperature is raised, and some Liquids are more expansible than others.



Let two globular glass vessels, with long narrow necks, as nearly as possible of the same size and shape, be supplied severally, with water and alcohol, excepting the necks from N N to O O, as represented in the preceding figure. Under each vessel, place equal quantities of charcoal, burning with a similar degree of intensity: or preferably, surround the bulbs simultaneously with hot water in an oblong vessel of suitable ~~directions~~. The liquids in both vessels will be expanded, so as to rise into the necks; but the alcohol will expand to a greater height than the water.

The dilatation of the liquids mentioned below, by a change of temperature from 32° to 212°, is as follows—alcohol 1-9, nitric acid 1-9, fixed oils 1-12, sulphuric ether 1-14, oil of turpentine 1-14, sulphuric or muriatic acid 1-17, brine 1-20, water 1-23 nearly, mercury about 1-55.

The rate of expansion for liquids increases with the temperature, as if their particles by becoming more remote, lost some of their ability to counteract the repulsive influence of caloric.

The number associated with each of the substances in the following list, shows its melting point as estimated by Fahrenheit's scale. One degree of Daniell's pyrometer,* by which the temperatures above 600° were measured, is calculated to be equal to seven of the former.

Cast iron 3479°, gold 2590°, silver 2233°, brass 1869°, antimony 810°, zinc 648°, lead 606°, bismuth 497°, tin 442°, sulphur 218°, beeswax 142°, spermaceti 112°, phosphorus 108°, tallow 92°, olive oil 36°, milk 30°, blood 25°, sea water 27½°, oil of turpentine 14°, mercury—39°, nitric acid—45½°, sulphuric ether—46°.

EXCEPTION TO THE LAW, THAT LIQUIDS EXPAND BY HEAT.

The bulk of water diminishes with the temperature, until it reaches 39° nearly. Below this point, it expands as it grows colder, and in freezing increases in bulk one-ninth. This wonderful exception to the law that liquids expand with heat, appears to be a special provision of the Deity, for the preservation of aquatic animals: for were water to increase in density, as it approaches the point of congelation, the upper stratum would continue to sink, as refrigerated, in bodies of water below 39°, as well as in others. Hence a whole river, lake, or sea, might, in high latitudes, be rendered too cold for animal life; and finally be so far converted into ice, as not to thaw during the ensuing summer. Subsequent winters co-operating, the whole might become irretrievably solid. But in consequence of the peculiarity in question, the coldest stratum, in a body of water below 39°, remains at top, until, if the cold be adequate, congelation ensues. The buoyant sheet of ice, which results in this case, forms effectively a species of winter clothing to the water beneath it; and by augmenting with the frost, opposes an increasing obstacle to the escape of caloric from the water which it covers.

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* See account of pyrometer, page 7, paragraph 1st.

EXPANSION OF AERIFORM FLUIDS.

Aeriform fluids are much more expansible than liquids. In order however to appreciate the changes of bulk, which they may be observed to sustain, it is necessary to understand the influence which the pressure of the atmosphere has upon their density, independently of temperature. The simple influence of heat, in expanding them, may be illustrated by holding a hot iron over the thermometer of Sanctorio, represented in the following figure.

ON THERMOMETERS.

The invention of the thermometer is ascribed to Sanctorio. The principle of that form of the instrument which he contrived, may be understood from the following article.

6. EXPANSION OF AIR.

Illustrated by the Air Thermometer of Sanctorio on a large scale.

The bulb of a matrass is supported, by a ring and an upright wire, with its neck downwards, so as to have its orifice beneath the surface of the water in a small glass jar. A heated iron being held over the matrass, the contained air is so much increased in bulk, that the vessel being inadequate to hold it, a partial escape from the orifice through the water ensues. On the removal of the hot iron, as the residual air regains its previous temperature, the portion expelled by the expansion is replaced by the water.

If in this case the quantity of air expelled be so regulated, that when the remaining portion returns to its previous temperature, the liquid rises about half way up the stem, or neck, the apparatus will constitute an air thermometer. For whenever the temperature of the external air changes, the air in the bulb of the matrass must, by acquiring the same temperature, sustain a corresponding increase or diminution of bulk, and consequently, in a proportionable degree, influence the height of the liquid in the neck. As elastic fluids are dilated equably, in proportion to the temperature, and are also much more expansible than liquids, this thermometer would be very accurate, as well as pre-eminent, in sensibility, were it not influenced by atmospheric pressure, as well as temperature. On this account, however, it was never of much utility. Subsequently liquids were resorted to, and the instrument assumed the form now generally employed, the principle of which is explained by experiment 5, page 8.

In the following pages I shall give engravings and descriptions of the form of the thermometer used in the laboratory, of the self-registering thermometer, of the differential thermometer, and of an apparatus which illustrates the difference between it and Sanctorio's thermometer.

Agreeably to the example of my predecessor, Dr. Woodhouse, I have been accustomed to exhibit to my class the blowing and filling of a thermometer. Of this process, an account is subjoined.

The tubes used in constructing thermometers are made at almost all the glass houses, having usually a capillary perforation. They are made by rapidly drawing out a hollow glass globe, while red hot, by which means it is changed into a long cylindrical string of glass, in the axis of which a perforation exists, in consequence of the cavity of the globe.

When a thermometer tube is softened by exposure to a flame, excited by a blowpipe, a bulb may be blown upon it.

While the bulb is still warm, the other end of the tube is immersed in mercury, or in spirit, according to the purposes for which the instrument is intended. As the bulb cools, the air within it contracts, and thus allows the liquid to enter, in obedience to the pressure of the atmosphere. The bulb thus becomes partially supplied with the liquid, which is next boiled in order to expel all the air from the cavity of the bulb and perforation. The orifice being again depressed into the liquid, when the whole becomes cold the liquid will fill the cavity of the bulb. This result will be hereafter fully explained and illustrated.

The open end of the tube being now heated, is drawn out into a filament with a capillary perforation. The bulb being raised to a temperature above the intended range of the thermometer, so as to expel all the superabundant liquid, the point is fused so as to seal the orifice hermetically, or in other words, so as to be perfectly air-tight.

In the next place, the bulb is to be exposed to freezing water, and the point to which the liquid reaches in the capillary perforation marked. In like manner the boiling point is determined, by subjecting the bulb to boiling water. The distance between the freezing and boiling points, thus ascertained, may be divided according to the desired graduation.

The scale of Reaumur requires 80 divisions, that of Celsius, 100. Fahrenheit, 180. The graduation of Celsius is the most rational, that of Fahrenheit the least so, although universally used in Great Britain and the United States.

The degrees of these scales are to each other obviously, as 80, 100, 180; or as 4, 5, 9. Hence it is easy to convert the one into the other, by the rule of three.

It should, however, be observed, that the scales of Celsius and Reaumur commence at the freezing of water, all above that being plus, all below it minus; while the scale of Fahrenheit commences at thirty-two degrees below freezing. Hence in order to associate correctly any temperature noted by his thermometer, with theirs, we must ascertain the number of degrees which the mercury is above or below freezing, and convert this number into one equivalent to it by their graduation: and conversely, after changing any number of degrees of theirs, into his, we must consider the result as indicating the number of degrees above, or below, 32 on his scale.

The process above described, for the construction of a thermometer, is equally applicable, whether the bulb be filled with alcohol or mercury. Each of these liquids has peculiar advantages. Mercury expands most equably. Equal divisions on the scale of the mercurial thermometer will more nearly indicate equal increments, or decrements of temperature. Mercury also affords a more extensive range, as it does not boil below 656°, and does not freeze above, 39°, of Fahrenheit's thermometric scale.

Alcohol boils at 176°, but has not been frozen by any cold, natural or artificial. Besides being more expansible than mercury, it is more competent to detect slight changes.

Besides those above mentioned, a thermometric scale has been used in Russia, which bears the name of its author, Delisle. In this, zero is at the boiling point of water, and five of his graduations are equal to six of Fahrenheit's.

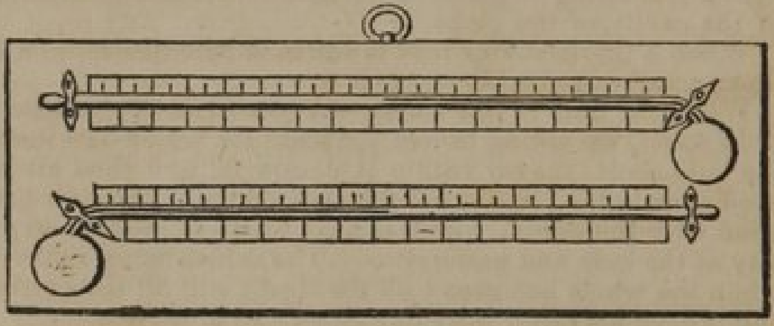
7. LABORATORY THERMOMETER.

The thermometers used in laboratories, are usually constructed so as to have a portion of the wood or metal, which defends them from injury, and receives the graduation, to move upon a hinge, as in the accompanying figure.

This enables the operator to plunge the bulb into fluids, without introducing the wood or metal, which would often be detrimental either to the process or to the instrument, if not to both.

The scale is kept straight, by a little bolt on the back of it, when the thermometer is not in use.

8. SELF-REGISTERING THERMOMETER.



This figure represents a self-registering thermometer.

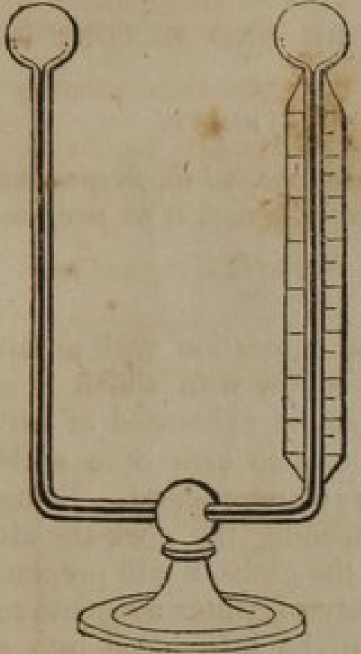
It comprises necessarily a mercurial and a spirit thermometer, which differ from those ordinarily used, in having their stems horizontal, and their bores round, also large enough to admit a cylinder of enamel, in the bore of the spirit thermometer, and a cylinder of steel, in the bore of the mercurial thermometer. Both the cylinder of enamel and that of steel, must be as nearly of the same diameters with the perforations, in which they are respectively situated, as is consistent with their moving freely, in obedience to gravity, or any gentle impulse.

In order to prepare the instrument for use, it must be held in such a situation, as that the enamel may subside as near to the end of the alcoholic column as possible, yet still remaining within this liquid.

The steel must be in contact with the mercury, but not at all merged in it.

Under these circumstances, if, in consequence of its expansion, by heat, the mercury advance into the tube, the steel moves before it; but, should the mercury retire, during the absence of the observer, the steel does not retire with it. Hence, the maximum of temperature, in the interim, is discovered by noting the graduation opposite the end of the cylinder nearest the mercury. The minimum of temperature is registered by the enamel, which retreats with the alcohol when it contracts; but, when it expands, does not advance with it. The enamel must retire with the alcohol, since it lies at its margin, and cannot remain unmoved in the absence of any force competent to extricate it from a liquid, towards which it exercises some attraction. But, when an opposite movement takes place, which does not render its extrication from the liquid necessary, to its being stationary, the enamel does not accompany the alcohol. Hence the minimum of temperature, which may have intervened during the absence of the observer, is discovered, by ascertaining the degree opposite the end of the enamel nearest to the end of the column of alcohol.

9. LESLIE'S DIFFERENTIAL THERMOMETER.



This instrument consists of a glass tube nearly in the form of the letter U, with a bulb at each termination. In the bore of the tube there is some liquid, as, for instance, coloured sulphuric acid, alcohol, or ether. When such an instrument is exposed to any general alteration of temperature in the surrounding medium, as in the case of a change of weather, the air in both bulbs being equally affected, there is no movement produced in the fluid; but the opposite is true, when the slightest change of temperature exclusively affects one of the bulbs. Any small bodies situated at different places in the same apartment warmed by a fire, will show a diversity of temperature, when severally applied to the different bulbs.

10. DIFFERENCE BETWEEN AN AIR THERMOMETER AND A DIFFERENTIAL THERMOMETER, ILLUSTRATED UPON A LARGE SCALE.

The adjoining figure represents an instrument, which acts as an air thermometer, when the stopple, S, is removed from the tubulure in the conical recipient, R; because in that case, whenever the density of the atmosphere varies either from changes in temperature, or barometric pressure, hereafter to be explained, the extent of the alteration will be indicated by an increase or diminution of the space occupied by the air in the bulb, B, and of course by a corresponding movement of the liquid in the stem, T. But when the stopple is in its place, the air cannot, within either cavity of the instrument, be affected by changes in atmospheric pressure: nor can changes of temperature which operate equably on both cavities, produce any movement in the liquid which separates them. Hence, under these circumstances, the instrument is competent to act only as a differential thermometer.

MODIFICATION OF THE EFFECTS OF CALORIC BY ATMOSPHERIC PRESSURE.

DIGRESSION TO DEMONSTRATE THE NATURE AND EXTENT OF ATMOSPHERIC PRESSURE.

11. EXPERIMENTAL PROOF THAT AIR HAS WEIGHT.

The air being allowed to replenish an exhausted globe, while suspended from a scale beam and accurately counterpoised, causes it to preponderate.

By a temporary communication with an air pump, by means of a screw with which it is furnished, a glass globe is exhausted of air. It is then suspended to one arm of a scale beam, and accurately counterpoised. Being thus prepared, if by opening the cock the air be allowed to re-enter the globe, it will preponderate; and if a quantity of water adequate to restore the equilibrium, be introduced into a small vessel, duly equipoised by a counter weight applied to the other arm of the beam, the inequality, in bulk, of equal weights of air and water, will be satisfactorily exhibited.

DEFINITION OF ELASTICITY.

The power which bodies have to resume their shape, position, or bulk, on the cessation of constraint, is called *elasticity*. The degree in which any body possesses this power, is not to be estimated by the force, but by the perfection of its recoil. A coach spring is far more powerful, but is not more elastic, than a watch spring.

Elasticity is erroneously spoken of as a varying property in the air, which, in common with aëriform fluids, in general, appears to be always perfectly elastic.

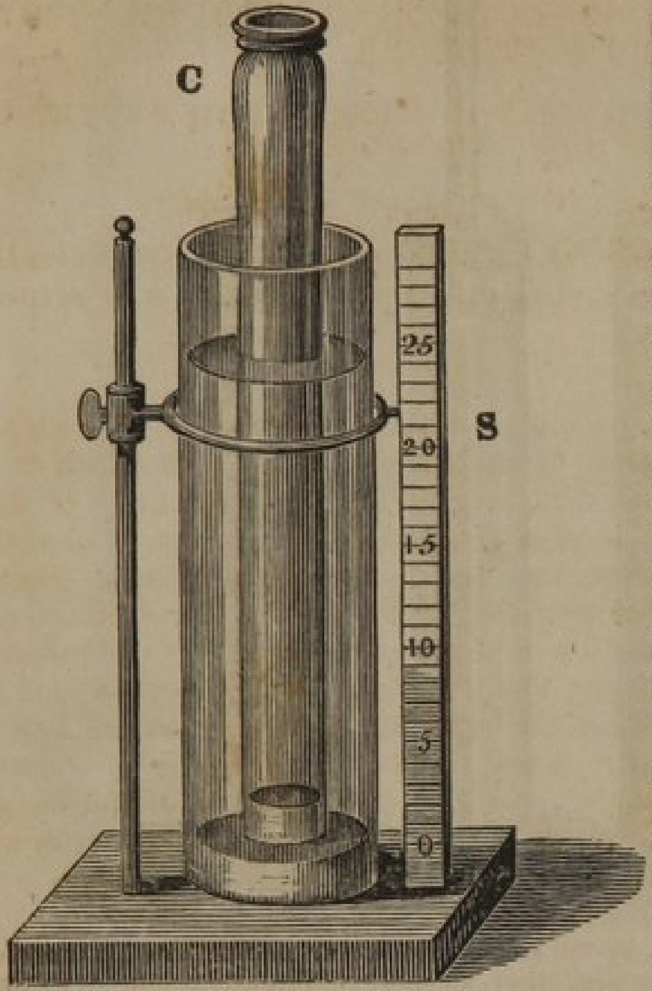
As a property distinguishing aëriform fluids from liquids, elasticity conveys the idea of a power in a given weight of a fluid, to expand or to contract with the space in which it may be confined, producing at the same time a pressure on the internal surface of the cavity, or any object within it inversely as the space.

THE EXISTENCE AND EXTENT OF THE PRESSURE OF THE ATMOSPHERE EXPERIMENTALLY DEMONSTRATED.

PRELIMINARY PROPOSITION.

For the pressure of any fluid, on any area assumed within it, the pressure of a column of any other fluid may be substituted, making it as much higher as lighter, as much lower as heavier; or in other words, the heights being inversely, as the gravities.

12. *Experimental Illustration in the case of Mercury and Water.*



If into a tall glass jar, such as is represented in the adjoining figure, a glass cylinder, C, (like a large glass tube open at both ends) were introduced, on filling the jar with water, this liquid would of course rise in the cylinder to the same height as in the jar; but, if, as in the figure, before introducing the water, the bottom of the jar be covered by a stratum of mercury, two inches deep, so as to be sufficiently above the open end of the cylinder, it must be evident, that the water will be prevented from entering the cylinder by the interposition of a heavier liquid. But as the pressure of the water on the mercury outside of the cylinder, is unbalanced by any pressure from water within the cylinder, the mercury within will rise until, by its weight, the external pressure of the water is compensated. When this is effected, on comparing, by means of the scale, S, the height of the two liquids, it will be seen that for every inch of elevation acquired by the mercury, the water has risen more than a foot; since the weight of mercury is, to that of water, as 13.6 to 1.

It may be demonstrated, that the pressure of the column of mercury is exactly equivalent to that of a column of water, having the same base, and an altitude equal to that of the water in the jar, by filling the cylinder with water. It will then be seen, that when the water, inside of the cylinder, is on a level with the water, on the outside, the mercury, within the cylinder, is also on a level with the mercury without.

It is therefore obvious, that the elevation of the column of mercury, within the tube, is produced by the weight or pressure of the water without, and measures the extent of that pressure, on the lower orifice of the tube.

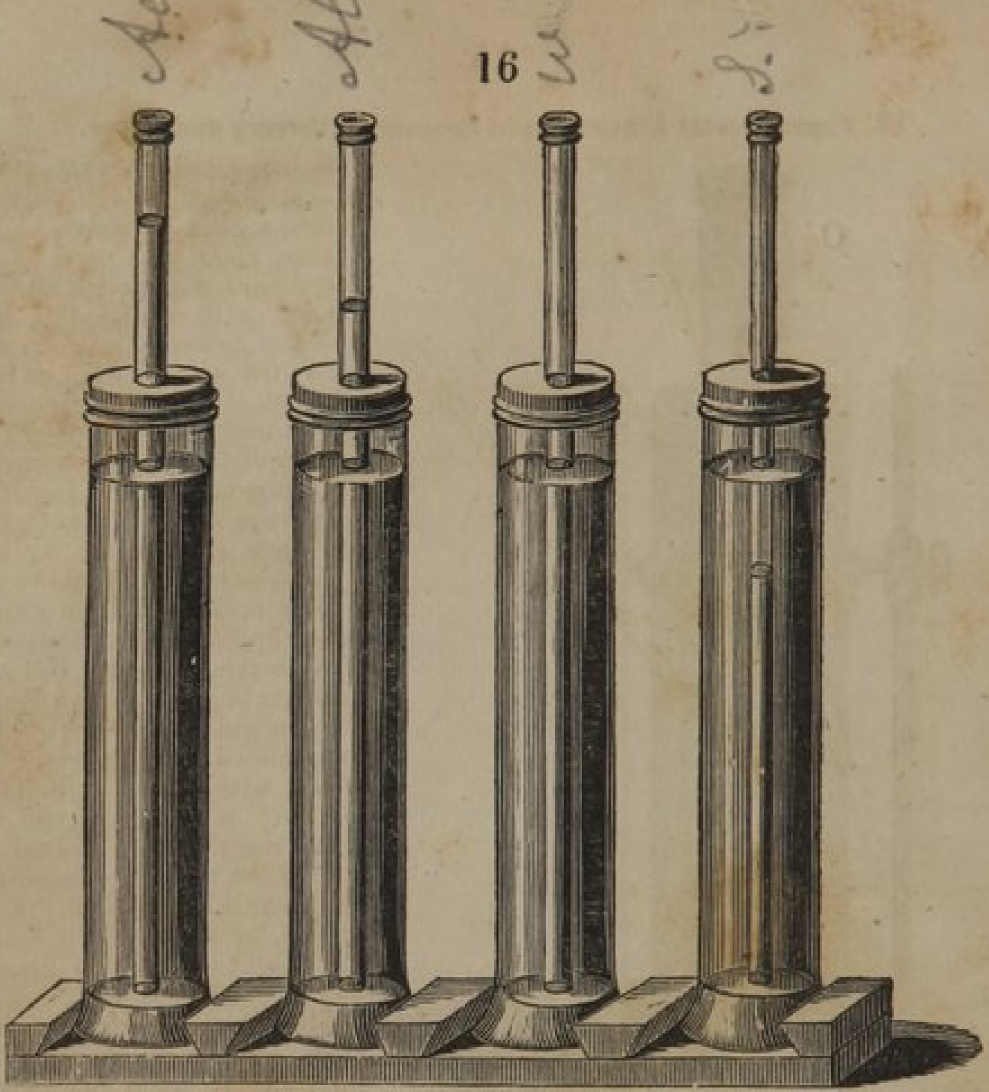
13. *The Illustration extended to the case of Liquids lighter than Mercury.*

Let there be four jars, each about four inches in diameter, and more than thirty inches in height—severally occupied by mercury to the depth of about two inches. In the axis of each jar, let a tube be placed, of about one inch and a half in diameter, and about one-fourth taller than the jar, with both ends open, and the lower orifice under the surface of the mercury. On pouring water into the jars, the mercury rises in the tubes, as the water rises in the jars; but the mercury rises as much less than the water, as it is heavier.

The mercurial columns, in this case, as in the preceding experiment, owe their existence to the pressure of the surrounding water, and by their height, measure the extent of that pressure on the areas, of their bases, respectively. They may be considered as substituted severally for the aqueous columns, which would have entered the tubes had not the mercury been interposed. Accordingly, water being poured into one of the tubes, the mercury in that tube subsides to a level with the mercury without; when the water, poured into the tube, reaches the level of the water without.

The three remaining columns of mercury may be considered as substituted, in water, for columns of water, and being as much lower as heavier, are found adequate to preserve the equilibrium.

It remains to be proved, that other fluids, heavier, or lighter, than water, may in like manner be substituted for the columns of mercury, and of course for the water, of which the mercury is the representative.



Into the three tubes, in which, by the addition of water in the jars, columns of mercury are sustained, pour severally, ether, alcohol, (differently coloured, so that they may be distinguished) and a solution of sulphate of copper, until the mercurial columns, within the tubes, are reduced to a level with the mercury without. It will be found, that the column formed by the cupreous solution, is much lower than the surface of the water on the outside of the tube; that the opposite is true of the column of alcohol; and that the ether (still more than the alcohol) exceeds the surrounding water in elevation.

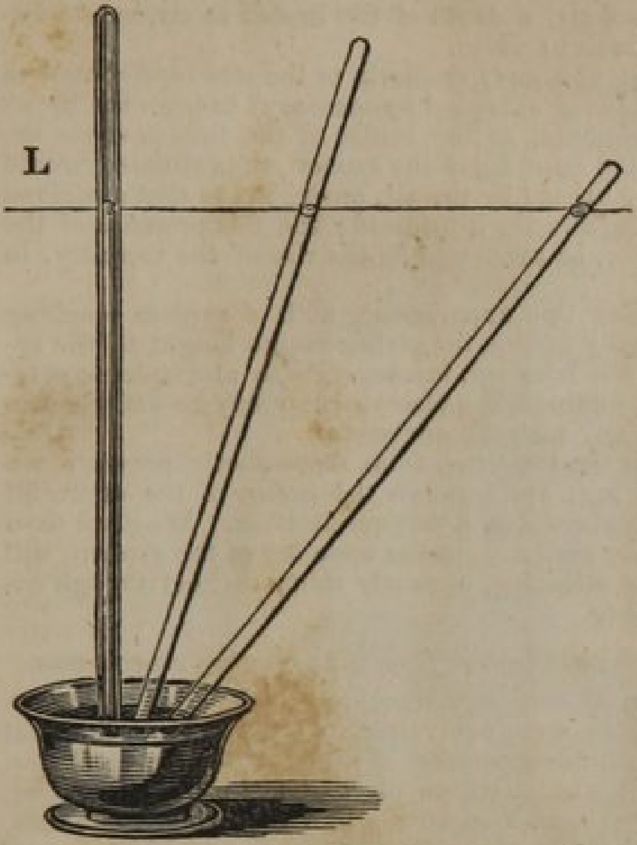
While it is thus proved, that columns of mercury, ether, alcohol, and of a saline liquid, may, in water, be substituted for columns of this fluid; it is also apparent, that they must be as much higher than it is lighter; as much lower as heavier; or in other words, their heights must be inversely as their gravities; which will hereafter be more accurately proved, by means of an instrument which I have contrived, called the Litrameter.

14. TORRICELLIAN EXPERIMENT.

Pursuant to the law which has been above illustrated, that the pressure of one fluid may be substituted for that of another; provided any difference of weight be compensated by a corresponding difference in height; if, in lieu of water, the mercury were pressed by air on the outside of the tubes, unbalanced by air within, colums of the metal would be elevated, which would be in proportion to the height and weight of the air thus acting upon it.

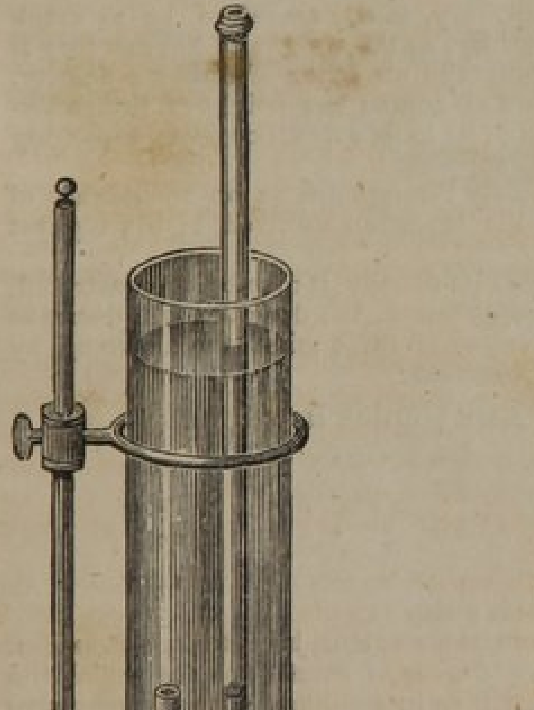
In order to show that the air exercises a pressure on the mercury outside of the tubes, analogous to that exercised by water, in the experiments just described, it is only requisite, that this external pressure be unbalanced by the pressure of air within the tube.

This desideratum is obtained, by filling with mercury, a tube about three feet in length, open at one end, and closed at the other, and covering the open end with the hand, until it be inverted and merged in a vessel containing some of the same metal, without allowing any air to enter. A mercurial column of about 30 inches in height, will remain in the tube, supported by the pressure of the surrounding air, and an index of its weight. This is a case obviously analogous to that of the mercurial columns, supported by aquatic pressure, in the experimental illustration above afforded.



The tube may be *supposed* to occupy either of the three positions, represented in the drawing. The mercury, in each position, preserves the same degree of elevation, its surface being always in the same horizontal plane, or level, whether upright, or inclined—or *we may suppose* three tubes, filled with mercury, and inverted in a vessel, nearly full, of the same metal, to be placed in the positions represented in the drawing. The upper surfaces of the columns of mercury in each tube, will be found always coincident with the same horizontal plane, however different may be the angle, which they make with the horizon. And the horizontal plane, in which their surfaces are thus found, will be between 28 and 31 inches, above the surface of the mercury in the vessel. The line, L, with which the mercury in each of the tubes is on a level, represents a cord rendered horizontal, by making it parallel to the surface of the mercury in the reservoir.

15. ADDITIONAL ILLUSTRATION OF ATMOSPHERIC PRESSURE.



I trust, that the preceding illustrations are well qualified to convey a clear conception of atmospheric pressure: but as it sometimes happens, fortuitously, that when truth cannot get access to the mind, under one form, it may reach it in another, even when less eligible, I subjoin the following illustration; which, though less amusing, and associating with it fewer instructive phenomena, is more brief, and perhaps equally conclusive.

If a tube, recurved into a crook at one end, so as to form a syphon, with legs of very unequal length, and both ends open, have the crook lowered into water, as in the adjoining figure, the fluid will, of course, rise within the tube, to the same height as without. But if, before the crook is sunk in the fluid, it be occupied by mercury, the water will enter the tube, only so far as the pressure which it exerts upon the mercury in the short leg of the syphon, is competent to raise the mercury in the other.

This pressure, or the effort of the water to enter the tube, is obviously measured by the height to which it forces the mercury, in the long leg of the syphon, above the mercurial surface, in the short leg. The height will of course be greater, or less, in proportion to the depth to which the lower surface of the mercury may be sunk. It will also be greater or less, accordingly, as the fluid in which it is immersed, is heavier or lighter. Hence, as water is about 820 times heavier than air, a depth of 820 inches in air, would displace the mercury, as much as one inch in water.

Let us imagine a tube recurved at one end, similarly to the one represented in the adjoining figure, (the crook likewise occupied by mercury) to have the upper orifice as completely above the atmosphere, as the orifice of the tube is above the water in the jar. The mercury, in the short leg of the syphon, thus situated, would be evidently exposed to a pressure, caused by the air, analogous to that sustained from water, in the case of the tube, as already illustrated: and this pressure of the air would, as in the case of the water, be measured by the rise of the mercury, in the long leg of the syphon.

It is obviously impossible to realize this experiment, with a syphon reaching above the atmosphere; but, as the only motive for giving such a height to the syphon is to render the mercury, in the long leg, inaccessible to atmospheric pressure, if this object can be otherwise attained, the phenomenon may be exhibited in the case of the atmosphere, without any material deviation.

In fact, to protect the mercury in the long leg, from atmospheric pressure, we have only to seal the orifice of that leg; and through the orifice of the other, fill the syphon with mercury, before we place it in a vertical position. We shall then find, that the pressure of the air on the mercury, in the open leg of the syphon, will support a column of this metal in the other leg, of nearly thirty inches; though occasionally varying from 28 to 31 inches.

Inferences respecting the weight of the atmosphere from the preceding experiments.

Supposing the base of the column of mercury, sustained by the atmosphere, as demonstrated in the preceding articles, were equivalent to a square inch, the total weight of the column would be about fifteen pounds. This of course represents the weight of that particular column of air only, whose place it has usurped; and as, for every other superficial inch in the earth's surface, a like column of air exists, the earth must sustain a pressure from the atmosphere, equal to as many columns of mercury, 30 inches high, as could stand upon it; or equal to a stratum of mercury, of the height just mentioned, extending all over the surface of the globe.

It has been shown, that the heights of heterogeneous fluids, reciprocally resisting each other, are inversely as their gravities; or, in other words, that they are as much higher as lighter, as much lower as heavier. The height of the column of air which, by its pressure, elevates the mercury, must, therefore, be as much greater than the height of the column of mercury, as the weight of the mercury is greater than the weight of the air; supposing the air to be of uniform density. Mercury is 11152 times heavier than air, and of course the height of the atmosphere would be (if uniform in density) 11152×30 inches $= 27880$ feet; supposing 30 inches the height of the mercurial column supported.

Hence the atmosphere, if of the same density throughout, as on the surface of the earth, would not extend much above the elevation ascribed to the highest mountains.

But as the pressure of the atmosphere causes its density, it may be demonstrated, that, the heights increasing in arithmetical progression, the densities will decrease in geometrical progression. Thus at an elevation of three miles, the air being, by observation, half as dense as upon the earth's surface:

At 6 miles it will be	$\frac{1}{4}$	At 21 miles it will be	$\frac{1}{128}$
9 - - - - -	$\frac{1}{8}$	24 - - - - -	$\frac{1}{256}$
12 - - - - -	$\frac{1}{16}$	27 - - - - -	$\frac{1}{512}$
15 - - - - -	$\frac{1}{32}$	30 - - - - -	$\frac{1}{1024}$
18 - - - - -	$\frac{1}{64}$		

or, rarer than we can render it by the finest air pump.

These results have been verified, to a considerable extent, by actual observation.

It is reasonable to suppose that there is a degree of rarefaction, at which the weight of the ponderable particles in the air, will be in equilibrio with the repulsive power of the caloric united with them. Beyond the distance from the earth's surface at which there should be such an equilibrium, the air could not exist. Hence it is inferred that the extent of our atmosphere is not unlimited.

16. OF THE WATER PUMP.

The admission of the atmosphere is necessary to the suction of the water from a receiver. *Air* may be removed from *close* vessels by the same process. Water rises by the pressure of the atmosphere. Air presses out by its own elasticity.

Mechanism and action of the suction pump rendered evident by means of a model, with a glass chamber. Difference between pumping an elastic fluid, and a liquid, illustrated by an appropriate contrivance.

A little suction pump is constructed, with a chamber, C C, of glass, which permits the action of its piston, P, and valves to be seen. Below the pump is a hollow glass globe filled with water. This globe communicates with the pump, by a tube visibly descending from the lower part of the pump, through an aperture in the globe, till it reaches the bottom nearly. This tube is luted, air tight, into the aperture by which it enters the globe. Its orifice, next the chamber, is covered by a valve opening upwards. In the axis of the piston, there is a perforation, also covered by a valve opening upwards.

If the piston, P, be moved alternately up and down, as usual in pumping, as often as it rises its valve will shut close, so that if nothing passes by the sides of the piston, nor enters into the chamber of the pump, from below, a vacuum must be formed behind the piston. Under these circumstances, it might be expected that the water would rise from the globe, through the lower valve, and prevent the formation of a vacuum. But being devoid of elasticity, and therefore incapable of self-extension, beyond the space which it occupies, the water does not rise into the chamber of the pump, so long as by means of the cock, C, of the recurved pipe, P P, communication with external air is prevented. But if this cock be opened, during the alternate movement of the piston, a portion of the water will mount from the globe into the chamber, at each stroke of the piston. The opening of the cock, permits the atmosphere to press upon the fluid in the globe, and to force it up the tube, leading to the pump chamber, as often as the chamber is relieved from atmospheric pressure by the rise of the piston.

As soon as the piston descends, the valve, over the orifice of the tube, shuts, and prevents the water from returning into the globe. It is of course forced through the perforation in the piston, so as to get above it. When the piston rises, the valve over its perforation being shut, it lifts the portion of water above this valve until it runs out, at the nozzle of the pump, while the chamber, below the piston, receives another supply from the globe. But if after all the water has been pumped from the globe, the pumping be continued *with the cock closed*, a portion of air will be removed from the globe, at each stroke, until the residue be so much rarefied, as, by its elasticity, no longer to exert against the valve, closing the tube, sufficient pressure to lift it; and thus to expand into the vacuity formed behind the piston, as often as it rises.

The rarefaction thus effected, in the air remaining in the globe, is rendered strikingly evident, by causing the orifice of the curved tube to be under the surface of some water in an adjoining vase, while the cock is opened. The water rushes from the vase into the exhausted globe, with great violence; and the extent of the rarefaction is demonstrated, by the smallness of the space, within the globe, which the residual air occupies, after it is restored to its previous density, by the entrance of the water.

17. DESCRIPTION OF A CHEMICAL IMPLEMENT.

The operation of sucking up a liquid through a quill, arises from the partial removal of atmospheric pressure from within the quill, by the muscular power of the mouth. There is a great analogy between the mode in which suction is effected by the mouth, and that in which a liquid is made to rise into the bulb of an implement which I am about to describe, and which is very useful for withdrawing small portions of liquids from situations from which otherwise they cannot be removed without inconvenience.

This instrument is constructed, by duly attaching a bag of caoutchouc, to the neck of a glass bulb, with a long tapering perforated stem.

In order to withdraw from any vessel into which the stem will enter, a portion of any contained liquid, it is only necessary to compress the bag so as to exclude more or less of the air from within it; then place the orifice of the stem below the surface of the liquid, and allow the bag to resume its shape. Of course, the space within it, becoming larger, the air must be rarefied, and inadequate to resist the pressure of the atmosphere until enough of the liquid shall have entered to restore the equilibrium of density, between the air within the bag, and the atmosphere. The air within the bag cannot, however, fully resume its previous density; since the column of the liquid counteracts, as far as it goes, the atmospheric pressure. Indeed, this counteracting influence is so great, in the case of mercury, that the instrument cannot be used with this liquid. It is however the only substance, fluid, at ordinary temperatures, which is too heavy to be drawn up into the bulb, of the instrument in question, when furnished with a stout bag.

OF THE AIR PUMP.

Difference between the Air Pump and the Water Pump.

The action of the air pump is perfectly analogous to that of the water pump; as there is no difference between pumping water and pumping air, which does not arise from the nature of the fluids; the one being elastic, the other, in common with liquids in general, almost destitute of elasticity.

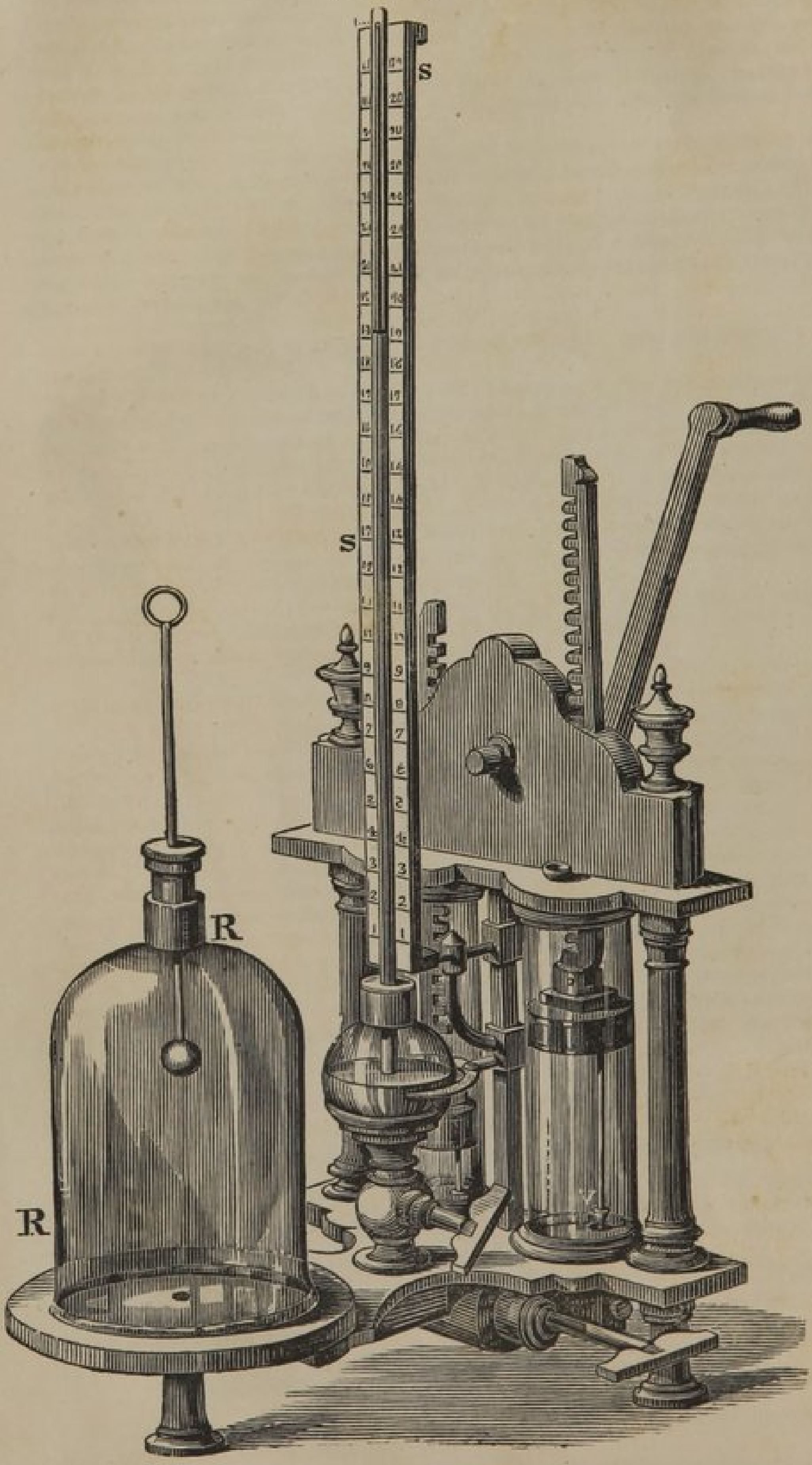
In the air pump, as in the water pump, therefore, there is a chamber, and an upper and a lower valve; which operate, in the same manner, as the valves of the water pump, already described.

18. DESCRIPTION OF A LARGE AIR PUMP WITH GLASS CHAMBERS.

The following engraving represents a very fine instrument, of an unusually large size, obtained from Mr. Pixii, of Paris.

From the figure, it must be evident that this pump has two glass chambers. They are unusually large, being nearly three inches in diameter inside. The lower valve, V, is placed at the end of a rod, which passes through the packing of

(C. p. 21.)



the piston. Hence, during the descent of the piston, the friction of the packing against the rod, causes it to act upon the valve with a degree of pressure adequate to prevent any escape of air, through the hole which it closes, at the bottom of the chamber. The air included between the piston, and the bottom of the chamber, is, therefore, by the descent of the piston, propelled through a channel in the axis of the piston, covered by a valve, opening upwards. When the motion of the piston is reversed, the air cannot, on account of the last mentioned valve, return again into the cavity which the piston leaves behind it. But in the interim, the same friction of the packing, about the rod, which had caused it to press downwards, has now, in consequence of the reversal of the stroke, an opposite effect, and the valve V, is lifted as far as a collar, on the upper part of the rod, will permit. The rise, thus permitted, is just sufficient to allow the air to enter the chamber through an aperture, which the valve had closed, and which communicates by means of a perforation with a hole in the centre of the air pump plate, and of course with the cavity of the receiver, RR, placed over the plate. The reaction of the air in the perforation and pump chamber being diminished, the air of the receiver moves into the chamber until the equilibrium of density is restored between the two cavities. The chamber will now be as full of air as at first; but the air with which it is replenished, is not so dense as before, as the whole quantity in the receiver, and the chamber, scarcely exceeds that which had existed before the stroke in the receiver alone. By the next downward stroke, the air which has thus entered the chamber is propelled through the valve hole in the piston. Another upward stroke, expels this air from the upper portion of the chamber; and the valve attached to the rod being again uplifted, the portion of the chamber, left below the piston, is supplied with another complement of air, from the receiver: and thus a like bulk of air is withdrawn at every stroke of the pump. I say a like *bulk* of air, since the *quantity* necessarily varies with the *density* of the air in the vessel subjected to exhaustion. This *density* is always directly as the *quantity* of air remaining; of course it finally becomes insignificant. Thus when the quantity, in the receiver, is reduced to one-hundredth of what it was at first, the weight of air removed, at each stroke, will be one-hundredth of the quantity taken at each stroke when the process began.

I have explained the action of one chamber only, as that of the other is exactly similar, excepting that while the piston of one descends, that of the other rises.

The gage represented in this engraving, is one which I have contrived upon a well known principle. It consists of a globular vessel to hold mercury, supported upon a cock. The mercury is prevented from entering the perforation in the cock, by a tube of iron, surmounted by a smaller one of varnished copper, which passes up into a Torricellian glass tube, till it reaches near the top. The glass tube opens at its lower extremity, under the surface of the mercury in the globe. The exhaustion of this tube, and that of any vessel placed over the air pump plate, proceed simultaneously, and consequently the mercury is forced up from the globe, into the glass tube, to an altitude, commensurate with the rarefaction.

By inspecting a scale, SS, behind the glass tube, the height of the mercury is ascertained. In order to make an accurate observation, the commencement of the scale must be duly adjusted to the surface of the mercury in the globe. On this account it is supported, by sliding bands, on an upright square bar, between the glass cylinders.

The receiver, RR, represented on the air pump plate, is one which I usually employ, in exhibiting the artificial Aurora Borealis. The sliding wire, terminated by a ball, enables the operator to vary the distance, through which the electrical corruscations are induced.

EXPERIMENTAL ILLUSTRATION OF THE ELASTIC REACTION OF THE AIR.

19. AIR OCCUPYING A SMALL PORTION OF A CAVITY, RAREFIED SO AS TO FILL THE WHOLE SPACE.

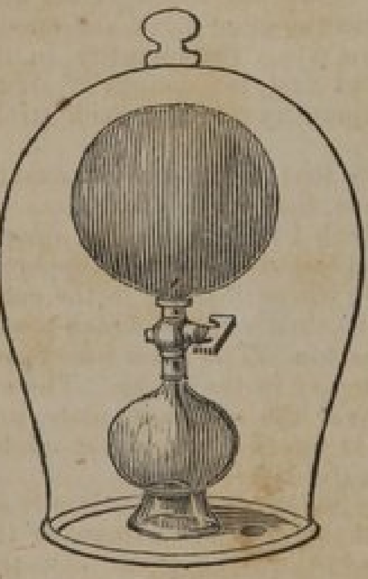
Air is dependent on its own weight for its density, and enlarges in bulk in proportion as the space allotted to it is enlarged.

The mode, in which the air occupying but a small part of a vessel may be rarefied so as to fill the whole cavity, is shown by the experiment represented in the annexed engraving. A bladder is so suspended within a vessel included in a receiver, as that the cavity of the bladder, communicates through its own neck and that of the vessel with the cavity of the receiver; while no such communication exists between the receiver, and the space between the bladder and the inside of the vessel.

Things being thus situated, and the receiver exhausted, the bladder contracts in consequence of the removal of air from within it, proportionably with the exhaustion of the receiver: for, as the air between the outside of the bladder, and the inside of the vessel, is no longer resisted within the bladder, by air of the same density, it expands into the space which the bladder had occupied, so as to reduce it into a very narrow compass.

This cannot excite surprise, when it is recollected, that the air, confined between the outside of the bladder, and the inside of the vessel, had, previously to the exhaustion, been condensed by supporting the whole atmospheric pressure, and must of course enlarge itself, from its elasticity, as that pressure is diminished.

20. DISTENTION OF A CAOUTCHOUC BAG, BY THE RAREFACTION OF CONFINED AIR.



The power of any included portion of air to extend itself, in consequence of a removal of pressure, is illustrated in another way, by subjecting to a highly rarefied medium a gum elastic bag, its orifice being previously closed, so as to be air-tight. The bag will swell up in a most striking manner, in proportion to the diminution of power in the air without the bag, to counteract the reaction of the air within it.

The experiment is reversed by subjecting a bag, while inflated, to the influence of a condenser, by which it may be reduced in size more than it had been expanded; the air within the receiver being rendered denser than without.

In the adjoining cut, the gum elastic bag is represented as when inflated. The glass represented below the bag, is one which happened to be used as a support when the drawing was made.

21. EXPULSION OF A LIQUID BY THE RAREFACTION OF AIR.

A flask half full of water, is inverted in another vessel, having some water at the bottom, and both are placed, under a bell glass, on the plate of an air pump. As the bell is exhausted, by the action of the pump, the air, included in the flask, enlarges its bulk, finally occupying the whole cavity, and partially escaping from the orifice, through the water in the lower vessel. When the atmosphere is allowed to re-enter the bell, the water rises into the flask, so as to occupy as much more space than at first, as the air occupies less, in consequence of a portion having escaped as abovementioned.

22. EXPERIMENTAL PROOFS, OF THE WEIGHT OF THE ATMOSPHERE.

ATMOSPHERIC PRESSURE ON THE HAND.

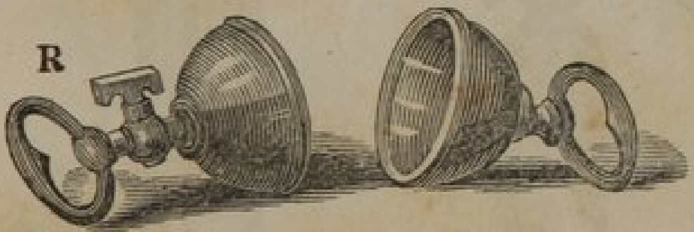
If, as represented in this figure, the air be exhausted from a vessel, covered by the hand, its removal will be found almost impracticable: for, supposing the opening, which the hand closes, to be equal to five square inches, the pressure on it will be seventy-five pounds.

23. BLADDER RUPTURED BY THE WEIGHT OF THE ATMOSPHERE.

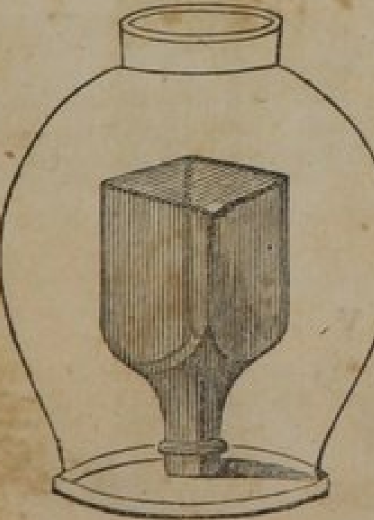
Let there be a glass vessel, open at both ends, as in this figure. Over the upper opening, let a bladder be stretched, and tied, so as to produce an air tight juncture. For every square inch of its superficies, the bladder, thus covering the opening in the vessel, sustains a pressure of about fifteen pounds; yet this is productive of no perceptible effect; because the atmosphere presses upwards, against the lower surface of the bladder, as much as downwards, upon the upper surface. But if the vessel be placed upon the plate of an air pump, so that, by exhaustion, the atmospheric pressure downwards, be no longer counteracted by its pressure upwards, the bladder will be excessively strained, and usually torn into pieces.

When the bladder is too strong to be broken, by the unassisted weight of the air, a slight score, with the point of a penknife, will cause it to be ruptured, not only where the score is made, but in various other parts, so that it will be, at times, torn, all round, from off the vessel.

24. THE HEMISPHERES OF OTHO GUERICKE, THE CELEBRATED INVENTOR OF THE AIR PUMP.



Two brass hemispheres are so ground to fit each other at their rims, as to form an air tight sphere, when duly united. One of the hemispheres is furnished with a cock, on which is a screw for attaching the whole, to the air pump.—Being by these means exhausted, the cock closed, and the ring, R, screwed on to the cock, great force must be exerted by persons severally taking hold of the rings, before the hemispheres can be separated.

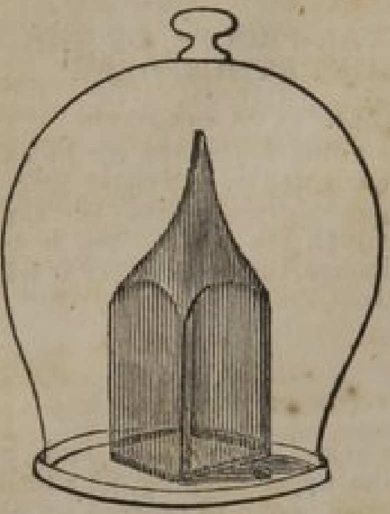


25. BOTTLE BROKEN BY EXHAUSTION OF THE AIR FROM WITHIN.

Proof that a square Glass Bottle may be broken by Atmospheric Pressure on the outside, as soon as it ceases to be counteracted by the resistance of the air within.

The mouth of a square bottle, being placed over the hole in an air pump plate, so as to be sufficiently tight for exhaustion, a few strokes of the air pump, by withdrawing the air from the interior, causes the bottle to be crushed.

A stout globular glass vessel, with an aperture at top, is placed over the bottle, to secure the spectators from the fragments.



26. BOTTLE BROKEN BY EXHAUSTION OF THE AIR FROM WITHOUT.

The elastic reaction of the Air, confined within a square Bottle, will burst it, as soon as relieved from the counteracting weight of the Atmosphere.

If a thin square bottle, so sealed, that while unbroken, the contained air cannot escape, be placed within the receiver of an air pump, the exhaustion, of the receiver, will, by removing the pressure which counteracts the elastic reaction of the contained air, cause the bottle to be fractured.

27. THE HEIGHT OF THE COLUMN OF MERCURY WHICH BALANCES THE ATMOSPHERE SHOWN BY EXHAUSTION.

R, fig. 1, is a glass receiver about 33 inches in height, and 2½ inches in diameter, with a perforated neck, into which a brass gallows screw G, is cemented; so that by means of the flexible pipe communicating with the air pump plate A, the receiver may be exhausted. The mouth of the receiver being immersed in mercury, in the vase; as the exhaustion proceeds, the metal rises in the receiver, until it reaches more or less nearly to the height, at which it stands in a Torricellian tube, accordingly as the pump is more or less perfect.

Fig. 1.

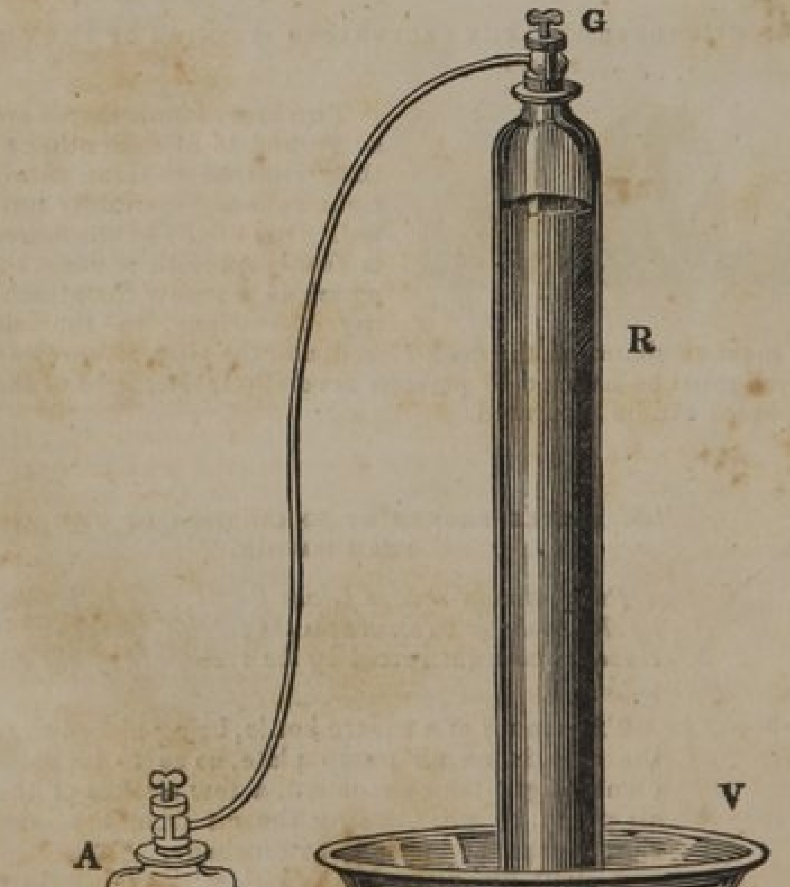


Fig. 2.

28. BAROMETRIC COLUMN OF MERCURY, LOWERED BY EXHAUSTION.

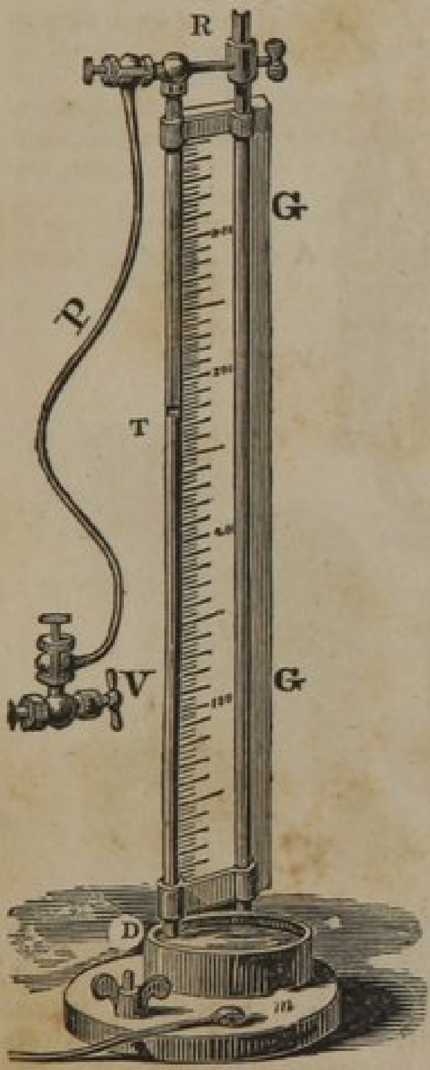
It has been shown, that in a tube void of air, a mercurial column may be supported at the height nearly of thirty inches; and this has been alleged to result from the pressure of the atmosphere on the surface of the mercury on the outside of the tube.

In order to verify this allegation, let a tube, fig. 2, supporting within it a column of mercury, be placed, under a competent receiver, upon the air pump plate.

It will be found, that, as the air is withdrawn from the receiver, the mercury in the tube will subside, and if the exhaustion be carried far enough, will sink to a level with the mercury on the outside.

If, while this experiment is performing, a communication exist between the air pump and the receiver, R, employed in the preceding experiment, the mercury will rise in the receiver, while it falls in the tube, thus proving that the force which is required to remove the air from the outside of the tube, and lower the mercury within it, is adequate to raise, in the receiver, a mercurial column equal in height to that which is reduced.

29. OF THE BAROMETER GAGE.



While I am upon the subject of atmospheric pressure, it appears to me expedient to give a description of an instrument which, in several of my illustrations, is employed to ascertain the quantity of air within a receiver.

It consists of a barometer tube, 33 inches in height, supported in a vertical position by a pedestal, and a strip of wood, G G. Attached to the latter is a brass scale, by which 30 inches is divided into 500 equal parts. The gage tube is surmounted by a ferrule and gallows screw, by the aid of which a flexible leaden pipe, P, communicates with the bore of the tube. By means of the valve cock, and gallows screw, at V, this pipe may be made to communicate also, with the cavity to be measured, the valve cock enabling us to suspend the communication when desirable. The lower orifice of the glass tube, T, is covered by mercury in a broad shallow receptacle, D. Supposing the cavity, under these circumstances, to be exhausted, and the communication with the bore of the glass tube open, the extent of the exhaustion, or in other words, the quantity, of air withdrawn, will be exactly in proportion to the rise of the mercury as indicated by the scale; and consequently reversing the operation, the fall of the mercury, as indicated by the scale, will show the quantity of air which may be introduced. If we count the degrees upwards from the surface of the mercury in the receptacle, D, their number will show the quantity of air withdrawn. If we count the degrees from the level of the top of the mercurial column in the barometer, the number will indicate the exact quantity of gas in the cavity examined. In short, the quantity taken out, or introduced, is always measured by the number of degrees which the mercury rises, or falls, in consequence. It is preferable to have two scales, one beginning above, the other below.

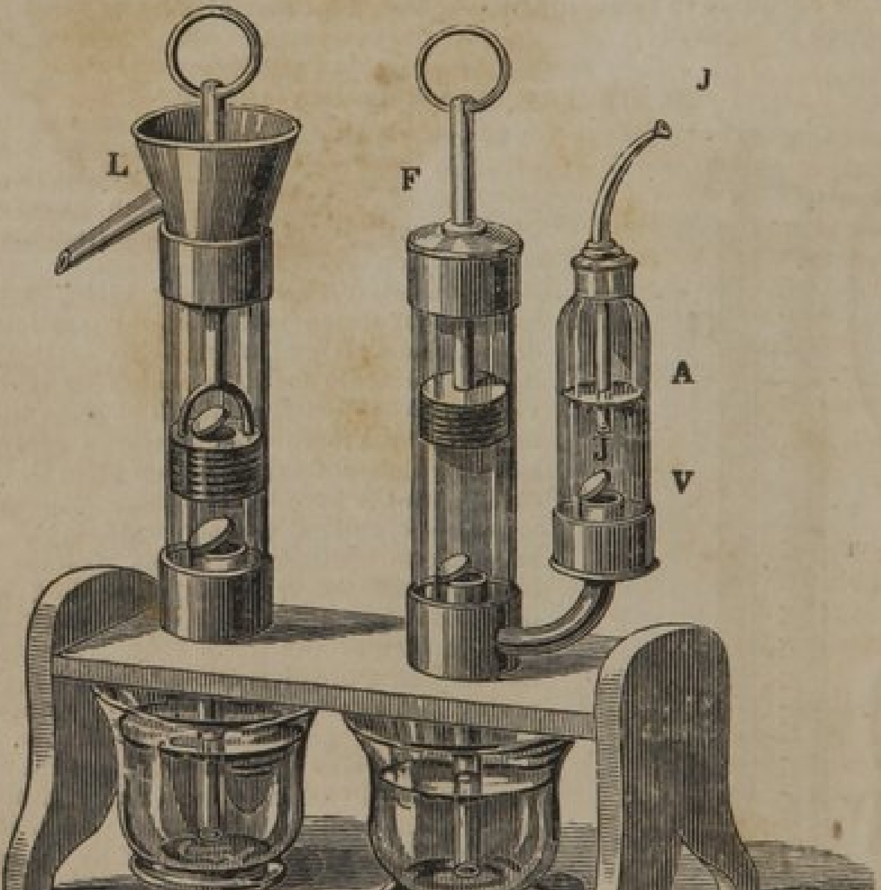
This gage may be employed to indicate the quantity of air, in any cavity. It only requires accuracy in the divisions of the scale, and in the adjustment of zero to the proper level. As the height of the mercurial column in the barometer varies with those changes of atmospheric pressure which it is employed to indicate, in counting downwards care must be taken to place the commencement of the scale on a level with the upper end of a column of mercury in a good barometer, at the time. To facilitate this adjustment, I have occasionally placed a Torricellian tube by the side of the gage tube. The top of the column of the mercury in the latter is then the proper point for the upper zero. As the strip of wood to which the scale is attached, slides upon the iron rod, R, the scale may be fixed at a proper height by a set screw.*

As the air pump will not produce a perfect vacuum, in order to wash out of the receiver all traces of atmospheric air, successive portions of the gas to be substituted, may be introduced and removed by exhaustion.†

The rise of the mercury in the tube will cause the surface of it in the receptacle, D, to be lower; but the breadth of this vessel is so great, and the descent of the mercurial surface in it, is so inconsiderable, that no error worthy of attention is thus produced.

I ought to mention, that the cavity of the tube ought to be so small in proportion to that of the receiver, as to create no error worthy of attention.

30. APPARATUS FOR ILLUSTRATING THE DIFFERENCE BETWEEN THE LIFTING AND FORCING PUMPS.



The process by which the water is drawn into the chamber, is the same in the case of the forcing, as in that of the lifting pump. In the lifting pump, L, the water which has entered the chamber, during the ascent of the piston, passes through the piston, during its descent, and is lifted by it, when the motion is reversed. In the forcing pump, F, the piston, being imperforate, in descending, forces the water into the adjoining air vessel, A, whence its regress is prevented by a valve, *v*. The stroke being repeated, the water accumulates in the air vessel, compressing the contained air, until it reacts upon the water sufficiently to cause an emission of this liquid, (through the jet pipe, J J,) commensurate with the supply.

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* Both the gage tube and the rod, R, should be longer than they are represented in the figure.

† One gas may be employed to wash another out of a cavity, in a mode analogous to that in which water may wash out alcohol, or alcohol, water.

OF CONDENSATION.

It has been shown, that in consequence of the elasticity of the air, the quantity of this fluid, in any close vessel, may be diminished until the residual portion has, by the action of an air pump, become too rare to escape in opposition to the very slight resistance made by the valves. It remains to show—that, in consequence of the same property, by an operation, the converse of that of the air pump, the air in any adequate vessel, may be made many times more dense than it would remain if liberated from confinement.

31. OF THE CONDENSER.

The instrument employed for the purpose of condensing air, is called a condenser.

The air pump was illustrated by its analogy with the suction pump. There is the same analogy between the condenser and the forcing pump. In the air pump, the valve between the chamber and receiver opens towards the chamber; in the case of the condenser a corresponding valve opens towards the receiver.

Besides the valve thus placed, between the chamber and receiver, there is in each pump another valve. In the air pump, the air passes this second valve only when the piston moves so as to lessen the vacancy between it and the bottom of the chamber; in the condenser, the air passes only when the piston moves so as to enlarge the vacancy. In other respects these machines are so much alike, that the one might be used for the other. In my experimental illustrations, I shall have occasion to employ instruments which serve either to exhaust, or to condense, according to the aperture selected for making a communication with the receiver.

Fig. 1.

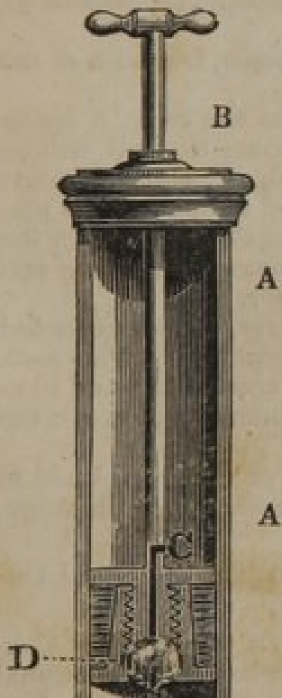
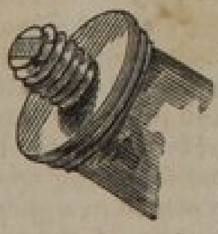


Fig. 2.



The adjoining figure represents the condenser.

It consists of a brass cylinder, A A, ground internally, so as to be perfectly cylindrical.

Into this a piston, B, is fitted by means of oiled leathers packed between screws, represented in the figure, and turned, in the lathe, so as to enter the chamber, in obedience to considerable force. At the lower end of the rod, a perforation, C C, may be seen, which commences at the lower extremity, rises vertically until it gets above the packing, and then passes out at right angles, to its previous direction, through the rod of the piston. Just above where it commences, a cavity, D, may be observed, which is left for the upper valve. This valve is formed of a strip of oiled leather tied over a brass knob represented within the cavity.

The upper and lower valves are exactly alike; hence, a good idea of either may be obtained from fig. 2, which affords a separate view of the lower valve.

The action of the condenser is as follows. When the piston is drawn up, all the air within it gets below the packing through the perforation, C C, and the upper valve, which opens downwards with ease so as to afford a passage. When the piston descends, the air included in the chamber cannot get by the leather packing. The upper valve at the same time shuts so as to prevent it from getting through the perforation, C C. It has therefore to proceed through the lower perforation, E. The piston being drawn up again, the valve at E shuts, and prevents a return of the air expelled, while the air of the chamber again gets below the piston as in the first instance. Thus, at every stroke, the contents of the chamber is discharged through the lower valve, while its retrocession from any receiver into which it may pass, is prevented by the valve, E.

As the quantity of air in the vessel increases, the force requisite to drive the piston home becomes greater, and it has to descend farther, ere the air within the chamber exceeds in density that in the receiver, so far as to open the lower valve.

32. INFLUENCE OF PRESSURE ON THE BULK OF AIR, AND OF ITS DENSITY ON ITS RESISTANCE.

Air lessens in bulk, as the pressure which it sustains augments; and the resistance, arising from its elasticity, is augmented, as the quantity, confined in the same space, is increased, or the confining space diminished.

For the illustration of this proposition, I have devised the apparatus represented in the opposite page.

If mercury be poured into the air tight vessel, A, through the tube, T T, which passes perpendicularly into this vessel until it touches the bottom; as the air, in the vessel, cannot escape, it resists the entrance of the mercury from the tube, so that an increasing column will be upheld, which by its height indicates the resistance. When the air in the vessel has been reduced to one-half its previous bulk, the height of the mercury in the tube will be about 30 inches, or equal to that of the mercury in the barometer, at the time of performing the experiment. Thus it is shown, that when air is condensed into half the space which it occupies under the pressure of the atmosphere, its reactive power is doubled, being adequate to support a column of mercury, equal to the pressure of the atmosphere, in addition to that pressure. It follows, that the quantity of air in any space is as the compressing force—and is always to that of an equal bulk of the atmosphere, as the height of the column of mercury which it can support in a Torricellian tube to the height of the mercury in the barometer: and likewise, that the resistance of included air increases, with the diminution of the space allotted to it; or, vice versa, that the space, which the same portion of air is capable of occupying, lessens as the compressing force increases.

It remains to be shown, that the *resistance* of air to compression, *increases* as the *quantity* in any space *increases.*

If, by means of the condenser, C, (the valve cock, *v c*, and the cock, *c*, being opened,) air be injected into the vessels, A and B, at the same time, it will be found that the liquid in the vase, V, will mount into the flask, F, and that when the pressure is adequate to cause the air in this to be reduced to one-half its previous volume, the mercury in the tube, TT, will have the same height as in the previous experiment; because the density of the air, and of course its quantity and reactive power, is doubled in one case, no less than in the other.

The communication between the condenser, and the receiver, A, is suspended during the first mentioned experiment, by closing the valve cock, *v c*. This cock is opened during the action of the condenser in the second experiment; and likewise another cock at *c*, which serves to intercept the communication between the condenser and the receiver, B.

See Appendix for an engraving, and description of the valve cock employed in this, and many other of my experiments requiring that there shall be no leakage.

33. MECHANICAL ACTION OF THE LUNGS IN RESPIRATION ILLUSTRATED.

The elevation of the sternum rarefies the air in the cavity of the thorax. Consequently, the atmospheric pressure not being adequately resisted, the external air rushes through the trachea into the lungs, dilating all the cells. The depression of the sternum and consequent diminution of the cavity, causes the air which had thus entered, or an equivalent portion, to flow out. For the illustration of the process here described, I have contrived the following apparatus:—

A tall receiver, R, with an orifice, O, is placed in a globe of water, so that about two-thirds of the receiver are occupied by this liquid, the remainder with air—whilst a bladder is so suspended from the orifice, as not to touch the water.

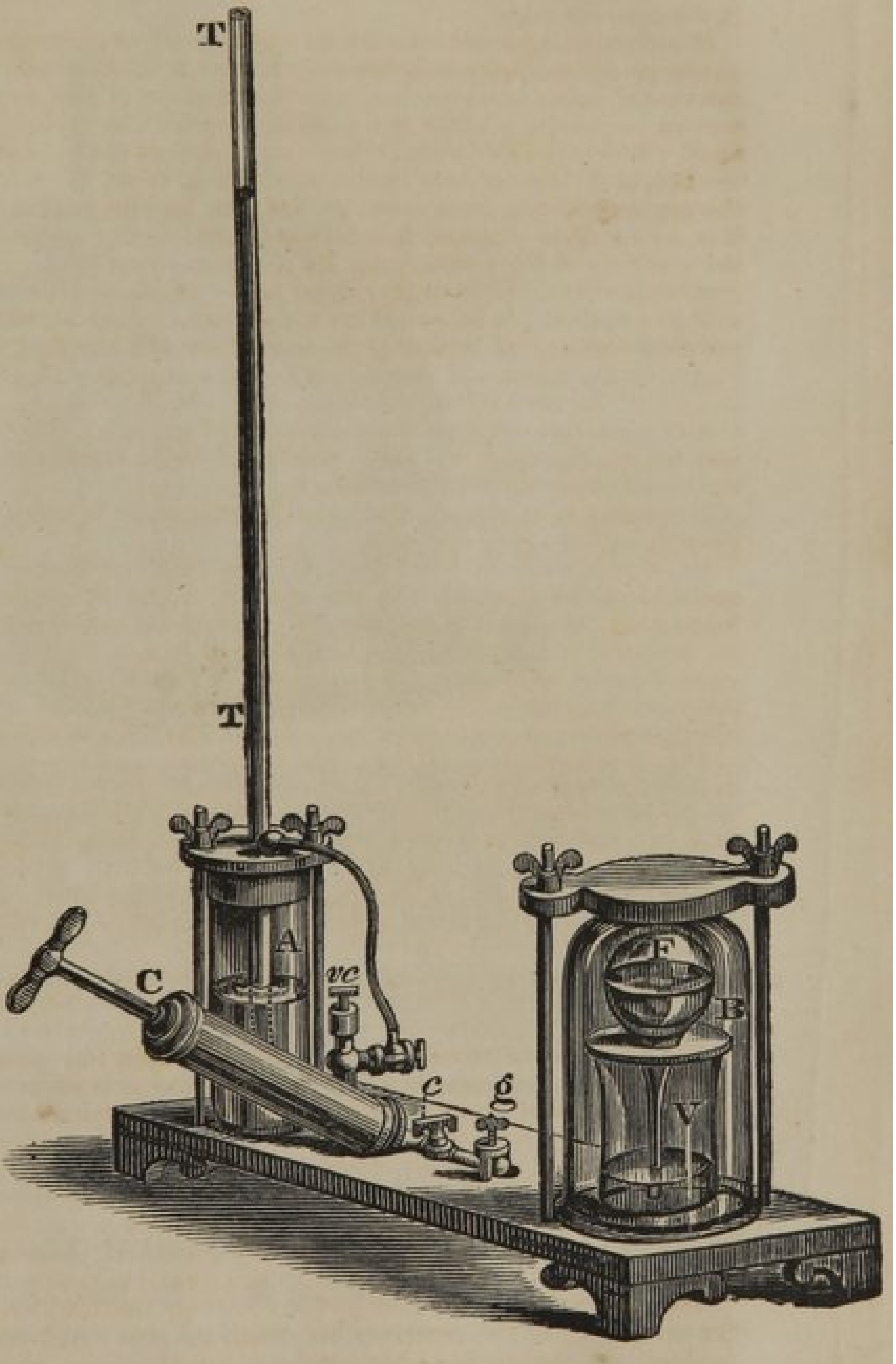
The atmosphere has access to the cavity of the bladder, through its neck, and the orifice, O, of the receiver, but not to the space A, between the outside of the bladder, and the inside of the receiver.

It may be assumed as an obvious consequence, of the preceding experiments 31, that the pressure, exerted by any given quantity of air, is inversely as the confining space; or in other words, that the pressure increases, as the space lessens, and diminishes, as the space enlarges.

It must be obvious, that when, by an enlargement of a cavity, the pressure of the

Influence of Pressure on the Bulk of Air.

(C. p. 28.)



contained air is reduced below that of the atmosphere, the external air must flow in through any opening, until the pressure within is rendered equal to that without: and vice versa, that when, by a diminution of a cavity, the pressure of the contained air is made greater than that of the atmosphere, if an opening exist, air will flow out, till the pressure, which it exerts, is no more than adequate to resist the atmospheric pressure. These consequences are well known to ensue, from an alternate enlargement and diminution of capacity, during the working of an air pump, a condenser, or bellows.

In like manner the elevation of the receiver, R, enlarging the cavity within it, unoccupied by water, causes the air to rush in through the orifice, O, and the reversal of the motion reducing the cavity, causes air to rush out through the same aperture. The bladder is so situated as to catch all the air that enters, and to supply all that is expelled. Hence when the receiver is lifted the bladder is inflated, when the receiver is lowered to its previous position, the bladder resumes its previous dimensions.

Supposing the space, A, between the outside of the bladder and the inside of the receiver, to represent the space between the outside of the lungs and the inside of the thorax, the cavity of the bladder representing the cavities of the lungs, and the orifice, O, performing the part of the trachea and nostrils: the explanation, above given, will be as applicable to the apparatus, by which nature enables us to breathe, as to that employed in the preceding illustration.

EXPANSION OF ELASTIC FLUIDS.

Having by means of the preceding digression explained the nature and extent of atmospheric pressure, I shall proceed to show the important influence exercised by it in all chemical processes in which elastic fluids are concerned.

It has been demonstrated, (6) in illustrating the principle of Sanctorio's thermometer, that the bulk of the air in any space varies with the temperature.

It has been shown (19, 21, 32,) that the same effect may be produced by variations in atmospheric pressure.

It follows that the volume of elastic fluids is inversely as the pressure, and directly as the heat. In other words, the less the pressure, and the greater the heat, the larger their bulk; and vice versa, the less the heat, and the greater the pressure, the less their bulk.

Agreeably to the observations of Dalton, Gay-Lussac and Crichton, 1000 parts of atmospheric air, in rising from the temperature of 32° to 212°, will expand so as to measure 1375 parts nearly, or $\frac{1}{480}$ the bulk which it would have at 32° for every additional degree.

Having therefore any given bulk of dry air, 100 cubic inches for instance, at 60°, to find its bulk at any other temperature, suppose at 80°, we must in the first place consider that 480 parts at 32 would at 60, adding one part for every degree above 32, be 508 parts; and would by a proportionable increase, become at 80, 528 parts. But if 508 at 60° become 528 at 80°, what will 100 parts at 60°, gain by being heated to 80.

508 : 528 : : 100 : 139.

It has been inferred by the same distinguished philosophers that all aëriform substances, whether gases or vapours, are expanded by heat at the same rate as dry atmospheric air, if they be not in contact with any vaporizable matter, in the liquid or solid state, which by vaporizing or condensing may vary the result.

THEORY OF EXPANSION.

The expansion of matter, whether solid, liquid, or aëriform, by an increase of temperature, may be thus explained.

In proportion as the temperature within any space, is raised, there will be more caloric in the vicinity of the particles of any mass contained in the space. The more caloric in the vicinity of the particles, the more of it will combine with them; and in proportion to the quantity of caloric thus combined, will they be actuated by that reciprocally-repellent power, which, in proportion to its intensity, regulates their distance from each other.

There may be some analogy between the mode in which each ponderable atom, is surrounded by the caloric which it attracts, and that in which the earth is surrounded by the atmosphere; and as in the latter case, so probably in the former, the density is inversely as the square of the distance.

At a height, at which the atmospheric pressure does not exceed a grain to the square inch, suppose it to be doubled, and supported at that increased pressure by a supply of air from some remote region; is it not evident that a condensation would ensue in all the inferior strata of the atmosphere, until the pressure should be doubled throughout, so as to become at the terrestrial surface, 30 pounds, instead of the present pressure of 15 pounds? Yet the pressure at the point from which the change would be propagated, would not exceed two grains per square inch.

In like manner, it may be presumed that the atmospheres of caloric are increased in quantity and density about their respective atoms, by a slight increase in the calorific tension of the external medium.

DEMONSTRATION, THAT ATMOSPHERIC PRESSURE OPPOSES, AND LIMITS, CHEMICAL ACTION, WHERE ELASTIC FLUIDS ARE TO BE GENERATED OR EVOLVED.

OF VAPORIZATION.

Water would boil at a lower temperature than 212°, if the atmospheric pressure was lessened; for when it has ceased to boil in the open air, it will begin to boil again in an exhausted receiver; and those who ascend mountains find, that for every 530 feet of elevation, the boiling point is lowered one degree of Fahrenheit's thermometer. It is in fact lowered, or raised, $\frac{176}{1000}$ of a degree, for every $\frac{1}{10}$ inch of variation in the height of the mercury in the barometer.

34. EBULLITION FROM DIMINISHED PRESSURE.

The adjoining figure represents a vessel of water boiling, within a receiver, in consequence of the diminution of pressure, by exhaustion.

35. CULINARY PARADOX.

Ebullition by Cold.

A matrass, half full of water, being heated until all the contained air is superseded by steam; the orifice is closed so as to be perfectly air-tight. The matrass is then supported, upon its neck, in an inverted position, by means of a circular block of wood. A partial condensation of the steam, soon follows, from the refrigeration of that portion of the glass which is not in contact with the water. The pressure of the steam upon the liquid of course becomes less, and its boiling point is necessarily lowered. Hence it begins again to present all the phenomena of ebullition; and will continue boiling, sometimes for nearly an hour.

By the application of ice, or of a sponge soaked in cold water, the ebullition is accelerated; because the aqueous vapour, which opposes it, is in that case more rapidly condensed: but as the caloric is at the same time more rapidly abstracted, from the water, by the increased evolution of vapour to replace that which is condensed, the boiling will cease the sooner.

This experiment may be varied in a way to afford additional instruction, by employing a glass retort, with a neck about three feet long, so situated, that the beak may extend from the bend nearly in a perpendicular direction, and terminate in mercury. The body of the retort is previously to be supplied with a small quantity of water, and to be supported at an elevation of more than 30 inches above the mercury. If, under these circumstances, by the application of fire, the water be made to boil, so as to occupy the cavity of the retort and beak, expelling the air entirely, and afterwards by the removal of the fire, the temperature be reduced, the mercury will rise in the beak gradually, in proportion to the refrigeration. Meanwhile the water will continue to boil, since the loss of temperature is compensated by the diminution of pressure. This diminution will be indicated and measured by the rise of the mercury in the beak, in which, if the experiment be well performed, it will finally nearly attain the height of the column in the barometer. But before this ensues, the water must cease to boil.

36. EXPERIMENTAL PROOF THAT SOME LIQUIDS WOULD BE PERMANENTLY AERIFORM, IF ATMOSPHERIC PRESSURE WERE REMOVED.

The power of sulphuric ether to assume in vacuo, at ordinary temperatures, the aëriform state, in opposition even to the pressure of a column of mercury, may be shown by the following means:—

A glass funnel is ground to fit air-tight into the neck of a glass decanter, so that the stem of the funnel may reach nearly to the bottom of the decanter, as represented in the adjoining cut. The decanter is filled with mercury, with the exception of a small portion of the neck, which is occupied by ether. The stem of the funnel is then introduced into the neck of the decanter, so as to be air-tight; and the whole being included in a receiver, the air is withdrawn by a pump. The ether converted into vapour, will force the mercury to rise from the decanter, through the stem, into the wider part of the funnel.

RATIONALE.

The attraction between the ponderable particles of the ether, and those of caloric, can be indulged only in opposition to the reciprocally repulsive power of the latter; since one tends to rarefy the caloric, the other to condense it into the limited space occupied by the ether. It follows that the caloric cannot combine with the ponderable matter beyond the point at which the repulsive power becomes equal to the attractive. But the repulsion exercised by the same number of particles of caloric will be greater, as the space is less, and vice versa. The larger therefore the space, occupied by the ponderable particles of the ether, the more caloric may combine with them, without rendering its reciprocally repulsive power paramount to its attraction for them.

The removal of atmospheric pressure, by allowing the ponderable particles to occupy a larger space, enables them to combine with that additional quantity of caloric which is necessary to the aëriform state.

This explanation may, of course, be extended to the ebullition of other liquids, in vacuo, at temperatures lower, than those at which they boil in the air. It is obviously applicable to the two preceding illustrations.

37. BOILING POINT ELEVATED BY PRESSURE.

Into a small glass matrass, with a bulb of about an inch and a half in diameter and a neck of about a quarter of an inch in bore, introduce nearly half as much ether as would fill it. Closing the orifice, with the thumb, hold the bulb over the flame of a spirit lamp, until the effort of the generated vapour to escape, becomes difficult to resist. Removing the matrass, to a distance from the lamp, lift the thumb from the orifice. The ether, previously quiescent, will rise up in a foam, produced by the rapid extrication of its vapour.

This experiment may be performed with less risk, by employing a vessel of hot water, instead of the lamp.

38. COLUMN OF MERCURY RAISED BY VAPORIZED ETHER.

An increase of Pressure results from Ebullition, when the Vapour, produced by it, is confined.

Having supplied a small flask, with a small quantity of mercury, and a minute portion of sulphuric ether; through the neck, let there be a glass tube, so introduced, and firmly luted, as that it may be concentric with the vertical axis of the vessel, and extend downwards until nearly in contact with the bottom. If the flask thus prepared, be held cautiously, over a spirit lamp, the ether will be more or less converted into vapour. The vapour being unable to escape, will soon cause the mercury to rise to the top of the tube. On the removal of the lamp, the mercury will gradually fall to its previous situation.

39. HIGH PRESSURE BOILER.

That the temperature of Steam increases with the pressure, may be demonstrated by means of a small Boiler, such as is represented in the following cut.

The glass tube in the axis, passes below the water in the boiler, and enters a small quantity of mercury at the bottom. The juncture with the tube, where it enters the boiler, is made perfectly tight. On the opposite side of the boiler, a tube, not visible in the drawing, descends into it. This tube consists of about two inches of a musket barrel, and is closed at bottom. The object of it is to contain some mercury, into which the bulb of a thermometer may be plunged, for ascertaining the temperature.

When the fire has been applied during a sufficient time, the mercury will rise in the glass tube, so as to be visible above the boiler; and continuing to rise, during the application of the fire, it will be found, that with every sensible increment in its height, there will be a corresponding rise of the mercury in the thermometer. In front of the tube, as represented in the figure, there may be observed a safety valve, with a lever and weight, for regulating the pressure.

It has been found, that when the effort made by the steam to escape, in opposition to the valve thus loaded, is equal to about fifteen pounds for every square inch in the area of the aperture, the height of the column of mercury, C, C, raised by the same pressure, is about equal to that of the column of this metal, usually supported by atmospheric pressure, in the tube of a barometer.

Hence the boiler, under these circumstances, is conceived to sustain an unbalanced pressure equivalent to one atmosphere, and for every additional fifteen pounds per square inch, required upon the safety valve, to restrain the steam, the pressure of an atmosphere is alleged to be added. To give to steam at 212 degrees, or the boiling point, such an augmentation of power, a rise of 38 degrees is sufficient, making the temperature equal to 250 degrees. To produce a pressure of four atmospheres, about 293 degrees would be necessary. Eight atmospheres would require nearly 343 degrees.

When, by means of the cock, an escape of steam is allowed, a corresponding decline of the temperature and pressure ensues.

If the steam, as it issues from the pipe, be received under a portion of water of known temperature and weight, the consequent accession of heat will appear surprisingly great, when contrasted with the accession of weight, derived from the same source.—It has in fact been ascertained, that one measure of water converted into aqueous vapour, will, by its condensation, raise about ten measures of water in the liquid form, one hundred degrees.

OF THE INCOMPETENCY OF A JET OF HIGH STEAM TO SCALD AT A CERTAIN DISTANCE FROM THE APERTURE.

Much attention has been excited by the observation, that the hands may be enveloped in a jet of vapour from a high pressure boiler without inconvenience, at a certain distance from the aperture through which it escapes.

40. EXPERIMENTAL DEMONSTRATION.

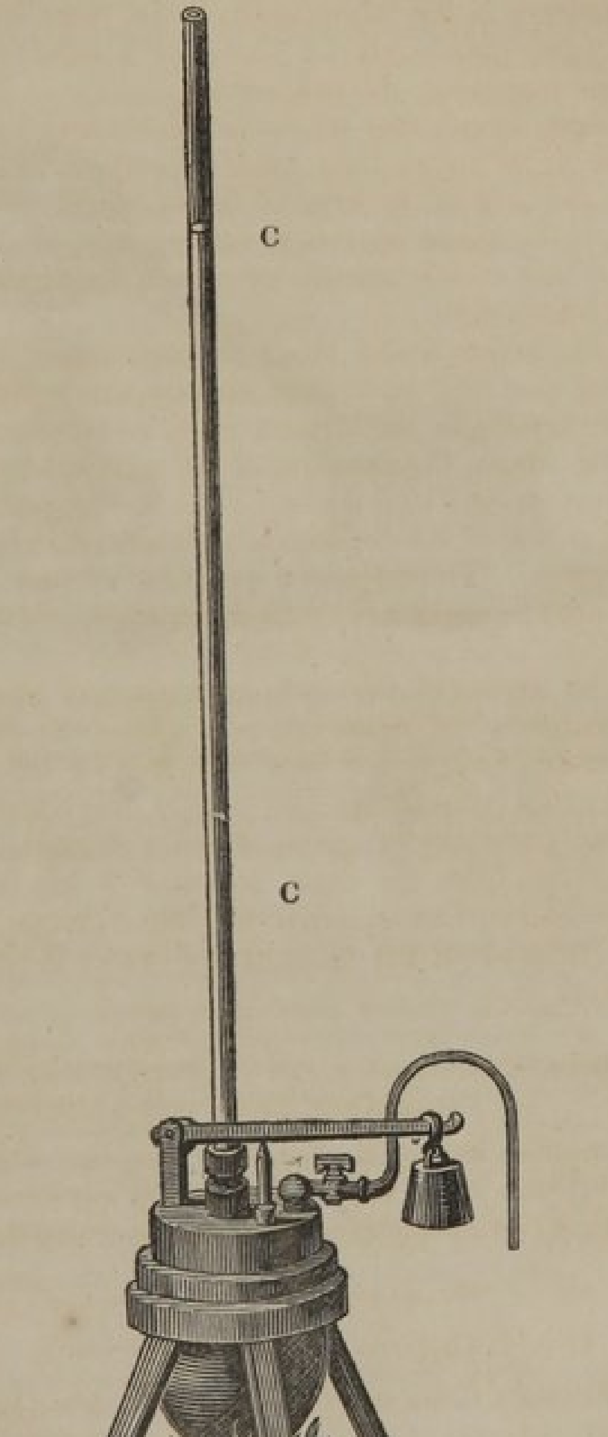
That the hand may be immersed in a jet of steam while issuing from a boiler, if not too near the aperture.

RATIONALE.

Since the temperature, density, and pressure, which form the distinguishing attributes of high steam, cannot be sustained without confinement, steam ceases to be *high steam* as soon as it is liberated. Consequently, a jet from a high pressure boiler, is essentially no more than a copious jet of aqueous vapour at the heat of boiling water.

High Pressure Boiler.

(C. p. 34.)



The only distinguishing characteristic, derived from its previously superior temperature and density, is a greater velocity of efflux. Without any superiority of temperature, the high pressure jet is propelled, into the atmosphere, with a momentum which cannot be given to low steam. Hence the rapid refrigeration to which the former is subjected, at a distance from the place of its efflux, sufficient to admit of an extensive diffusion in the atmosphere. See Appendix.

41. OF THE STEAM ENGINE.

THE PRINCIPLE OF SAVARY'S STEAM ENGINE ILLUSTRATED.

A matrass, situated as in the preceding figure, and containing a small quantity of water, being subjected to the flame of a lamp, the water, by boiling, will soon fill the matrass with steam. When this is accomplished, bubbles of air will cease to escape from the neck of the matrass, through the water in the vase.

The apparatus being thus prepared, on removing the lamp, the water of the vase will quickly rush into the vacuity in the matrass, arising from the condensation of the steam.

OF SAVARY'S ENGINE.

The celebrated engine of Savary, which led to the invention of that of Newcomen, and finally to the almost perfect machine of Boulton and Watt, consisted essentially of a chamber in which steam, after being introduced from a boiler, was condensed by a jet of cold water, as in the experiment above described.

Just before the condensation of the steam, the communication with the boiler was closed, and a cock, or valve, in a pipe descending into a reservoir of cold water, was opened. The chamber was consequently filled with water, which was expelled through an aperture opened for the purpose, by allowing the steam to enter again, above the water. The aperture through which the water escaped, and that through which the steam entered, being closed simultaneously; the operation of condensing the steam, and filling the chamber with water, was reiterated, as likewise in due succession the other steps of the process, as above stated.

Of Newcomen's Engine.

The great objection to Savary's engine, was the waste of steam arising from its entrance into a cold, moist, chamber; for so great is the power of cold water in condensing steam, that had the steam been introduced into the chamber under the surface of the water, this liquid could not have been expelled until ebullition should have been excited; but heat, as we shall soon show, being propagated downwards in liquids with extreme difficulty, the steam entering from above was not condensed so rapidly as to paralyze the engine.

To diminish the very great loss sustained in the engine of Savary, Newcomen, instead of causing the vacuum, produced by the condensation, to act directly upon water, contrived that it should act upon a piston, moving, air tight, in a large cylinder, like a pump chamber. The piston was attached to a large lever, to the end of which, on the other side of the fulcrum, a pump rod and a weight were fastened. By the vacuum arising from the condensation, the piston, being exposed to the unbalanced pressure of the atmosphere, was forced down to the bottom of the cylinder, drawing up, of course, the rod and weight at the other end of the lever.

The cylinder being replenished with steam, the weight on the beam at the end attached to the pump rod, caused this rod to descend, and at the same time drew up the piston at the other end of the beam, and thus by the alternate admission and condensation of steam, the piston and pump rod were made to undergo an alternate motion, by which the pump, actuated by the rod, was kept in operation. Although less caloric was wasted by Newcomen's engine than by Savary's, there was still great waste, as the cylinder was to be heated to the boiling point, each time that steam was admitted, and to be cooled much below that point, as often as condensation was effected.

Of Watt's Engine.

At this stage of the invention, Mr. James Watt, who combined, in an uncommon degree, mechanical ingenuity with philosophical knowledge, discovered that to produce a vacuum in a vessel replete with steam, it is only necessary to open a communication with a vessel which is duly refrigerated by cold water. This being done, the vapour passes almost entirely into the latter. Hence his contrivance of a condenser to remove the steam from the cylinder occupied by the piston, as often as necessary. The necessity of cooling the cylinder at each reversal of the stroke, being obviated, the improvement of admitting the steam alternately above and below the piston became admissible. In Newcomen's engine, the steam was acting only half the time; in that of Watt, while the steam is entering into the cylinder above the piston, the portion which had previously entered below, passes into the condenser, and that which is meanwhile entering above the piston, passes into the same receptacle, as soon as another portion enters below the piston.

Of the High Pressure Engine.

The only material difference between the operation of the high pressure engine, and that above described, is, that the steam escapes alternately from above, and below the piston, into the air, instead of passing into a condenser.

The steam in these engines acts simply by its expansive power; it is therefore necessary that there should be greater strength than in engines working with a condenser.

The engines in our steam boats generally combine the two principles—using steam which will support a weight of from seven to fifteen pounds per square inch.

A true Boulton and Watt steam engine, having an ample supply of water, cannot explode while the safety valve is of a proper size, and not improperly loaded.

42. EXPLOSIVE POWER OF STEAM.

If a small glass bulb, hermetically sealed, while containing a small quantity of water, be suspended by a wire over a lamp flame, an explosion soon follows, with a violence and noise which is surprising, when contrasted with the quantity of water, by which it is occasioned.

RATIONALE.

Supposing that the bulb were, in the first instance, merely filled with steam, without any water in the liquid form, the explanation of this phenomenon would be comprised in the theory of expansion, given, page 30. In that case, the effort of the steam to enlarge itself, would be nearly in direct arithmetical proportion to the temperature; but when water is present in the liquid form, while the expansive power of the steam, previously in existence, is thus increased, more steam is generated, with a like increased power of expansion. It follows, that the increments of heat being in arithmetical proportion, the explosive power of the confined vapour will increase geometrically, being actually doubled, as often as the temperature is augmented, 38°. See page 34.

INTERESTING EXPERIMENTS WITH RESPECT TO CONSTRAINED VAPORIZATION BY MR. CAGNIARD DE LA TOUR, AND MR. PERKINS.

Agreeably to some experiments, performed by Mr. Cagniard de la Tour, in which liquids were exposed to heat in very stout tubes, vaporization was performed in a space which was to that previously occupied.

In the case of {
Ether, as 2 to 1, producing a pressure of 33 atmospheres.
Alcohol, as 3 to 1, producing a pressure of 119 atmospheres.
Water, as 4 to 1, producing a pressure greater than that of the alcohol.

Mr. Perkins alleges that a small iron boiler of great strength may be heated red-hot while holding a quantity of water, and that, if, under these circumstances, an aperture be opened of ¼ of an inch in diameter, the steam will not escape, although upon a reduction of temperature, it will rush out with great violence.

It was inferred that the repulsion between the particles of the caloric, in union with the water, and those in union with the metallic ring bounding the aperture, was paramount to the pressure tending to produce the expulsion of the steam.

I am unable to reconcile this experiment with one which I performed by heating to incandescence, in a forge fire, a tube of iron, of which the bore was less than ¼ of an inch; while by means of a cock, a communication with a high pressure boiler was made. Under these circumstances, the steam was not prevented from escaping through the pipe.

It appears to be sufficiently proved that the quantity of caloric combined with any given weight of steam, is the same, whatever may be the temperature; the sensible heat increasing, and the latent heat diminishing, as the density and pressure are augmented.

43. COLD AND CLOUDINESS ARISING FROM RAREFACTION.

Incipient rarefaction in the air of a receiver is usually indicated by a cloud, which disappears when the exhaustion has proceeded beyond a certain point. A delicate thermometer placed in the receiver, shows that a decline of temperature accompanies this phenomenon. We may therefore infer, that the cloud is the consequence of refrigeration. If the suggestions were correct which were made (see page 30, Theory of Expansion) respecting the mode in which caloric exists in atmospheres, around the particles of ponderable matter, it will not be difficult to understand why aëriform fluids should absorb more caloric, in proportion as their constituent particles are enabled, by a diminution of pressure, to become more remote. Hence, by rarefaction, the capacity of air is increased, and cold is produced, which condenses the aqueous vapour until its sensible heat is restored by an accession of caloric from the surrounding medium. See article 36.

44. OF THE CONSTRUCTION OF THE PALM GLASS.

AND OF THE COLD PRODUCED BY IT.

In forming the bulbs, severally, at the ends of the glass tube represented in this figure, one is furnished with a perforated projecting beak. By warming the bulbs, and plunging the orifice of the beak into alcohol, a portion of this liquid enters, as the air within contracts, by returning to its previous temperature. The liquid, thus introduced, is to be boiled in the bulb which has no beak, until the whole cavity of the tube, and of both bulbs not occupied by liquid alcohol, is filled with its steam. While in this situation, the end of the beak is to be shortened and sealed, by subjecting it to a flame excited by a blowpipe.

As soon as the instrument becomes cold, the steam which had filled the space, vacant of alcohol in the liquid form, condenses, and with the exception of a slight portion of vapour, which is always emitted by liquids when relieved from atmospheric pressure, a vacuum is produced within the bulb.

The instrument, thus formed, has been called a palm glass, because the phenomenon which it exhibits, is seen by grasping one of the bulbs so as to bring it completely into contact with the palm of the hand. One of the bulbs, B, being thus situated, and while surcharged with the alcohol, and held in the position represented in the figure, both the liquid, and vapour, are propelled from it into the other bulb. This phenomenon combines the characteristics of the differential thermometer, (9,) with those of the culinary paradox, (35,) being the joint effect of the expansion, and evolution of vapour, in one part of the apparatus, and its contraction and condensation in another. The phenomena are precisely similar, whether we warm the lower bulb, or cool the upper one by means of ice. The motive for recurring to the experiment here, is to state, that as soon as the last remnant of the liquid is forced from the bulb in the hand, a striking sensation of cold, is experienced by the operator.

This cold is produced by the increased capacity of the residual vapour for caloric, in consequence of its attenuation. The analogy is evident between this phenomenon and that above described, as taking place in the receiver of the air pump, both being attributable to the increase of capacity for caloric, resulting from a diminution of density.

45. COLD CONSEQUENT TO A RELAXATION OF PRESSURE.

It is immaterial whether a diminution of density, arise from relieving condensed air from compression, or from subjecting air of the ordinary density to rarefaction. A cloud similar to that which has been described as arising in a receiver partially exhausted, may usually be observed in the neck of a bottle recently uncorked, in which a quantity of gas has been evolved in a state of condensation by a fermenting liquor.

Apparatus for showing the influence of Relaxed Pressure, on the capacity of Air for Heat, or Moisture.

A glass vessel with a tubulure and a neck, has an air thermometer fastened air tight by means of a cork into the former, while a gum elastic bag is tied upon the latter, as represented in this figure. Before closing the bulb, the inside should be moistened. Under these circumstances, if the bag, after due compression by the hand, be suddenly released, a cloud will appear within the bulb, adequate in the solar rays, to produce prismatic colours. At the same time the thermometer will show that the compression is productive of warmth—the relaxation of cold.

The tendency in the atmosphere to cloudiness, at certain elevations, may be ascribed to the rarefaction which air inevitably undergoes, in circulating from the earth's surface to such heights.

ON THE INFLUENCE OF THE ATMOSPHERE, IN PROMOTING EVAPORATION.

It has been seen that by its pressure, the atmosphere opposes vaporization; yet a free access of air is found indispensable in the desiccation of hay, or in the evaporation of water, or other solvents. It was at one time generally conceived, that evaporation resulted from an affinity between the liquid and the air, analogous to that between water and sugar, or alcohol and resin; but Dalton presented a different view of this subject, which is now generally approved. He has shown that whatever may be the temperature, no more vapour is formed during the presence of the air, than would be evolved in vacuo in the same space. It would seem from investigations made by that philosopher, by Gay-Lussac, and others, that a current of atmospheric particles promotes evaporation, only by removing the necessity, to which the vapour would otherwise be exposed, of diffusing itself through the atmospheric interstices to a greater distance. Nevertheless, it appears to me that the influence of a current of atmospheric air, in promoting evaporation, is greater than can be reasonably accounted for upon this Daltonian doctrine; and I am at a loss to explain, consistently with this doctrine, wherefore spirits of turpentine and other essential oils, which in the absence of the air are less vaporizable than water, should, when the air has access to them, be comparatively more ready to evaporate. It is difficult to conceive that atmospheric air should have no affinity for vaporizable liquids: or that having such affinity, it should not, in consequence, by attracting the liquid particles, promote the process of evaporation. Nothing can be more certain than that evaporation is accelerated in proportion to the extent to which contact may be induced between the aeriform and liquid particles. Hence, when surfaces moistened with such volatile liquids, as sulphuret of carbon, or the more volatile ethers, are exposed to the wind, or to a blast, intense cold is produced by the accelerated evaporation.

It is well known that the direction of the wind becomes evident, from the sensation of coldness experienced in that part of the wetted finger on which it blows. With the refreshing influence of a breeze, when the skin is moistened by perspiration, we are all familiar. In these cases, the reduction of temperature must be ascribed to some property in the air which enables it to assist in the formation of vapour.

In fact the processes of evaporation, and vaporization (in the sense of ebullition) cannot be confounded in practice, however they may be identified agreeably to prevailing theories. In either case heat is requisite, though much less is necessary in that of evaporation, but the process last mentioned, is accelerated in proportion to the extent of surface exposed to the air. Vaporization takes place in proportion to the surface exposed to the fire, without access of air. It only requires that the vapour generated, should have an aperture sufficient to allow of its escape, without increase of pressure. Hence evaporating vessels are made broad and shallow, while boilers are made deep, with narrow openings.

46. EXPERIMENTAL ILLUSTRATION.

Of the cold produced by the evaporation of ether when accelerated by a current of air.

The cold, produced by evaporation, accelerated by a current of air, may be advantageously shown by subjecting a thermometer bulb simultaneously, to a jet of ether and a blast from a bellows, so that the aerial, and etherial, particles may be thoroughly mingled just before reaching the bulb. Water freezes when contained in a bulb thus refrigerated.

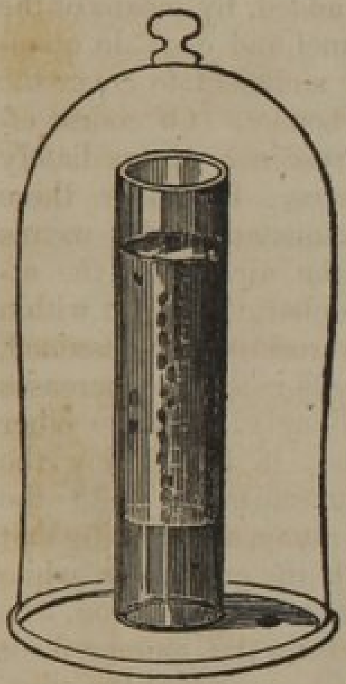
DEFINITION OF VAPOUR BY BERZELIUS.

Berzelius objects to the use of the word vapour, as implying a condensible aëriform fluid. He uses it in the sense in which English authors employ the word fog, or cloud. Vapour and steam were originally, and still are used in English in this sense. Yet high steam, or low steam, can apply only to that which the distinguished Swede, would call aqueous gas. Johnson defines steam to be the smoke or vapour of any thing hot and moist. Of course steam, vapour, and smoke, in the old acceptation, were synonymous. In truth before Black's discoveries, as I have elsewhere stated, atmospheric air was the only aëriform fluid whose existence was recognised. Hence the use of the words steam, and vapour, has grown with our knowledge, and consequently the names applied to visible steam or vapour, have been extended to mean the invisible aëriform fluids from which it is produced by refrigeration. I confess I have some repugnance to designating by a common epithet, permanent gases, and the condensible elastic fluids produced from liquids above their boiling points. I do not see that any disadvantage arises from the customary use of the word vapour to designate the latter.

OF THE OPPONENT INFLUENCE OF PRESSURE, ON THE EXTRICATION OF GASEOUS SUBSTANCES FROM A STATE OF COMBINATION.

When one of the ingredients of a solid, or liquid, is prone to assume the aeriform state, its extrication will be more or less easily effected, in proportion as the pressure of the air is diminished, or increased.

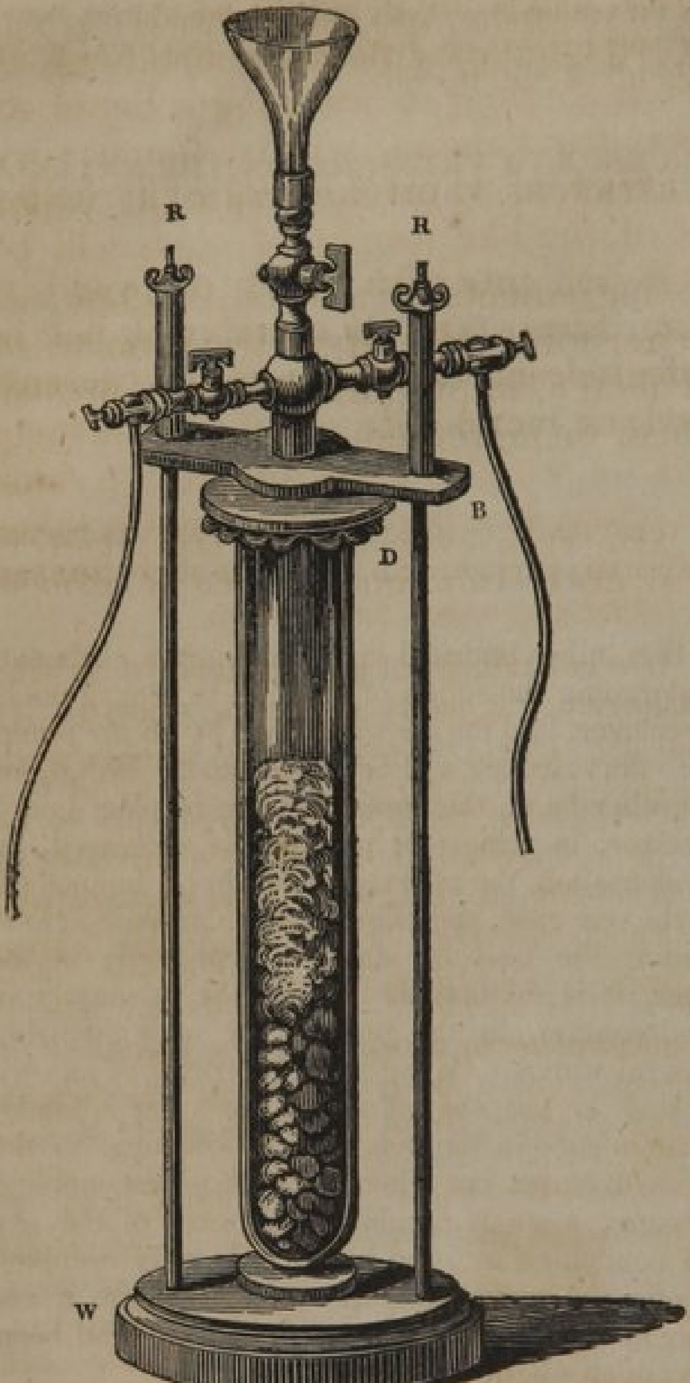
47. ESCAPE OF CARBONIC ACID FROM CARBONATE OF LIME, SUBJECTED TO AN ACID PROMOTED BY EXHAUSTION, AND CHECKED BY CONDENSATION.



If a tall cylindrical jar, containing a carbonate undergoing the action of an acid, be placed under a receiver, and the air withdrawn by an air pump, the effervescence will be augmented. But if, on the other hand, the same mixture be placed in a receiver, in which the pressure is increased, by condensation, the effervescence will be diminished. In the one case, the effort of the carbonic acid to assume the gaseous state, is repressed; in the other, it is facilitated. Hence the advantage of condensation, in the process for manufacturing mineral water. Beyond an absorption of its own bulk of the gas, the affinity of the water is inadequate to subdue the tendency of the acid to the aëriform state; but when, by exterior mechanical pressure, a great number of volumes of the gas are condensed into the space ordinarily occupied by one, the water combines with as large a volume of the condensed gas, as if there had been no condensation.

48. IMPROVED APPARATUS FOR SHOWING THE INFLUENCE OF PRESSURE ON EFFERVESCENCE.

A cylindrical receiver, about 30 inches in height, is supported on a wooden pedestal, between upright iron rods, R R, fastened into the pedestal, P, and at top cut into screws furnished with nuts. By means of these screws and nuts, and an intervening cross bar, B, a brass disk, D, is pressed upon the rim of the receiver. The disk is so fitted to the rim of the glass, as that, with the aid of sheet gum elastic, or oiled leather, an air-tight juncture may be made. In the middle of the disk there is an aperture, from which proceeds a stout tube, with a cock on each side, severally furnished with gallows screws, by means of which, lead pipes may be made to communicate with an air pump on one side, and a condenser on the other. The tube is also surmounted by a cock, into which



a glass funnel has been cemented. Before closing the receiver with the disk, some carbonate of lime, or carbonate of ammonia, must be introduced, so as to rise to about half the height of the receiver. I have found calcareous stalactites, like those from Weyer's cave, to be excellent for this purpose. The carbonate being introduced, and the disk fastened into its place, as represented in the figure, diluted muriatic acid may be added, by means of the funnel and cock, in quantity sufficient to cover the carbonate. Of course effervescence immediately ensues. If, under these circumstances, by means of the air pump, the atmospheric pressure within the receiver be lessened, the effervescence increases strikingly. On the other hand, if by closing the communication with the air pump, and opening that with the condenser, while this is in operation, the pressure be increased, it will be seen that the effervescence is diminished proportionably.

This experiment is much facilitated and improved, by my newly contrived air pump, by which we can either exhaust or condense at pleasure. (See Appendix.)

OF THE SCREW ROD, AND PLATE FRAME, EMPLOYED IN THE PRECEDING AND MANY OTHER EXPERIMENTS.

The means by which the glass receiver employed in the preceding experiment, is upheld and rendered air-tight by the rods, R R, the wooden block, W, the bar, B, and circular plate or disk, D, is one to which I shall resort repeatedly in the course of my experiments. Hence, to avoid unnecessary recurrence to analogous description, I shall in future designate as *a screw rod and plate frame*, that portion of the apparatus above described, which consists of the *block*, *bar*, *plate*, and *screw rods*.*

The glass is in this case made quite true by grinding on a large lap wheel, such as is employed by lapidaries. The same object is effected in the case of brass plates without grinding, by turning them in a lathe with a slide rest, and a tool with a fine pyramidal point.

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* Modifications of the screw rod and plate frame are represented in article

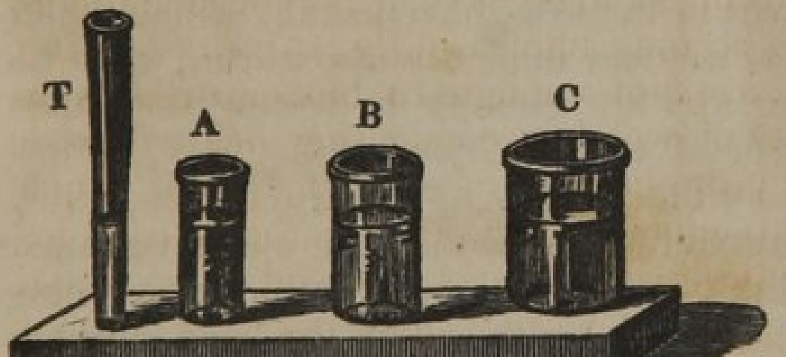
OF CAPACITIES FOR HEAT. OF SPECIFIC HEAT.

The power of equal weights of different substances, at the same temperature, in cooling or warming a liquid at a temperature, different from theirs, will be found very unequal. Thus the effect of a given weight of water being 1000, the effect of the like weight of glass will be 137; of copper 94; tin 51; lead 29; iron 110; gold 29; platinum 31; zinc 92; silver 55. If equal weights of water and mercury, at different temperatures, be mixed, the effect on the water will be no greater, than if instead of the mercury $\frac{1}{28}$th of its weight of water, at the same temperature as the mercury, had been added; and it takes twice as much mercury by measure, as of water heated to the same point, to have the same influence.

The term specific heat is usually employed to designate the quantity of *caloric* in a body in proportion to its *weight* or *bulk*, as specific gravity is used to convey an idea of *weight*, comparatively with *bulk*.

In the process above described, the specific heats of substances are found in order to estimate their capacities, the one being, necessarily, as the other, and the same series of numbers, expressive of either.

49. APPARATUS FOR ILLUSTRATING CAPACITIES FOR HEAT.



Let the vessels A, B, and C, be supplied with water through the tube, T, which communicates with each of them, by a horizontal channel in the wooden block. The water will rise to the same level in all. Of course the resistance made by the water, in each vessel, to the entrance of more of this liquid will be the same, and will be measured by the height of the column of water in the tube, T. Hence if the height of this column were made the index of the quantity received by each vessel, it would lead to an impression that they had all received the same quantity. But it must be obvious, that the quantities severally received, will be as different as are their horizontal areas. Of course we must not assume the resistance exerted by the water within the vessels against a further accession of water from the tube, as any evidence of an equality in the portions *previously* received by them.

In like manner, the height of the mercury in the thermometer, shows the resistance which substances, whose temperatures it measures, are making to any further accession of caloric: but it does not demonstrate the quantities, respectively received by them, in attaining to the temperature in question. This varies, in them, in proportion to their attraction for this self-repellent fluid; as the quantities of water, received by the vessels, A, B, C, are varied in the ratio of their respective areas.

RATIONALE.

It may be conjectured that this diversity in the power of substances, equally hot or cold, in influencing temperature, is due to a difference in their capacity to attract caloric, in consequence of which it forms, probably, denser atmospheres about the atoms of some substances, than it does about those of others.

An analogy has already been suggested as existing between the manner in which these calorific atmospheres surround atoms, and that in which the earth is surrounded by air; and also the mode has been suggested in which changes of temperature in the external medium would operate upon the density of such atmospheres. Supposing these preliminary suggestions correct, it would follow, that the quantity of caloric absorbed, or given out, at each exterior change of temperature, by any one congeries of atoms, would be to that absorbed or given out by any other congeries, as the previous condensation of caloric in the one, is to its previous condensation in the other. See Theory of Expansion, page 32.*

OF THE SLOW COMMUNICATION OF HEAT, COMPRISING THE CONDUCTING PROCESS, AND CIRCULATION.

OF THE CONDUCTING PROCESS IN SOLIDS.

It is well known that if one end of a piece of metallic wire, as a common pin, for instance, be held in a candle flame, the other end soon becomes too hot for the fingers. It is also known that the heated irons used in soldering, and other processes in the arts, have usually wooden handles, which do not become unpleasantly warm, when the irons within them are hot enough to blister the hands. This inferior power of wood in conducting heat, is also well exemplified by the handles of silver tea-pots, which are sometimes altogether of wood; in other instances principally of metal, small portions of wood intervening. In either case, the facility with which the heat is propagated, in the comparatively thin metallic socket, is strongly contrasted with its almost utter inability to permeate the wood.

An inferiority of conducting power, when compared with metals, is also displayed by common bone, whale bone, ivory, porcelain, and especially by glass.

Metals are by far the best conductors of caloric. There are, however, scarcely two that conduct it equally well.

Silver and copper are probably the best conductors among them, and platinum and lead, the worst.

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* The doctrine of Petit and Dulong that the capacities of all elementary atoms for heat are the same, will be deferred till I have treated of atomic proportions.

50. INEQUALITY OF CONDUCTING POWER, EXPERIMENTALLY ILLUSTRATED.

Let there be four rods, severally of metal, wood, glass, whale bone, each cemented at one end to a ball of sealing wax. Let each rod, at the end which is not cemented to the wax, be successively exposed to the flame excited by a blow pipe. It will be found, that the metal becomes quickly heated throughout, so as to fall off from the wax—but, that the wood, or whalebone, may be destroyed, and the glass bent, by the ignition, very near to the wax, without melting it, so as to liberate them.

RATIONALE OF THE FRACTURE OF GLASS, OR PORCELAIN, BY HEAT.

The fracture of glass and porcelain, exposed to fire, is the consequence of an inferior conducting power; as the heat is not distributed with quickness enough to produce a uniform expansion. Hence glass is less liable to crack by heat, in proportion as it is thinner. It may be divided by a heated iron; by a string steeped in oil of turpentine and inflamed; or by the heat generated by friction. See article 60.

TABLE OF THE CONDUCTING POWER OF VARIOUS SOLIDS.

Despretz has ascertained by exact experiments, that the conducting power of the following solid bodies is in the ratio of the subjoined numbers.

Gold,	1000.0
Silver,	973.0
Copper,	898.0
Platinum,	381.0
Iron,	374.3
Zinc,	363.0
Tin,	303.9
Lead,	179.6
Marble,	23.6
Porcelain,	12.2
Clay,	11.4

EXPLANATION OF THE PROCESS BY WHICH HEAT IS SUPPOSED TO BE COMMUNICATED IN SOLIDS.

I conceive that in solids, the stratum of atoms, forming the surface first exposed to the heat, combining with an excess of this principle, divides it with the next stratum. The caloric received by the second stratum, is in the next place divided between the second and third stratum. In the mean time the first stratum has received an additional supply of caloric, which passes to the second and third stratum, as in the first instance; while the quantity, at first received by them, is penetrating further into the mass.

It is I trust easy to conceive, that, by the process thus suggested, caloric may find its way throughout any body, towards the particles of which it may have sufficient affinity. Probably the superior conducting power of metals, is due in great measure to a proportionably energetic affinity for caloric.

The conjectures, which I ventured to advance respecting the mode in which caloric may exist in atmospheres, about atoms, seem to be peculiarly applicable in the case of metals, on account of their great expansibility by heat, and susceptibility of contraction by cold.

If caloric be not interposed in a dense repulsive atmosphere between metallic atoms, how can its removal cause that approximation of those atoms towards each other, without which the diminution of bulk invariably consequent to refrigeration could not ensue?

51. LIQUIDS ALMOST DESTITUTE OF CONDUCTING POWER.

That liquids are almost devoid of power to conduct heat, proved by the inflammation of ether, over the bulb of an air thermometer, protected only by a thin stratum of water.

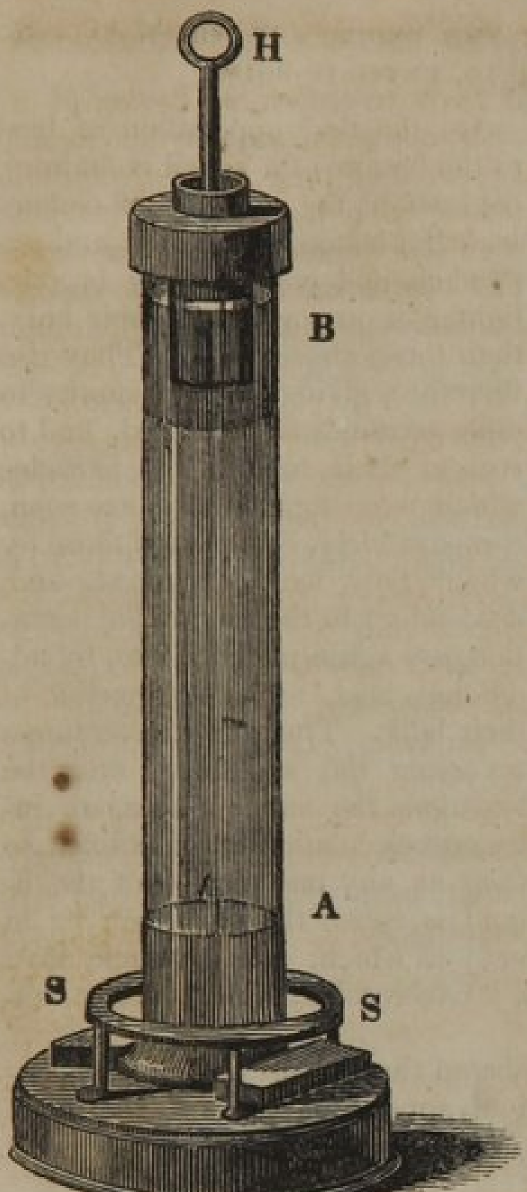
The inflammation of ether, upon the surface of water, as represented in this figure, does not cause any movement in the liquid included in the bore of the thermometer at L, although the bulb is within a quarter of an inch of the flame. Yet the thermometer may be so sensitive, that touching the bulb, while under water with the fingers, may cause a very perceptible indication of increased temperature.

By placing the sliding index, I, directly opposite the end of the liquid column in the stem of the thermometer, before the ether is inflamed, it may be accurately discovered whether the heat of the flame causes any movement in the liquid.

ON THE COMMUNICATION OF CALORIC BY CIRCULATION.

That caloric cannot be communicated in liquids, unless it be so applied as to cause a circulation of the particles, experimentally demonstrated.

A glass jar, about 30 inches in height, is supplied with as much water as will rise in it within a few inches of the brim. By means of a tube descending to the bottom, a small quantity of blue colouring matter is introduced below the colourless water so as to form a stratum as represented at A, in the engraving. A stratum, differently coloured, is formed in the upper part of the vessel, as represented at B. A tin cap, supporting a hollow tin cylinder, closed at bottom, and about an inch less in diameter



than the jar, is next placed as it is seen in the drawing, so that the cylinder may be concentric with the jar, and descend about 3 or 4 inches into the water.

The apparatus being thus prepared, if an iron heater, H, while red hot, be placed within the tin cylinder, the coloured water, about it, soon boils; yet neither of the coloured strata, intermingle with the intermediate colourless mass; and on sliding the finger upwards in contact with the glass, the heat will be found to have penetrated only a very small distance below the tin cylinder. But if the ring, R, be placed, while red hot, upon the iron stand which surrounds the jar at S S, the portion of the liquid, coloured blue, being opposite to the ring, will rise until it encounters the warmer, and of course lighter, particles, which have been in contact with the tin cylinder. Here its progress upwards is arrested; and, in consequence of the diversity of the colours, a well defined line of separation is soon visible.

The phenomena of this interesting experiment may be thus explained.

If the upper portion of a vessel, containing a fluid, be heated exclusively, the neighbouring particles, of the fluid, being rendered lighter, by expansion, are more indisposed, than before, to descend from their position. But, if the particles, forming the inferior strata of the fluid in the same vessel, be rendered warmer than those above them, their consequent expansion and diminution of specific gravity, causes them to give place to particles above them, which, not being as warm, are heavier. Hence, heat must be applied principally to the lower part of the vessel, in order to occasion a uniform rise of temperature in a contained fluid.

This statement is equally true, whether the fluid be aëriform, or liquid, excepting that in the case of aëriform fluids, the influence of pressure on their elasticity, may sometimes co-operate with, and at others oppose, the influence of temperature.*

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* See Appendix for Essay on the gales experienced in the Atlantic states of North America.

53. EXPERIMENTAL ILLUSTRATION OF THE PROCESS BY WHICH CALORIC IS DISTRIBUTED IN A LIQUID, UNTIL IT BOILS.

On the first application of heat to the bottom of a vessel containing cold water, the particles in contact with the bottom are heated and expanded, and consequently become lighter in proportion to their bulk, than those above them. They rise therefore, giving an opportunity to other particles to be heated, and to rise in their turn. The particles which were first heated, are soon, comparatively, colder than those by which they were displaced, and, descending to their primitive situation, are again made to rise, by additional heat, and enlargement of their bulk. Thus the temperatures reversing the situations, and the situations the temperatures, an incessant circulation is maintained, so long as any one portion of the liquid is cooler than another: or in other words, till the water boils; previously to which, every particle must have combined with as much caloric, as it can receive, without being converted into steam.

The manner in which caloric is distributed throughout liquids by circulation, as above described, is illustrated advantageously by an experiment contrived by Rumford, who first gave to the process the attention which it deserves.

Into a glass nearly full of water, as represented by the foregoing figure, some small pieces of amber are introduced, which are in specific gravity so nearly equal to water, as to be little influenced by gravitation.

The lowermost part of the vessel being subjected to heat, while thus prepared, the pieces of amber are seen rising vertically in its axis, and after they reach the surface of the liquid, moving towards the sides, where the vessel is colder from the influence of the external air. Having reached the sides of the vessel, they sink to the bottom, whence they are again made to rise as before. While one set of the fragments of amber, are at the bottom of the liquid, some are at the top, and others at intermediate situations; thus demonstrating the movements, by which an equalization of temperature is accomplished in liquids.

When the boiling point is almost attained, the particles being nearly of one temperature, the circulation is retarded. Under these circumstances, the portions of the liquid which are in contact with the heated surface of the boiler, are converted into steam, before they can be succeeded by others; but the steam thus produced, cannot rise far before it is condensed. Hence the vibration and singing, which is at this time observed.

According to an observation of Gay-Lussac, water boils in metallic vessels, at a temperature nearly *two and a half* degrees lower than in those of earthenware.

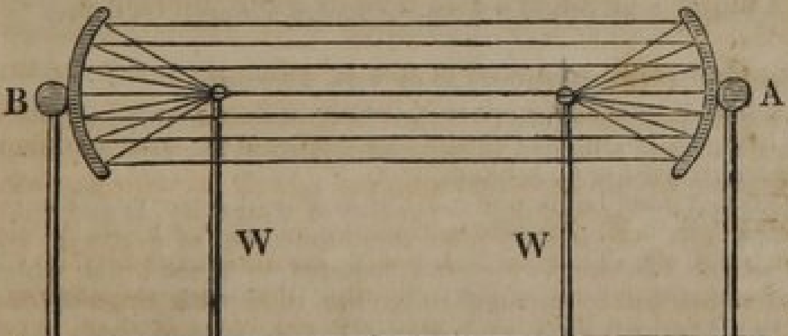
OF RADIATION, OR THE QUICK COMMUNICATION OF CALORIC.

It must be evident that the heat which we receive from a fire, in opposition to the draught, reaches us, neither by the conducting process, nor by circulation. Actual contact is evidently indispensable to the passage of heat in either of these modes. The aeriform matter which is in contact with the embers, or the blaze of a fire, forms part of a current, which tends rapidly towards the flue; as must be evident from the celerity with which the sparks which accompany it are propelled. The rapidity with which the aerial particles, heated by the fire, are thus carried up the chimney, far exceeds that with which caloric can be communicated, in the opposite direction, either by the conducting process, or circulation.

The caloric received from a fire, under the circumstances above mentioned, and which is analogous to that by means of which the culinary operation of toasting, or that of roasting, is accomplished, is called radiant caloric, or more usually, radiant heat. It has been called radiant, because it appears to emanate in radii or rays, from every hot, or even warm body, as light emanates from luminous bodies.

Radiant heat resembles light also, in its susceptibility of being reflected by bright metallic surfaces, in which case it obeys the same laws as light, and is of course liable, in like manner, to be collected into a focus by concave mirrors.

54. MODEL FOR ILLUSTRATING THE OPERATION OF CONCAVE MIRRORS.



The object of the model represented by this diagram, is to explain the mode in which two mirrors operate, in collecting the rays of radiant heat emitted from one focus, and in concentrating them in another.

The caloric emitted by a heated body in the focus of the mirror, A, would pass off in radii or rays lessening their intensity, as the space into which they pass enlarges; or, in other words, as the squares of the distances. But those rays which are arrested by the mirror, are reflected from it in directions parallel to its axis.* Being thus corrected of their divergency, they may be received, without any other loss, than such as arises from mechanical imperfections, by the other mirror; which should be so placed, that the axis of the two mirrors may be coincident; or, in other words, so that a line drawn through their centres, from A to B, may at the same time pass through their foci, represented by the little balls supported by the wires, W W.

The second mirror, B, reflects to its focus, the rays which reach it from the first; for it is the property of a mirror, duly concave, to render parallel the divergent rays received from its focus—and to cause the parallel rays which it intercepts, to become convergent, so as to meet in its focus.

The strings, in the model, are intended to represent the paths, in which the rays move, whether divergent, parallel, or convergent.

55. PHOSPHORUS IGNITED AT THE DISTANCE OF SIXTY FEET, BY AN INCANDESCENT IRON BALL.

On the opposite page is a figure representing the mirrors, which I employ in the ignition of phosphorus, and lighting a candle, by an incandescent iron ball.

I have produced this result at sixty feet, and it might be always effected at that distance, were it not for the difficulty of adjusting the foci with sufficient accuracy and expedition. I once ascertained that a mercurial thermometer, when at the distance last mentioned, was raised to 110 degrees of Fahrenheit.

Some cotton, imbued previously with phosphorus, is supported by a wire over a candle wick, placed as nearly as possible, in the focus of one of the mirrors. A lamp being similarly situated with respect to the other mirror; by receiving the focal image of the flame on any small screen, it will be seen in what way the arrangement must be altered to cause this image to fall upon the phosphorus.

The screen, S, placed between the mirrors, is then lowered so as to intercept the rays. The iron ball being rendered white hot, is now substituted for the lamp, and the screen being lifted, the phosphorus takes fire, and the candle is lighted.†

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* The axis of a mirror is in a line drawn from its centre through its focus.

† DESCRIPTION AND CONSTRUCTION OF THE MIRRORS.

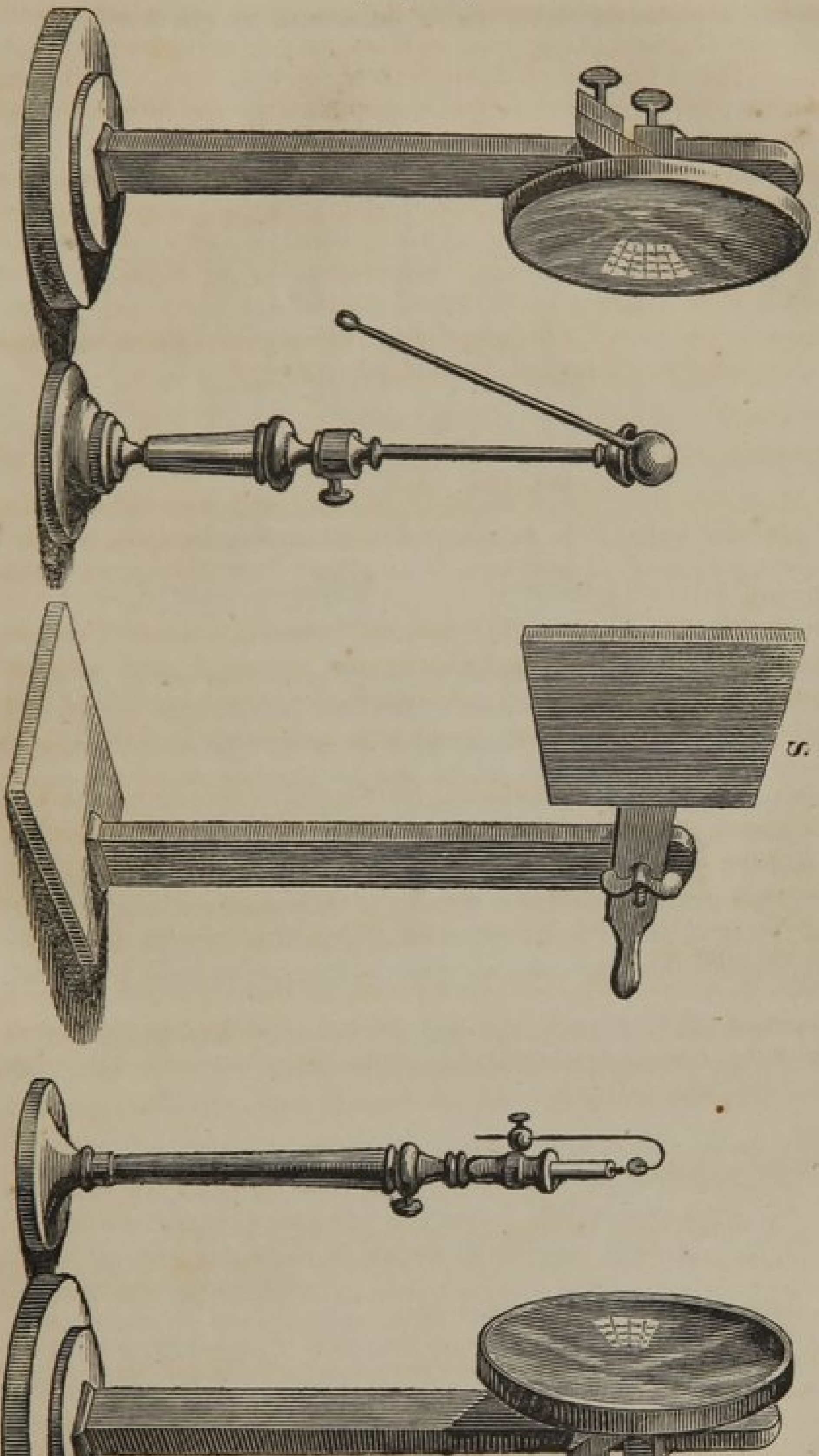
The mirrors represented by the figure, are 16 inches in diameter, and were turned in the lathe, the cutting tool being attached to one end of an iron bar two feet long, which at the other end turned upon a fixed pivot.

Of course the focal distance, being one-half the radius of concavity, is one foot.

I designed these mirrors, and proposed to have them made out of castings; but pursuant to the advice of Dr. Thomas P. Jones, I resorted to sheet brass, which was rendered the more competent by strengthening the rims with rings of cast brass, about three-fourths of an inch thick each way. For the idea of these rings, and the execution of the mirrors, I am indebted to Mr. Jacob Perkins.

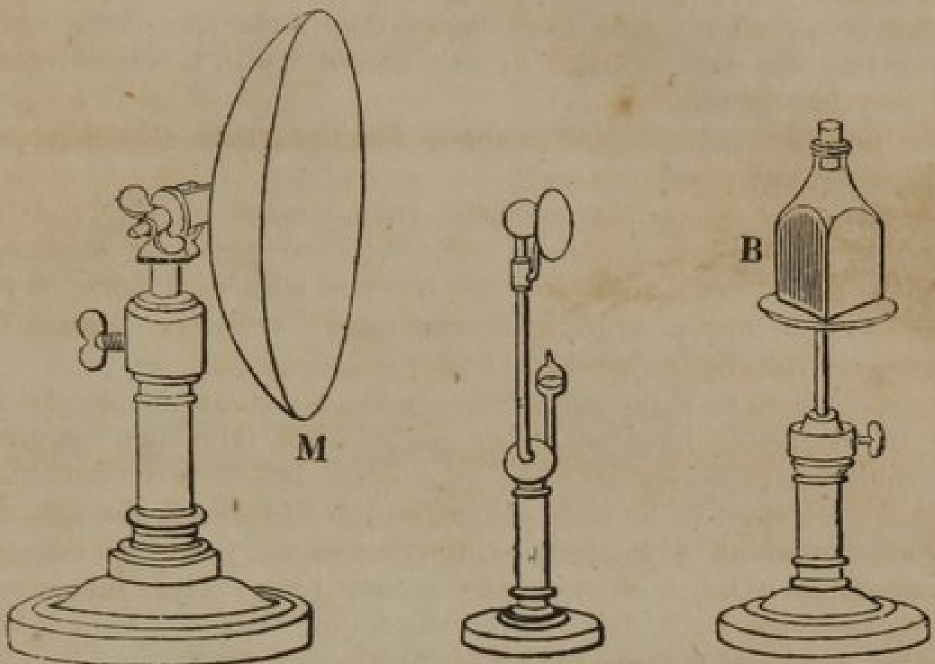
I believe there are none superior, as the face is reflected by them much magnified, but without the slightest distortion.

Phosphorus Ignited by Radiant Heat.
(C. p. 50.)



56. OF THE DIVERSITY OF RADIATING POWER IN METALS, WOOD, CHARCOAL, GLASS, POTTERY, &C.

Diversity of Radiating Power experimentally illustrated.



At M, in the preceding figure, a parabolic mirror is represented. At B, is a square glass bottle, one side of which is covered with tin foil, and another so smoked by means of a lamp, as to be covered with carbon. Between the bottle and mirror, and in the focus of the latter, there is a bulb of a differential thermometer, protected from receiving any rays directly from the bottle, by a small metallic disk. The bottle being filled with boiling water, it will be found that the temperature in the focus, as indicated by the thermometer, is greatest when the blackened surface is opposite to the mirror; and least, when the tin foil is so situated; the effect of the naked glass being greater than the one, and less than the other.

The worst radiators are the best reflectors, and the best radiators are the worst reflectors; since the arrangement of particles, which is favourable for radiation, is unfavourable for reflection, and vice versa.

A polished brass andiron does not become hot when exposed from morning till night to a fire, so near as that the hand, placed on it, is scorched intolerably in a few seconds. Fire places should be constructed of a form and materials to favour radiation: flues, of materials to favour the conducting process.

To preserve heat, in air, or to refrigerate, in water, vessels could be made of bright metal. In the latter case, the brightness is beneficial only because the surface cannot be bright without being clean. If soiled, its communication with the liquid would be impeded.

RATIONALE.

Metals appear to consist of particles so united with each other, or with caloric, as to leave no pores through which radiant caloric can be projected. Hence the only portion of any metallic mass, which can yield up its rays by radiation, is the external stratum.

On the other hand, from its porosity, and probably also from its not retaining caloric within its pores tenaciously, as an ingredient in its composition, carbon opposes but little obstruction to the passage of that subtile principle, when in the radiant form; and hence its particles may all be simultaneously engaged in radiating any excess of this principle, with which a feeble affinity may have caused them to be transiently united—or in receiving the rays emitted by any heated body, to whose emanations they may be exposed.

We may account in like manner for the great radiating power of earthenware and wood.

For the same reason that calorific rays, cannot be projected from the interior of a metal, they cannot enter it, when projected against it from without. On the contrary, they are repelled with such force, as to be reflected, without any perceptible diminution of velocity. Hence the preeminence of metallic reflectors.

It would seem as if the calorific particles, which are condensed between those of the metal, repel any other particles, of their own nature, which may radiate towards the metallic superficies, before any contact actually ensues; otherwise, on account of mechanical imperfection, easily discernible with the aid of a microscope, mirrors would not be as efficacious as they are found to be, in concentrating radiant heat. Their influence, in this respect, seems to result from the excellence of their general contour, and is not proportionably impaired by blemishes.

RADIATION OF COLD.

A thermometer, placed in the focus of a mirror, indicates a decline of temperature, in consequence of a mass of ice or snow being placed before it, in the situation occupied by the bottle, in the preceding figure. This change of temperature has been considered as demonstrating the radiation, and consequently the materiality of cold. For since the transfer of heat by radiation, has been adduced as a proof of the existence of a material cause of heat; it is alleged that the transmission of cold, by the same process, ought to be admitted as equally good evidence, of a material cause of cold.

The following is the explanation which I give of this phenomenon, agreeably to the opinion that cold is diminished heat.

I suppose that caloric exists throughout the sublunary creation, as an atmosphere held to the earth by the general attraction of all the matter in it, being in part combined with bodies in proportion to their affinities, or capacities for it, and partly free. The particles of the free caloric, I suppose incessantly to exert a self-repellent power, which increases with its density, as in the case of aëriform fluids. The repulsive power of caloric being in the ratio of the quantity, it follows that either a diminution or increase of temperature in any spot, must equally produce a movement in the calorific particles, in the one case from the spot, which sustains the change, in the other towards it.

Supposing the surface of a mirror to be subjected to the influence of a space, in which a diminution of temperature has been produced, the rows of calorific particles between the mirror and the space, will move into the space. The removal of one set of the calorific particles, from the surface of the mirror, must make room for another to flow into the situations thus vacated. The curvature of the surface of the mirror, renders it more easy for those particles to succeed, which lie in the direction of the focus.

ON THE MEANS OF PRODUCING HEAT, OR IN OTHER WORDS, OF EVOLVING CALORIC.

OF THE SOLAR RAYS, AS A SOURCE OF HEAT.

Of all the natural sources of heat, the sun is obviously the most prolific.

The solar rays may be collected into a focus, either by the refracting influence of glasses, or the reflecting power of mirrors. They may be converged by reflection, in a mode analogous to that illustrated in the case of radiant heat.

The glasses employed in concentrating light are called lenses, from their shape, which is that of a double convex lens.

As the intensity of the heat, produced by the solar beams, is in proportion to the quantity of them which may be collected upon any given spot, there appears to be scarcely any limits to the temperature producible by their condensation, excepting our incompetency to enlarge or multiply burning glasses or mirrors, without rendering them unmanageable or inefficient.

Scarcely any occurrence of antiquity has excited more curiosity than the destruction of the Roman ships, which Archimedes is alleged to have accomplished, by concentrating upon them the rays of the sun.

Buffon arranged a number of plane mirrors so as to *concur* in reflecting the solar image upon the same spot. He was by these means enabled to fuse lead, at a distance of 140 feet. This contrivance resembles that which Archimedes employed, if we may judge from the accounts which have been given of the latter. Previously to the employment of pure oxygen gas, of the hydro-oxygen blowpipe, or voltaic series, there was no known mode of rivalling the heat produced by large burning-glasses, and mirrors.

SENSIBLE HEAT EVOLVED BY ELECTRICITY.

The power of lightning to produce ignition, has been displayed by the conflagration of ships and barns, in consequence of the ignition of cotton, hay, or other combustibles. The power of the electric spark, to ignite an inflammable gaseous mixture, is agreeably illustrated, by means of the apparatus described in the following article,

57. APPLICATION OF AN ELECTROPHORUS TO THE IGNITION OF HYDROGEN GAS, GENERATED IN A SELF-REGULATING RESERVOIR.

In order that the interior of this apparatus may be described, the side of the box, B, below the reservoir, R, is supposed to be removed. On the bottom of the box is a square metallic dish covered by a stratum of sealing wax. The metallic plate, D, is supported, behind, by a glass rod, cemented to a socket, soldered to a hinge. Upon this hinge, like the lid of a trunk, the plate moves freely, while connected with the lever, L, by a silken cord. The lever, L, is attached to the key of the cock, C; so that opening the cock, causes the plate to rise, and touch the knob *n*, of the insulated wire. This wire terminates just before the orifice of the tube, *t*, proceeding from the cock, about one-eighth of an inch from another wire, supported upon that tube.

The glass reservoir, R, receives into its open neck, the tapering part of a glass vessel, V, which is so proportioned, and fitted to the neck by grinding, as to make with it, an air tight juncture.

Below this juncture, the vessel, V, converges, until it assumes the form of a tube, reaching nearly to the bottom of the reservoir. Around the tube thus formed, a coil of zinc is supported, so as to be above the orifice of the tube, constituted as abovementioned.

If the reservoir be sufficiently supplied with diluted sulphuric acid, the reaction between this solvent and the zinc, will evolve hydrogen gas. The gas thus evolved, if not allowed to escape, will force the liquid which generates it, through the orifice of the tube proceeding from the vessel, V, into the cavity of this vessel, until the quantity of the acid remaining below, be insufficient to reach the zinc. Whenever this takes place, the evolution of hydrogen ceases. As soon, however, as, by opening the cock, any portion of the gas is allowed to escape, an equivalent bulk of acid descends into the reservoir, and reacts with the zinc, until by the further generation of hydrogen, as much acid as may descend, be again expelled from the lower, into the upper vessel. At the same moment that, by turning the cock, C, a jet of gas is emitted, the plate of the Electrophorus being lifted against the knob of the wire, an electrical spark will pass from the other end of this wire, to that of the wire, supported by the cock, and of course uninsulated by its communication with the operator's hand.—Consequently, the jet of hydrogen will be ignited, and will light a candle, exposed to its influence.

For a rationale of the Electrophorus, also for other exemplifications of the igniting power of electric discharges, I refer to my Lectures on Electricity, articles 43, 44, 45, 49.

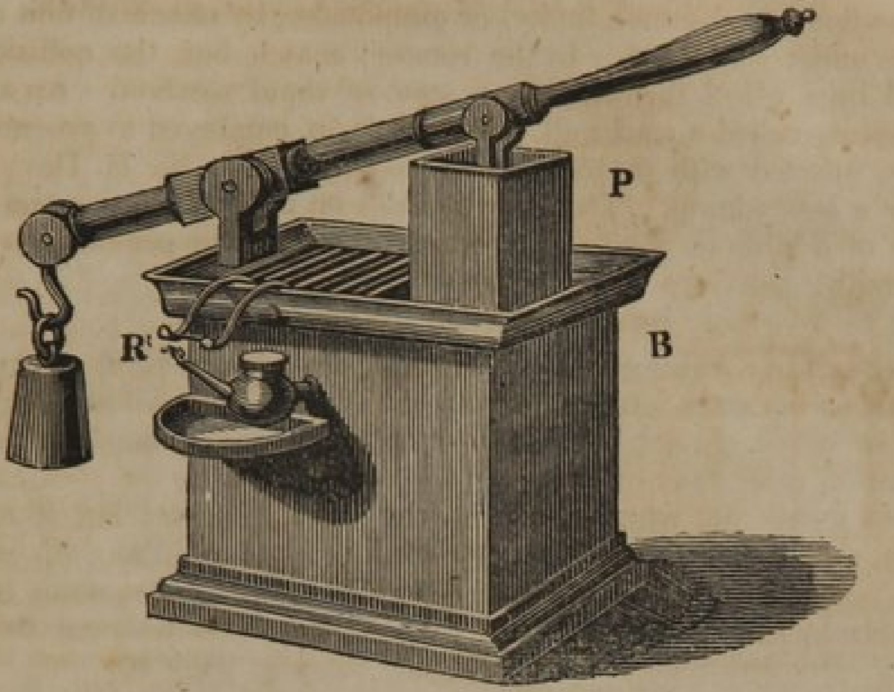
58. IGNITION BY GALVANISM.

GALVANIC APPARATUS FOR LIGHTING A LAMP.

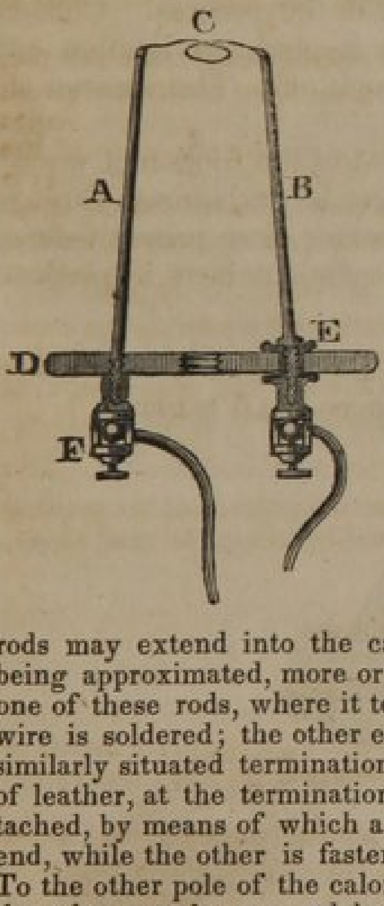
The following figure represents an instrument for lighting a lamp, by means of a galvanic discharge from a Calorimotor; for an explanation of which, I must refer the reader to my galvanic lectures.

The plunger, P, being depressed, by means of the handle attached to it, some acid, contained in the box, B, is displaced, so as to rise among the galvanic plates. By the consequent evolution of the galvanic fluid, a platina wire fastened between the brass rods forming the poles of the calorimotor, and projecting over the lamp, as seen at R, is rendered white hot, and a filament of the wick, previously laid upon it, is inflamed.

The weight, W, acts as a counterpoise to the plunger, and when it is not depressed by the hand, keeps it out of the acid.



58. GALVANO IGNITION APPARATUS.



In many of my experiments for the purpose of producing the temperature of combustion in cavities inaccessible by ordinary means, I employ a wire, ignited, by being made a part of a galvanic circuit.

Of the apparatus, by which this object is effected, I shall here give a description, accompanied by a figure, which must convey a general idea of the contrivance, applicable to all cases where it may be used. Having thus prepared the student, I shall in future refer to it under the name at the head of this article, in order to avoid circumlocution, and the unnecessary recurrence of analogous description. DD, represent a section of a metallic disk; AB, two metallic rods, which should be of iron, if in contact with mercury, but which otherwise may be of brass, are made to enter the cavity. If, as in general, the rods pass through a metallic plate, or cylinder, one of them may be soldered to the plate, or cylinder. The other must be so secured, where it passes through the metal, by a collar of leather, E, as to insulate it from all metallic contact, and to render the aperture through which it enters, air tight if necessary. The rods may extend into the cavity to any convenient distance, their terminations being approximated, more or less, as may be desirable; but never in contact. To one of these rods, where it terminates within the cavity, one end of a fine platina wire is soldered; the other end of the wire, being soldered in like manner, to the similarly situated termination of the other rod. To the rod secured by the collar of leather, at the termination on the outside of the cavity, a gallows screw is attached, by means of which a flexible lead, or copper rod, may be made fast at one end, while the other is fastened to one of the poles of a competent calorimotor.[*] To the other pole of the calorimotor, another rod is attached at one end, which at the other may be secured by a gallows screw, either soldered to the plate, or to the projecting extremity of the uninsulated rod, as in the figure. Sometimes the last mentioned rod is left at liberty, so as to be made to touch, when desirable, any part of the apparatus having a metallic communication with the uninsulated rod. If, under these circumstances, the calorimotor be put into operation, the wire will be ignited.

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[*] See Lectures on Galvanism, or Voltaic Electricity.

IGNITION BY COLLISION.

The ignition of spunk, tinder, or gunpowder, by means of flint and steel, comes under this head. In the rotatory match box, the collision is produced by a wheel thrown into a state of rapid rotation. An analogous apparatus, called a steel mill, had long been employed to procure light in mines, infested with carburetted hydrogen, prior to Sir H. Davy's invention of a safety lamp. This gas explodes on coming into contact with the flame of a lamp or candle; but is not ignited by the scintillation from the steel mill.

HEAT PRODUCED BY PERCUSSION.

A rod of iron hammered with great rapidity by a skilful workman, will become so hot as to ignite a sulphur match; and phosphorus may, in this way, be easily ignited, but the same piece of iron cannot be ignited by percussion more than once.

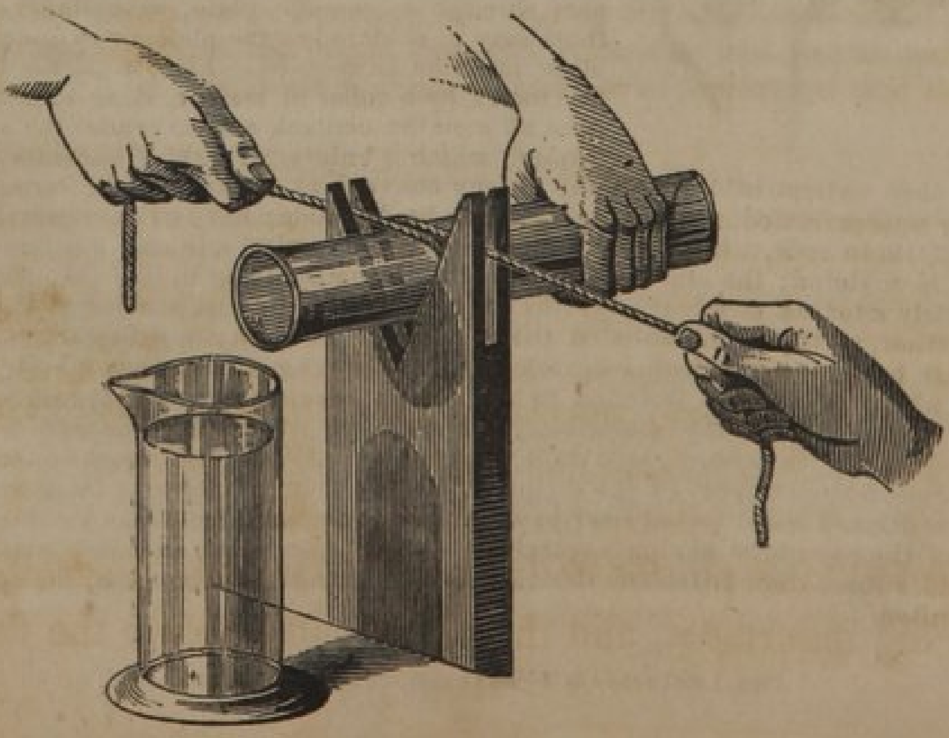
Coin grows hot when struck in the coining press; but if repeatedly struck, and cooled during each interval, is less heated at each successive blow. At the same time the density of the mass is permanently increased, probably by the expulsion of the caloric, interposed between the metallic atoms. See rationale of the conducting process, page 45.

HEAT PRODUCED BY FRICTION.

Friction, as a mean of producing heat, differs from percussion; since in the case of friction, the effect being confined to the surfaces of bodies, there is no condensation of the mass subjected to the process. Collision differs both from percussion and friction; since it produces ignition only in the minute portions of matter which are struck off. The masses employed, are not heated.

It is well known that savages avail themselves of the friction of wood to generate fire. Wood revolving in the lathe may be carbonized, throughout the circle of contact, by holding against it another piece properly sharpened. By rubbing one cork against another, sufficient heat is produced to ignite phosphorus.

60. GLASS SO HEATED BY THE FRICTION OF A CORD, AS TO SEPARATE INTO TWO PARTS, ON BEING SUBJECTED TO COLD WATER.



The process for dividing a tube, which I am about to describe, illustrates at once, the heat produced by friction, and the non-conducting power of glass.

Some years ago, Mr. Isaiah Lukens showed me, that a small phial, or tube, might be separated into two parts, if subjected to cold water, after being heated by the friction of a cord made to circulate about it by two persons alternately pulling in opposite directions. I was subsequently enabled to employ this process in dividing large vessels, of four or five inches in diameter; and likewise to render it in every case more easy, and certain, by means of a piece of plank forked like a boot-jack, as represented in the preceding figure; and also having a kerf, or slit cut by a saw, parallel to, and nearly equidistant from, the principal surfaces of the plank, and at right angles to the incisions, productive of the fork.

By means of the fork, the glass is easily held steady by the hand of one operator. By means of the kerf, the string, while circulating about the glass, is confined to the part, where the separation is desired. As soon as the cord smokes, the glass is plunged in water, or if too large to be easily immersed, the water must be thrown upon it. This method is always preferable when the glass vessel is so open, that on being immersed, the water can reach the inner surface. As plunging is the most effectual method of employing the water, in the case of a tube, I usually close the end which is to be sunk in the water, so as to restrict the refrigeration to the outside.

RATIONALE.

If the friction be continued long enough, the glass, though a very bad conductor of heat, becomes heated throughout in the part, about which the friction takes place; of course, it is there expanded. While in this state, being suddenly refrigerated by cold water on the outside only, the stratum of particles immediately affected contracts, while that on the inside not being chilled, undergoes no concomitant change. Hence a separation usually follows.

IGNITION BY ATTRITION.

If whilst a thin disk of sheet iron is made to revolve rapidly upon its axis by means of a lathe, the circumference be brought into contact with a plate of steel, heat will be so copiously evolved, at the place of collision, that the steel may be actually divided by the successive ignition and abrasion of a portion of its particles. The ignition is confined to the steel, because the heat, evolved in this case, is too much divided, upon the whole circumference of the iron, to affect any part materially; whereas, a few particles of steel having to encounter successively many of iron, the heat, generated by the attrition, accumulates in the former, so as to produce visible ignition.

This case differs from that of pure collision, since although heat is produced, in the abraded particles, it is also produced in the mass; and it differs from that of friction; since, although one of the masses is heated, the greatest heat is evolved, in the matter which is abraded.

HEAT PRODUCED BY COMBINATION.

The union of tin, or lead, with platinum, is productive of a remarkable elevation of temperature. For the exhibition of this phenomenon, both metals must be in the state of foil, and the more fusible metal rolled up in the platinum, so as to form a scroll as large as can be conveniently ignited by means of a blowpipe. As soon as the scroll reaches a red heat, it becomes instantaneously incandescent, the union being effected with an astonishing energy.

EXPERIMENTAL ILLUSTRATION.

Tin foil, and platina foil, are rolled up into a scroll, the tin being innermost, and the whole subjected to the flame of the hydro-oxygen blowpipe. Almost as soon as the mass reddens, it becomes incandescent.

61. BOILING HEAT PRODUCED IN ALCOHOL, BY THE MIXTURE OF SULPHURIC ACID WITH WATER.

The evolution of caloric, produced by the mixture of liquids, has long been an object of attention among chemists. A sensible increase of temperature arises from the mixture of alcohol with water. The same consequence ensues, to a much greater extent, from mixing water with sulphuric acid. The heat, thus generated, may be conveniently displayed by means of the apparatus represented by the adjoining figure.

Into the inner tube, represented in the adjoining figure, introduce as much alcohol, coloured to render it more discernible, as will occupy it to the height of three or four inches. Next pour water into the outer tube, till it reaches about one-third as high as the liquid within; and afterwards add to the water, about three times its bulk of concentrated sulphuric acid. The liquid in the inner tube will soon boil violently, so as to rise in a foam.

SOLUTION THE MEANS OF PRODUCING HEAT OR COLD.

Solution produces either heat or cold, according to the nature of the substance dissolved, and of the solvent employed.

Nitric acid grows warm while dissolving silver or copper, and is still more heated during its reaction with tin. Water becomes cold, in dissolving nitre, and still colder, in dissolving nitrate of ammonia. Sulphuric acid becomes at first boiling hot, and afterwards freezing cold, by successive additions of snow.

HEAT PRODUCED BY MECHANICAL ACTION INDUCING CHEMICAL DECOMPOSITION.

With the view of showing the necessity of distinguishing heat as a latent cause, from sensible heat, the explosion of a fulminating powder by percussion, was exhibited. This phenomenon falls under the definition given at the head of this article. Ignition produced in this way, has of late been advantageously applied to fire arms, and fowling pieces.

It seems probable that the mechanical force of the blow, causes some particles of the compound to be nearer to each other, in consequence of which an arrangement of the elements ensues, inconsistent with the retention of a large quantity of caloric, with which they were previously combined.

HEAT PRODUCED BY CONDENSATION EXPERIMENTALLY ILLUSTRATED.

Spunk, or tinder, may be ignited, if introduced into a condenser of an appropriate construction, and the air forcibly condensed upon it.

It has already been shown, that during its rarefaction air becomes cooler, while during its condensation it becomes warmer. It seems that when the compression is carried very far, so much caloric is liberated as to cause ignition. This result is attained by means of a small condenser, the construction of which does not differ from that which has been described (31), excepting that a cock for the introduction of spunk, is substituted for the valves. The ignition is accomplished by having the piston so situated, as that there may be as much air as possible included by it, and then driving it home, with a jerk, so as to condense the air upon the matter, to be ignited, with great force and rapidity. Sometimes the instrument is made of glass, without a cock, so that the ignition may be seen, the spunk being inserted into a cavity in the end of a piston; which must of course be withdrawn as soon as the ignition is effected, in order to make any useful application of the ignited spunk.

It appears evidently from this phenomenon, that in air, when the temperature is uniform, the quantity of caloric in proportion to the ponderable matter lessens, as the density increases.

This inference would appear, at first view, irreconcilable with those experiments, which demonstrate, that, in steam, the quantity of caloric is always directly as the weight of water; but the discordancy disappears when we consider that the heat, of the condensed air, is estimated, after the escape of the sensible heat liberated by the compression; while in the case of steam, this cannot be permitted, as a loss of sensible heat must be attended, by a partial condensation, producing a proportionate diminution of density.

If steam formed at the boiling point of 212° and having no access to water in the liquid form, were to be raised to some higher temperature, 500° for instance, it might be subjected to compression without being partially liquefied, so that the same law would apply to it as to atmospheric air, which is always heated far above its boiling point, and has no access to any of its own kind of ponderable matter in the liquid form.

In speaking of the boiling point of air, I mean that temperature, below which it would become liquid. We have, I think, reason to infer that all aëriform fluids would prove susceptible of liquefaction, if our power of abstracting caloric or producing cold were unlimited.

62. EXPERIMENTAL ILLUSTRATION.

Spunk ignited in consequence of the compression of air surrounding it, by means of an appropriate condenser.

OF FERMENTATION, AS A SOURCE OF HEAT.

It is well known that vegetable substances, while undergoing fermentation, acquire a great accession of heat; and that green hay is at times spontaneously ignited. The heat generated in stable litter, is employed to sustain the temperature necessary to the corrosion of the metal, in the manufacture of white lead.

OF VITALITY, AS A SOURCE OF HEAT.

The temperature of warm blooded animals, demonstrates the power of animal life to evolve caloric.

In no other respect is chemical reaction so analogous to that which takes place within the region of vitality, as in their common association with heat, both as a cause and as an effect. The old chemical law, that bodies do not act, unless fluid, to which the exceptions actually are but few, shows how much the processes of chemistry are dependent on the principle, without which, there could be no fluidity. The dependency of life on temperature, is self evident. Seeds and eggs lie dormant until excited by a due degree of heat.

ON THE MEANS OF EXCITING, OR SUPPORTING, HEAT FOR THE PURPOSES OF CHEMISTRY.

It is well known that the activity of fire is dependent on the supply of air, as well as on the quantity and quality of fuel.

As the air which comes into contact with a fire is necessarily much rarefied by the expansive power of heat, it has consequently a tendency to ascend, in a vertical current, giving place to the colder and heavier air, in the vicinity, agreeably to the principles already illustrated. See 52 and 53.

The limits of this vertical current of heated air, in the case of a smoky lamp flame, are well indicated by the fuliginous particles. It may, however, be observed, that the influx of the cold air takes place not only on a level with the flame where it must quicken the combustion: but also above the flame, where it narrows the heated column, and retards its progress. In the Argand lamp, a glass chimney defends the vertical current from lateral pressure, until it attains a sufficient height to cause an adequate current of air to act upon the flame.

In conformity with the principle thus illustrated by this elegant and useful contrivance, all air furnaces are constructed. The hot air and vapour, proceeding from the fire, being received into a flue, or the furnace being tall enough of itself to protect the ascending current, all the air which flows in to take its place, is made to pass through the fuel.

It would not be expedient to take up the time of the student, with a detailed explanation of the various furnaces used by chemists. Some of them will be introduced, in subsequent illustrations, as associated with processes, in which their utility, and the method of using them, will be evident.

63. EXPERIMENTAL ILLUSTRATION.

An Argand lamp produced and explained.

Also an Argand lamp with concentric wicks.

OF BELLOWS, AND OF FORGE FIRES.

Bellows are so universally known, as the means of exciting combustion, employed by smiths, as to render it scarcely necessary to mention the forge fire as among the most efficient and convenient methods of producing heat for the purposes of chemistry. The supply of air is, in this case, yielded by an operation analogous to that of the condenser.

In the double bellows, the additional compartment performs a part, in equalizing the efflux, equivalent to that of the air vessel in the case of the forcing pump, the valves operating in the same way.

64. LAMP WITHOUT FLAME.

About the wick of a spirit lamp, a fine wire of platinum is coiled, so as to leave a spiral interstice between the spiral formed by the wire; a few turns of which should rise above the wick.

If after lighting a lamp thus constructed, the flame be extinguished by a gentle blast, or the transient application of an extinguisher, the wire will be found to remain red hot, as it retains sufficient heat to support the combustion of the alcoholic vapour, although the temperature be inadequate to constitute, or produce inflammation.

RATIONALE.

The metallic coil appears to serve as a reservoir for the caloric, and gives to the combustion a stability, of which it would otherwise be deficient.

There is some analogy, between the operation of the wire, in acting as a reservoir of heat in this chemical process, and that of a fly wheel, as a reservoir of momentum, in equalizing the motion of machinery.

65. OF THE MOUTH BLOWPIPE.

As a fire is quickened by a blast from a bellows, so a flame may be excited by a stream of air propelled through it from the blowpipe.

The instrument known by this name, is here represented in one of its best forms. It is susceptible of various other constructions; all that is essential being a pipe of a size at one end suitable to be received into the mouth, and towards the other end, having a bend, nearly rectangular, beyond which the bore converges to a perforation, rather too small for the admission of a common pin. There is usually, however, an enlargement, as represented in this figure, to catch the condensed moisture of the breath.

The mouth blowpipe is of great service in assaying minute portions of matter, so as to form a general idea of their nature.

The celebrated Berzelius, who has written an octavo volume on the subject of this instrument, informs us that by means of it, Gahn discovered tin in a mineral, in which it had not been detected by analysis, although existing only in the proportion of one per cent.: also that he had often seen him extract a globule of metallic copper from the ashes of a quarter of a sheet of paper. The utility of the mouth blowpipe will be manifested in several illustrations required by this course of instruction.

66. AN ACCOUNT OF THE HYDROSTATIC BLOWPIPE.

The following passage is quoted from a memoir which I published in 1802:—

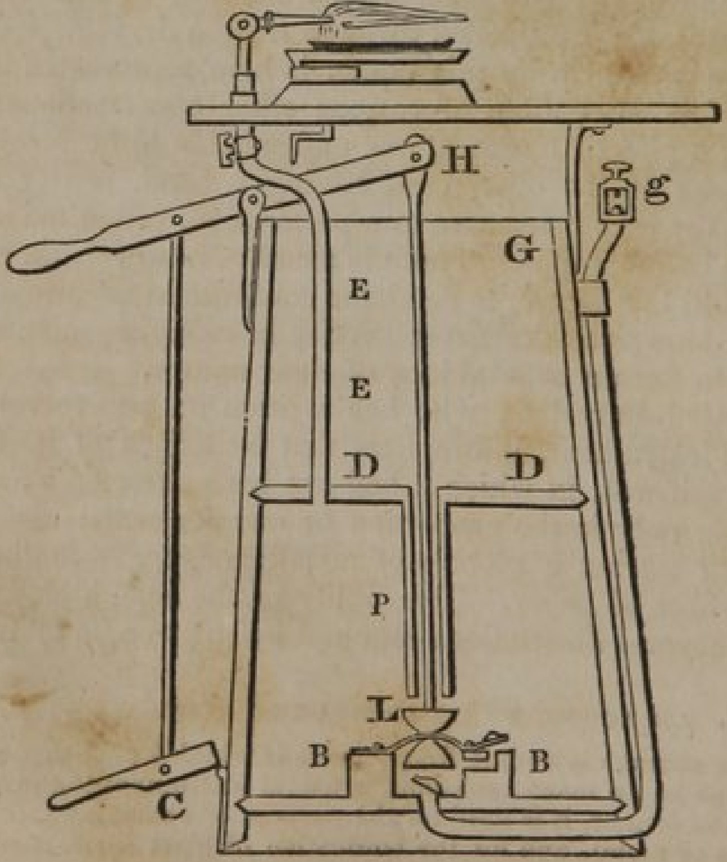
"The blowpipe is, on many occasions, a useful instrument to the artist and philosopher. By the former, it is used for the purpose of enamelling, to soften or solder small pieces of metal, and for the fabrication of glass instruments; while the latter can, by means of it, in a few minutes, subject small portions of any substance to intense heat; and is thus enabled to judge of the advantage to be gained, and the method to be pursued, in operations on a larger scale.

"To all the purposes which I have mentioned, the blowpipe is fully adequate, when properly supplied with air, and applied to a proper flame; but it appears that the means which have hitherto been employed to accomplish these ends, are more or less defective.

"The most general method, is that of supplying this instrument with the breath. In addition to the well known difficulty of keeping up a constant emission of air during respiration, and its injurious effect upon the lungs,* it may be remarked, that as the breath is loaded with moisture, and partially carbonized, it is proportionably unfit for combustion; and, the impossibility of supporting a flame with oxygen gas, by this method, is obvious.

"Another way of supplying the blowpipe with air, is that of connecting with it a small pair of double bellows. A contrivance of this kind possesses obvious advantages over the mouth blowpipe; but, owing to the pervious nature of the materials of which bellows are constructed, and the difficulty of making their valves air tight, the greater part of the air drawn into them, escapes at other places than the proper aperture. A pair of bellows, of this kind, belonging to an artist of this city, which were not considered as less air tight than usual, were found to discharge the complement of their upper compartment, in six-sevenths of the time, when the orifice of the pipe was open, which was requisite when it was closed. Hence, it appears that six-sevenths of the air ejected into the upper compartment, escaped at other places than the proper aperture; and if to this loss be added that sustained by the lower compartment, the waste would be much greater. As in operating with these machines, it is necessary constantly to move the foot, the operator cannot leave his seat; and, in nice operations, the motion of his body is an inconvenience, if not a source of failure. Bellows of this kind cannot be used for supplying combustion with oxygen gas; because, as this air is only to be obtained by a chemical process, it is very desirable to avoid any waste of it; and, as there is always a portion of air remaining in them, even when the boards are pressed as near to each other as the folding of the leather will permit, any small quantity of oxygen gas which might be drawn into them, would be contaminated.

"Being sensible of the advantage which would result from the invention of a more perfect method of supplying the blowpipe with oxygen gas or atmospheric air, I was induced to search for means of accomplishing this object. The result of my attention to the subject, is the production of a machine, of which an engraving and description follows."



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* In consequence of this, some artists have been obliged to abandon the use of the instrument.

The machine, which the preceding figure represents, does not differ essentially from that alluded to in the passage above quoted. The construction is, however, more simple and easy.

Explanation of the Figure.

The *Hydrostatic Blowpipe* consists of a cask, divided by a horizontal partition, D D, into two apartments. From the upper apartment, a pipe of about three inches in diameter, (its axis coincident with that of the cask,) descends, until within about six inches of the bottom. On the bottom is fastened, by screws, a hollow cylinder of wood, B B, externally twelve inches, internally eight inches, in diameter.* Over the cavity of the wooden cylinder thus formed, a disk of leather is fastened by nailing it to the wood, as the parchment is fastened over the cavity of a drum, excepting that the leather is left loose so as to bulge as much as possible. On one side, a small groove is made in the upper surface of the block, which, when the leather is nailed on each side of it, constitutes a lateral air tight passage. This lateral passage communicates with a hole bored vertically into the wood by a centre-bit; and a small strip of the leather, being extended so as to cover this hole, is made, with the addition of some disks of metal, to constitute a valve, opening upwards. In the bottom of the cask, there is another valve opening upwards. A piston rod, passing perpendicularly through the pipe, P, from the handle, H, is fastened near its lower end, to a hemispherical mass of lead, L. The portion of the rod beyond this, proceeds through the centre of the leather, which covers the cavity formed by the hollow cylinder; also through another mass of lead, like the first, which being forced up by a screw and nut, subjects the leather, between it and the upper leaden hemisphere, to a pressure sufficient to render the juncture air tight. From the partition, D D, an eduction pipe is carried under the table, where it is fastened, by means of a screw, to a cock which carries a blowpipe so attached by a small swivel joint, as to be adjusted into any direction which can be necessary. A suction pipe passes from the opening covered by the lower valve, under the bottom of the cask, and rises vertically, close to it, on the outside—terminating in a gallows, *g*, for the attachment of any flexible tube which may be necessary.

The apparatus being thus arranged, and the cask supplied with water, until the partition is covered, to the depth of about two inches; if the piston be lifted, the leather will be bulged up, and will remove, in some degree, the atmospheric pressure from the cavity beneath it; consequently, the air must enter through the lower valve, to restore the equilibrium. When the piston is depressed, the leather being bulged in the opposite direction, the cavity beneath it is diminished, and the air, being compressed, forces its way through the lateral valve into the lower apartment of the cask. This apartment being previously full of water, a portion of this fluid is pressed up, through the pipe, into the upper apartment. The same result ensues every time that the stroke is repeated; so that the lower apartment soon becomes replete with air, which is retained by the cock, until its discharge by the blowpipe is requisite.

The cock being opened, the air confined in the lower apartment, is expelled by the pressure of the water in the upper apartment, which, as the air which had displaced it escapes, descends and reoccupies its former situation. The piston is worked either by the handle, or the treadle, at C.

In order to supply the cask with oxygen gas, it is only necessary to attach to the suction pipe, (by means of the gallows and screw at *g*,) another pipe, duly flexible, and terminating within a bell containing the gas in question, over the pneumatic cistern: or the pipe may communicate with a leather bag, filled with oxygen. I have one which will hold fifty gallons. The seams are closed by rivets, agreeably to Pennock and Sellers' plan for mail bags, or fire-hose.

Having used the Hydrostatic Blowpipe for six-and-twenty years, I am enabled to speak in favour of its conveniency, with the confidence due to this long trial. I am persuaded, that it would be found exceedingly useful, to all artists who employ the blowpipe in soldering, or in blowing, or moulding the tubes of thermometers, barometers, and other processes, to which the enameller's lamp is applied.

OF THE ENAMELLER'S LAMP.

On the table of the hydrostatic blowpipe, a lamp is represented, which I use in blowing the bulbs of thermometers. This is a modification of the "enameller's

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* It should be stated that the leather air pump, B B, is not correctly represented as respects its dimensions, which ought to be in diameter as large nearly as the space will admit. The cavity in the block, under the leather, ought to be nine inches in width.

lamp," so called, because such lamps have been used in a certain species of enamelling.

It is essential to the enameller's lamp, that the flame be excited by a jet of air. Usually, a small double bellows is placed under the table so as to be worked by the foot, causing a jet of air to act upon the flame through a pipe terminating in a beak like that of a blowpipe.

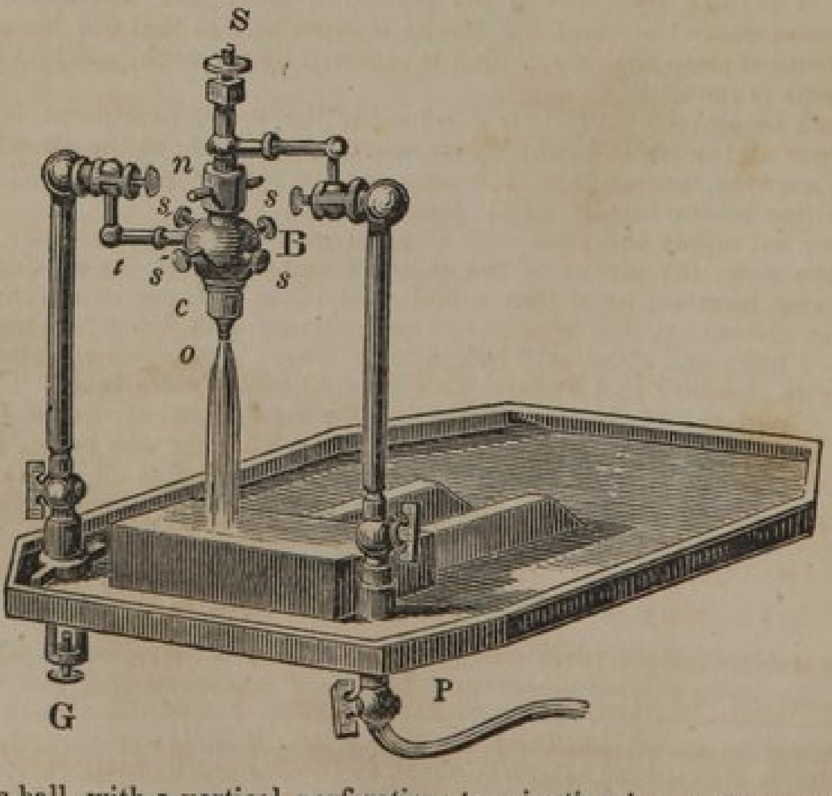
67. OF THE HYDRO-OXYGEN OR COMPOUND BLOWPIPE.

In the year 1801, by the invention of the hydro-oxygen or compound blowpipe, of which I published an account the following year, I was enabled to fuse several of the pure earths which had previously been deemed infusible; and likewise not only to fuse, but to volatilize pure platina. Subsequently, my friend, Professor Silliman, by a more extended use of the instrument, fused a great number of substances insusceptible of fusion by the common blowpipe. My Memoir was republished in London, in Tilloch's Magazine; also at Paris, in the Annales de Chimie, and was noticed by Murray in his Treatise of Chemistry, and by Dr. Hope, in his Lectures: yet, when a modification of the hydro-oxygen blowpipe was contrived by Mr. Brooke, Dr. Clarke, by means of this modification, repeated my experiments and those of Professor Silliman, without any other notice of our pretensions, than such as were calculated to convey erroneous impressions. For an exposure of the injustice of this procedure, I refer to some " Strictures on Clarke's Gas Blowpipe," which will be found in the Appendix to this Compendium.

Much has been said in some of the British newspapers, of the application in light-houses of the light reflected by lime, when subjected to the flame of the compound blowpipe. This is treated as a new invention, although in my original Memoir, published more than twenty years before, I spoke of the light so created, as intolerable to the naked eye. A similar observation will be found in the description given by my friend, Professor Silliman, of the phenomenon in question. It follows, that the English operator can only lay claim to a new application of a previous discovery.

Engraving and description of an improved Compound Blowpipe and its Appendages.

The following figure represents a compound blowpipe which I contrived, and executed myself, in the year 1813; but, fearing it might be deemed unnecessarily complex, I did not then publish an account of it. Experience has shown, that the complication of its structure does not render it more difficult to use, than the simplest instruments intended for the same purpose; while its parts are peculiarly susceptible of advantageous adjustment.



B is a brass ball, with a vertical perforation, terminating in a male screw above, and in a female screw below. Another perforation, at right angles to this, causes a communication with the tube, *t*, which enters the ball at right angles. A similar, but smaller brass ball, may be observed above, with perforations similar to those in the larger ball, and a tube, in like manner, entering it laterally. This ball terminates in a male screw below, as well as above. The thread of the lower screw is curved to the left, while that of the screw of the larger ball, which enters the same nut, *n*, is curved to the right. Hence the same motion causes the male screws to approach, or recede from each other, and thus determines the degree of compression given to a cork which is placed between them, in the nut. At S, above the ball, a small screw may be observed, with a milled head. This is connected with a small tube which passes through the cork in the nut, and reaches nearly to the external orifice, *o*, from which the flame is represented as proceeding. This tube is for the most part of brass, but at its lower end terminates in a tube of platina. It communicates by lateral apertures with the cavity of the upper ball, but is prevented, by the cork, from communicating with the cavity in the other ball. Hence it receives any gas which may be delivered into the upper ball from the lateral pipe which enters that ball, but receives none of the gas which may enter the lower ball, B.

Into the female screw of the latter, a perforated cylinder of brass, *c*, with a corresponding male screw, is fitted. The perforation in this cylinder, forms a continuation of that in the ball, but narrows below, and ends in a small hollow cylinder of platina, which forms the external orifice of the blowpipe, *o*.

The screws, *s s s s*, are to keep, in the axis of the larger ball, the tube which passes through it, from the cavity of the smaller ball. The intermediate nut, by compressing, about the tube, the cork which surrounds it, prevents any communication between the cavities in the two balls. By the screw, *s*, in the vertex, the orifice of the central tube may be adjusted to a proper distance from the external orifice.—Three different cylinders, and as many central tubes with platina orifices of different calibres, were provided, so that the flame might be varied in size, agreeably to the object in view.

I have always deemed it best to transmit the oxygen gas through the tube in the axis; since two volumes of the hydrogen, being required for one volume of oxygen, the larger tube ought to be used for the former; and the jet of hydrogen is placed between a jet of oxygen, within it, and the atmospheric air without.

Under the table, is a gallows, G, with a screw for attaching a pipe, leading from a self-regulating reservoir of hydrogen.

In order to put this apparatus into operation, it is placed over the cask of the hydrostatic blowpipe, as it appears in the figure which has been given of that apparatus. The pipe, P, is the eduction pipe, which forms a part of that figure.

Another pipe, proceeding from a reservoir of hydrogen gas, is attached, by means of the screw and gallows, G, to one of the tubes communicating with the blowpipe.

By the operation of the bellows, the cavity of the hydrostatic blowpipe may be supplied, either with oxygen gas, or atmospheric air. In either case, in order to have the instrument in full operation, it is only necessary to open the cocks, and inflame the hydrogen.

The heat produced, in this way, by the combustion of hydrogen with atmospheric air, is sufficient to fuse platina; and when oxygen gas is employed, that metal, or any other, may be volatilized. The facility with which the hydro-oxygen flame, whether excited by pure oxygen, or common air, merely, may be made to act, in any convenient direction, renders it peculiarly serviceable in many operations. Its superior cleanliness is a great recommendation.

MEANS OF PRODUCING COLD, OR OF RENDERING CALORIC LATENT.

68. COLD BY VAPORIZATION.

The cold produced by evaporation* has been illustrated by an experiment in which a jet of ether, co-operating with a blast, was productive of the congelation of water. Pure prussic acid will enable me hereafter to exhibit a phenomenon still more surprising; I mean that of the freezing of one portion of a liquid, by the vaporization of

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* See page 39.

another portion. I shall now proceed to show that the freezing of water may be caused by the ebullition of ether.

WATER FROZEN BY BOILING ETHER.

Let a portion of water, just adequate to cover the bottom, be introduced into the vessel, represented in the subjoined drawing, as suspended within a receiver. Over the water, let ether be added, in quantity sufficient to form a stratum, from an eighth to a quarter of an inch in depth. If, under these circumstances, the receiver be placed on the air-pump plate, and sufficiently exhausted; while the ether boils, the water freezes.

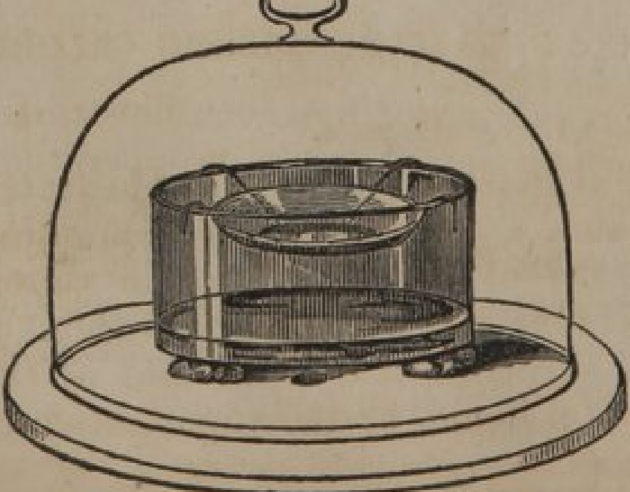
RATIONALE.

The freezing of the water in contact with the boiling ether, is in consequence of that increased capacity to combine with caloric explained already in article 36. Under these circumstances, the boiling point of the ether is depressed below the freezing point of water, and consequently it causes the congelation of that liquid from the same cause, that melted tin or lead will congeal under boiling water.

It will appear from an article in page 68, quoted from Silliman's Chemistry, that even mercury may be frozen by vaporizing ice.

69. CONGELATION OF WATER IN AN EXHAUSTED RECEIVER, BY THE AID OF SULPHURIC ACID.

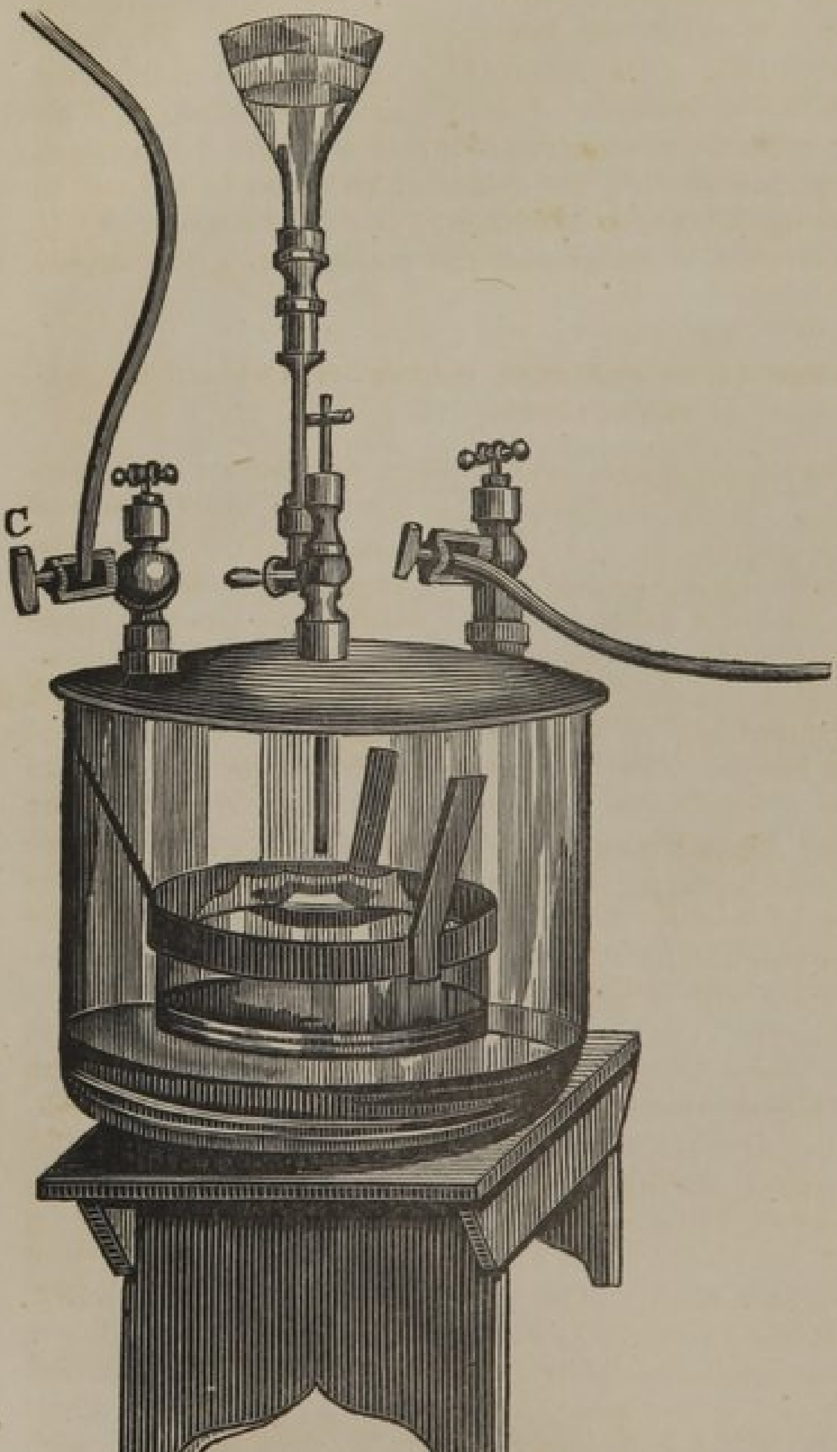
In the preceding experiment, water is frozen by the rapid abstraction of caloric, consequent to the copious vaporization of ether, when unrestrained by atmospheric pressure. In vacuo, water undergoes a vaporization, analogous to that of the ether in the preceding experiment; but the aqueous vapour evolved in this case, is so rare, that it cannot act against valves with sufficient force, to allow of its being pumped out of a receiver with the rapidity requisite to produce congelation. However, by the process which I am about to describe, water may be frozen by its own vaporization.



A thin dish, or pane of glass, covered by a small quantity of water, and situated over some concentrated sulphuric acid, in a broad vessel, is placed within a receiver, on the air-pump plate, as represented in this engraving. Under these circumstances, the exhaustion of the receiver causes the congelation of the water.

Apparatus for the Congelation of Water in Vacuo, by means of Sulphuric Acid.

(C. p. 67.)



RATIONALE.

So long as there is no diminution of the thin aqueous vapour, which in the absence of the air, occupies the cavity of the receiver, the elastic reaction of that vapour, prevents the production of more vapour; but when as in the case in point, the vapour is largely in contact with sulphuric acid and consequently rapidly absorbed, a corresponding vaporization of the water takes place to supply the deficiency thus created. The caloric requisite to the generation of the vapour thus formed is taken from the residual liquid which finally freezes in consequence. According to Wollaston, if the caloric requisite to convert one grain of water into vapour, were taken from 32 grains at 60°, the temperature would be reduced to freezing; and if from the 30 grains remaining, the caloric necessary to vaporize four grains more were abstracted, the residual 27 grains would be frozen.

70. IMPROVED APPARATUS FOR FREEZING WATER BY THE AID OF SULPHURIC ACID.

Finding the experiment, for which the apparatus represented by the preceding figure is usually employed, liable to fail from the imperfection of cocks, dependent for their efficacy on a metallic joint, I contrived the apparatus which the opposite figure is intended to represent, and which I shall proceed to describe. A brass cover is so well fitted to the rim of a large glass jar as to be quite air tight. In operating, the bottom of the jar was covered with sulphuric acid, and another jar with feet, also supplied with acid enough to make a stratum half an inch deep on the bottom, is introduced as represented. The bottom of the vessel last mentioned, is, by means of the feet, kept at such a height above the surface of the acid in the outer jar, as not to touch it. Upon the surface of the glass vessel, a small piece of very thin sheet brass is placed, made concave in the middle, so as to hold a small quantity of water. The brass cover is furnished with three valve cocks, one communicating with the air pump, another with a barometer gage, and the third with a funnel supplied with water.

With this apparatus thus arranged, having made a vacuum on a Saturday, I was enabled to freeze water situated on the brass, and to keep up the congelation till the Thursday following. As water in the state of ice evaporates probably as fast as when liquid, the whole quantity frozen would have entirely disappeared, during the night, but for the assistance of a watchman whom I engaged to supply water at intervals. At a maximum I suppose the mass of ice was at times about two inches square, and from a quarter to a half an inch thick. The gradual introduction of the water, by aid of the funnel and valve cock, also of the pipe represented in the figure, by which it was conducted to the cavity in the sheet brass, enabled me to accumulate a much larger mass than I could have procured otherwise. The brass band which embraces the inner jar near the brim, with the three straps proceeding from it, serves to keep this jar in a proper position; that is in fact concentric with the outer jar.

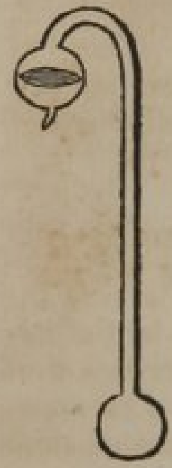
In this last mentioned experiment, I employed an air pump upon a new construction, which I have lately contrived, and of which I shall give a description.

Congelation as effected in the experiments above described may be accomplished by the aid of any substances having a very strong affinity for water, as for instance chloride of calcium, clay, or whinstone, after being rendered anhydrous by ignition; even parched meal or flour has been successfully employed in this process.

OF THE FREEZING OF MERCURY BY THE VAPORIZATION OF ICE.

If a pear shaped mass of ice containing the metal, be suspended over a large surface of sulphuric acid, and a good exhaustion obtained, it will freeze the quicksilver, which may be kept solid for several hours.

71. WOLLASTON'S CRYOPHORUS.



The adjoining figure represents the cryophorus, or frost bearer; an instrument, invented by the celebrated Wollaston, in which congelation is produced in one cavity, by rapid condensation in another.

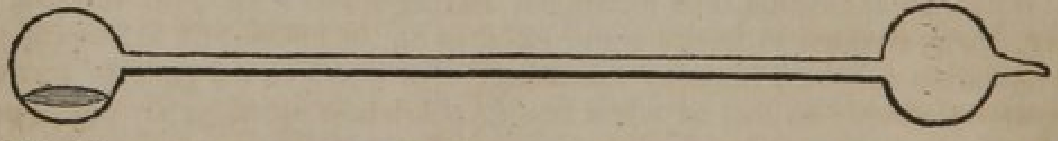
In form, this instrument obviously differs but little from the palm glass, already described (44). It is supplied by the same process, with a small portion of water, instead of alcohol; so that there is nothing included in it besides water, either liquid, or in vapour.

The cryophorus being thus made, if all the water be allowed to run into the bulb near the bent part of the tube, and the other bulb be immersed in a freezing mixture, the water will freeze in a few minutes.

RATIONALE.

There is no difference between the causes of this phenomenon and those by which the congelation of water in vacuo is effected by the aid of sulphuric acid, excepting that in the one case the aqueous vapour is absorbed by the acid, in the other condensed by the cold. In either instance it is rapidly removed, and a proportionably rapid vaporization of the water ensues, abstracting the caloric of fluidity from the residual portion.

72. LARGE CRYOPHORUS.



This figure represents a very large cryophorus, the blowing of which I superintended; and by means of which I have successfully repeated Wollaston's experiment.

This instrument is about four feet long; and its bulbs are about five inches in diameter.

CHEMICAL COMBINATION AS A CAUSE OF COLD.

Chemical union, although more frequently the cause of increased temperature, is in many instances productive of the opposite effect.

There are few instances of chemical union, which are not accompanied by a change of capacity. Of the cause of such changes, we are utterly ignorant, and of course have no more reason to wonder when, by an absorption of caloric, cold is the consequence of chemical reaction, than when, by an evolution of caloric, heat arises from the same source.

In the case of the solution of snow in concentrated sulphuric acid, already adduced, we find these opposite effects resulting apparently from the same cause. Under the same head of solution, as a cause of heat or cold, it was mentioned that nitre and nitrate of ammonia produce cold during their solution. This is equally true in the case of many other salts. But the most efficient mean of artificial cold, is the solution of ice, in consequence of the reaction between it and the more deliquescent salts, or the mineral acids.

It may be inferred, from the statements already made, that the temperature of freezing water, or melting ice, is 32°; and that when ice is surrounded by other bodies at a higher temperature, it will continue to abstract from them the caloric necessary to its fusion, until it is all liquefied. It must be evident that the minimum temperature which can be thus attained is 32°. But by mingling ice in a divided state, with certain salts or acids, having a great affinity for water, and which form with it compounds of which the freezing point is lower than 32°, the mass will abstract caloric from adjoining bodies in a mode quite analogous to that in which ice has been stated to operate: while the minimum temperature attainable is as much lower as the freezing point is lower. Thus the freezing point of salt and snow is about zero of Fahrenheit's scale; consequently on mingling salt with snow, the liquefaction of the resulting mass will proceed at any temperature above zero, abstracting caloric from all adjoining bodies until they are as cold as the mixture. By the addition of crystallized chloride of calcium, or of diluted nitric, or sulphuric, acid, to snow, a compound may be formed, of which the freezing point is below that at which mercury freezes, or 39°. Housekeepers have latterly availed themselves of the influence of salt, to remove ice from the marble steps at the entrance of their dwellings, as in this way it may be detached without injury to the marble.

TABLE OF FREEZING MIXTURES.

The following tables are taken from Thomson's Outline of the Sciences of Heat and Electricity, page 191.

Frigorific Mixtures without Ice.

Mixtures.	Parts.	Thermometer sinks.	Degree of cold produced.
Nitrate of ammonia	1	From + 50° to + 4°.	46
Water	1		
Nitrate of ammonia	1	From + 50° to — 7°.	57
Carbonate of soda	1		
Water	1		
Phosphate of soda	9	From + 50° to — 12°.	62
Diluted nitric acid	4		
Phosphate of soda	9	From + 50° to — 21°.	71
Nitrate of ammonia	6		
Diluted nitric acid	4		
Sulphate of soda	8	From + 50° to 0°.	50
Muriatic acid	5		
Sulphate of soda	5	From + 50° to + 3°.	47
Diluted sulphuric acid	4		

Frigorific Mixtures with Ice.

Mixtures.	Parts.	Thermometer sinks.	Degree of cold produced.
Snow, or pounded ice	2	From any tem. to — 5°.	*
Muriate of soda	1		
Snow, or pounded ice	12	From any tem. to — 25°.	*
Muriate of soda	5		
Nitrate of ammonia	5		
Snow	3	From + 32° to — 23°.	55
Diluted sulphuric acid	2		
Snow	8	From + 32° to — 27°.	59
Muriatic acid	5		
Snow	7	From + 32° to — 30°.	62
Diluted nitric acid	4		
Snow	4	From + 32° to — 40°.	72
Muriate of lime	5		
Snow	2	From + 32° to — 50°.	82
Cryst. muriate of lime	3		
Snow	1	From 0° to — 66°.	66
Cryst. muriate of lime	2		
Snow	1	From — 40° to — 73°.	33
Cryst. muriate of lime	3		
Snow	8	From — 68° to — 91°.	23
Diluted sulphuric acid	10		

OF THE THREE STATES IN WHICH CALORIC EXISTS IN NATURE.

With two of the modes, in which caloric exists in nature, the student of this Compendium, has been made acquainted; and these are the only modes of its existence, generally recognised. As it exists in one of them, it is called sensible heat, being susceptible of detection by the senses, or by the thermometer. In the other it is called latent heat, because the quantity present, in that mode of existence, is not open to those means of detection. But even in this latent state, caloric is known to be influenced by temperature; being liable to be removed entirely from vapours, or liquids, by communication with colder substances; so as to render its subsequent presence, in these, a proof of its previous existence in the matter, from which it may have been abstracted.

It seems to me, however, that, in some substances, caloric evidently exists, in a state, in which it is wholly independent of external changes of temperature. In this predicament, I suppose it to reside in the nitrates, chlorates, and fulminates; and generally in all detonating compounds.

If, agreeably to the received chemical doctrines, we are to ascribe the explosive power of such compounds, to combined caloric, it must be evident that its condensation in them is wonderfully great. Yet no good reason can be assigned for this prodigious condensation. It cannot be ascribed simply to the attraction of ponderable matter; since the same ponderable matter which confines it at one moment, liberates it in the next, without any adequate assignable cause.

Thus the presence of platina-sponge, a cold metallic congeries, causes the caloric of a gaseous mixture of hydrogen and oxygen to escape explosively. An electric spark, or the contact of any ignited matter, produces the same result. The case of gunpowder, exploded by the ignition of the most minute portion of the mass, is equally unaccountable, and likewise the explosive recomposition of water by a discharge from the same galvanic wires, by which its decomposition may have been effected.

The almost irresistible extrication of oxygen in the gaseous state from oxygenated water, by contact with the oxide of silver, is still more in point, and even more surprising.

The fixation of caloric in detonating compounds, I, therefore, consider as a peculiar state, and due to some peculiar cause, the discovery of which, would probably unfold many mysteries, in galvanism, and electro-magnetism, as well as in chemistry. I deem it more than probable that electricity is a principal agent in these mysterious phenomena.

ON LIGHT, OR THE MEDIUM OF VISION.

It must necessarily belong to chemistry, to treat of light, so far as it is productive of heat, deoxydizement, or other chemical effects, and so far as it is evolved by chemical processes.

According to Newton, light is a subtile fluid, which is either radiated, or reflected, from every visible point in the universe, in consequence of its elasticity, or the self-repellent power of its particles.

It comes from the sun, about ninety-five millions of miles, in eight minutes, or nearly at the rate of two hundred thousand miles in a second.

Light appears to have no sensible weight. The products of the combustion of phosphorus, carbon, and other combustibles, appear fully equal in weight to the ponderable matter employed. It follows that the loss of the light, and the heat, occasions no diminution of weight; yet enough is emitted by the flame of a candle, or lamp, to be perceived by many hundred millions of eyes. There is not a luminous point, in the universe, from which a sphere of rays is not emitted, in radius, equal to any distance, from which that point may be seen.

OF THE SOURCES OF LIGHT.

As a source of light, the sun is obviously even more prolific, than as a source of heat; and it must be evident, that all the processes which produce ignition, must also produce light.

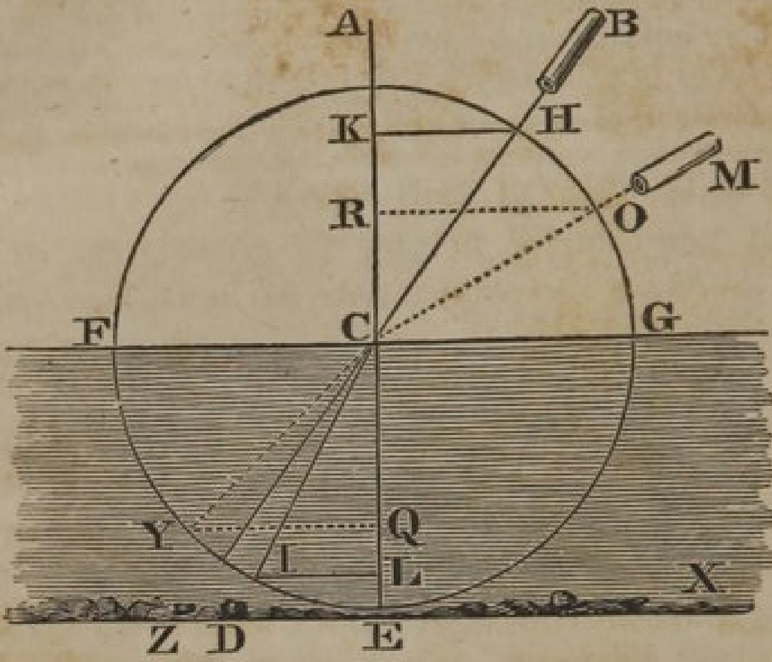
There are some cases in which light is emitted without heat. As it comes to us from the moon, as emitted by luminous insects, decayed wood, or the phosphorescent wave, it appears to be unaccompanied by caloric.

In the fire-fly, and in many other insects, it is evolved by vital action.

73. REFRACTION OF LIGHT.

When a ray of light passes obliquely, from a rarer into a denser medium, it is bent *towards* the perpendicular direction. When the course of the oblique ray is from the denser medium, into one which is rarer, it is bent *from* the perpendicular direction.

Fig. 1.



Suppose F G X Z to be a body of water. If a pencil of the solar rays fall upon the surface of the water perpendicularly at C, it will penetrate the water without deviating from its previous course; for whatever may be the attraction between the light and the water, it cannot cause any deflection, since it must act equally on either side of each ray. But should a pencil of rays, passing through the tube, B, and penetrating the water at C, reach the bottom, it would shine on the pebble, D; whereas, it would shine upon Z, were the water removed. The light in this case passing from a rarer into a denser medium, and entering the latter obliquely, the rays are attracted by the denser medium most on the side nearest to it, and consequently are bent, or refracted, from their previous course.

About C, as a centre, describe the circle, F H E, and from A draw a diameter, A C E, perpendicular to the surface of the water. Let the lines B C, C I, represent the path of the light in passing from the tube to the bottom of the water. Where these lines intersect the circle, draw K H, I L, parallel to the surface of the water. The angle A C H, which the incident ray makes with the perpendicular, is called the angle of incidence, and K H the sine of this angle. I C E is called the angle of refraction, and I L its sine. In the case of water, the sine I L is always found to be to the sine K H, as 3 to 4; but were a mass of glass substituted for the water, the sine of the angle of refraction to that of incidence would be as 2 to 3, and if the glass were replaced by a similar mass of diamond, the ratio would be nearly as 2 to 5: the ratio being always invariable, in the same medium, whatever the angle of incidence may be; for if the pencil of rays were to proceed to C, from a tube at M, making the angle of incidence, A C M, and the angle of refraction, Y C E, the sine, Y Q, would be to the sine, R O, in the same ratio as I L to K H; and this would hold good as before stated, whether F G X Z were water, diamond, crystal, or any other homogeneous and transparent refracting medium. The refraction, which has been thus described as taking place during the passage of rays from air into other denser media, equally ensues when light passes out of such media into the air. Nor is it in air alone that it takes place; it is enough that the substances through which it passes be of different densities, or chemically different in their natures. Combustible liquids, or solids, have been found to refract most powerfully. It was his discovery of this association between combustibility and refracting power, that led Sir Isaac Newton truly to infer the combustible nature of diamond, from its superior efficacy in causing refraction.

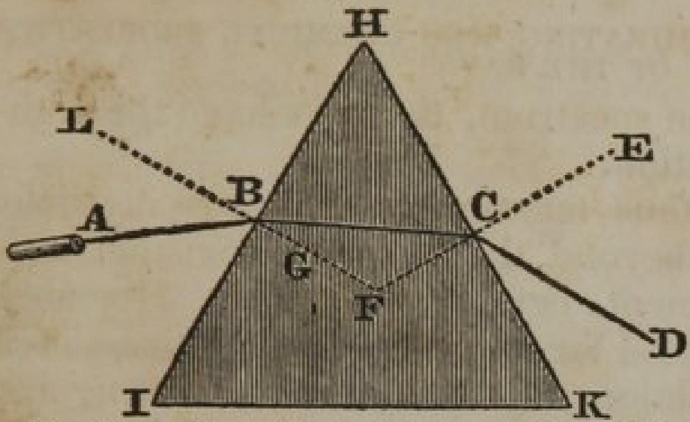
As an illustration of the case of light refracted, in passing out of denser matter into rarer, let us imagine the eye of an observer placed at the upper orifice of the tube, B, in the figure. Instead of the pebble, Z, which he would see, if the water were removed, the pebble, D, will be seen by him. Hence the well known power of water in rendering an object visible, when, in the absence of a liquid, our view would be intercepted by the side of the containing vessel, and likewise the broken image which a stick, or a cord, presents to us, when seen partially under water.

DIFFERENCE BETWEEN THE REFRACTING INFLUENCE OF A TRIANGULAR PRISM AND OF A PLATE, OR PANE, OF GLASS.

In passing through a plate of glass whose surfaces are parallel, the refraction which light sustains from one surface, is compensated by an opposite refraction by the other surface; but during its passage through a prism, as represented in the following diagram, it is subjected to a concurrent refraction from two surfaces.

Supposing that the refracting medium, F G X Z, (fig. 1) were bounded by air below, as well as above, and its upper and lower surfaces parallel, as in the case of a plate or pane of glass, in passing obliquely through it, a ray of light will be *equally* attracted on *one side*, as it *enters*; on the *other side*, as it *emerges*.—Hence after its emergence, it will proceed parallel to its original direction.

Fig. 2

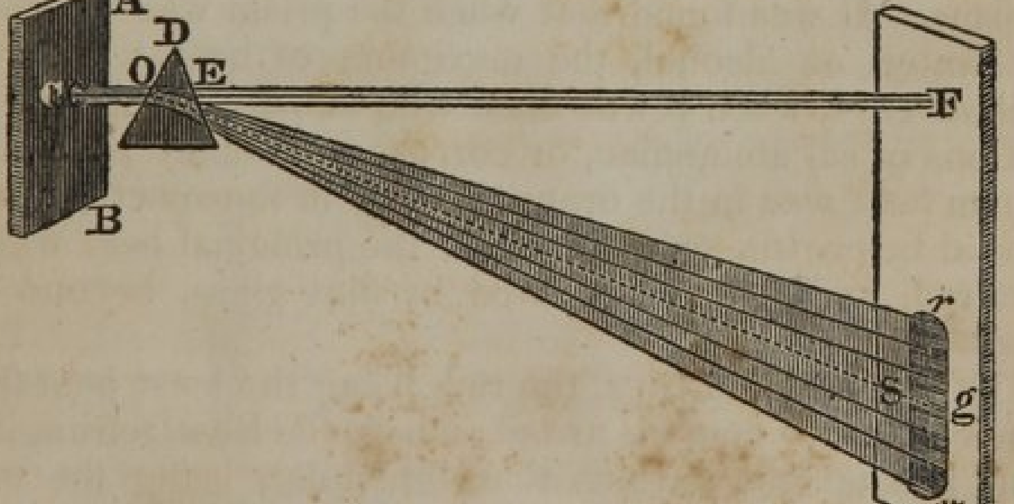


But should a ray fall upon a prism, as represented in Fig. 2, in the direction of the line, A B; agreeably to the preceding demonstration, it will, on account of the obliquity of its approach, be refracted towards C, and emerging thence, obliquely to another surface of the prism, H C K, it will be again most attracted by that portion of the surface towards which it inclines. Consequently, it will be refracted so as to proceed in the direction C D.

Thus it must be evident, that two surfaces of the prism have a concurrent influence, in bending the rays from their previous course, while in the pane, the influence of one surface is neutralized by that of the other.

The lines, L F, and E F, being perpendiculars to the surfaces of the prism, A B L, is the angle of incidence, and G B C, the angle of refraction, to the surface at which the rays enter the prism. F C B, is the angle of incidence, and E C D, the angle of refraction to the surface, from which the rays emerge.

74. DISPERSION OF LIGHT.



Besides the refraction sustained by a pencil of rays, agreeably to the preceding illustration, they undergo another alteration, the effects of which are very pleasing, and agreeably to the doctrine of Newton, highly instructive, being the foundation of his theory of colours.

Light appears to consist of particles of different kinds; each kind having the property of producing on the retina of the eye a peculiar impression, which being conveyed to the sensorium creates the idea of a colour. The rays thus capable of acting differently on the retina, seem to be unequally susceptible of refraction. Hence in passing through the prism they are separated from each other, forming a beautiful series of all the various colours of the rainbow, in an oblong figure which is called a spectrum. Under these circumstances, the rays are said to be dispersed, and the process by which they are separated, is called dispersion.

Let A B, represent a part of a window shutter of a room, into which light enters only through the hole C. If the light thus entering be received on a screen, a circular spot on it will be made luminous. But if a glass prism, D O E, be placed before the hole, so that the light may duly fall upon the prism, the rays, which had before produced the luminous circle, will be refracted and dispersed, so as to form the spectrum, *r g v*, consisting of the following colours, arranged in the following order—red, orange, yellow, green, blue, indigo, violet.

The red rays are found to be pre-eminent in heating power; the violet as remarkable for their superior influence, in certain chemical changes, dependent on deoxidation.

OF THE HEATING, ILLUMINATING, AND CHEMICAL PROPERTIES OF THE RAYS.

In the middle of the spectrum, the rays have the highest power of illumination.

Besides the rays thus mentioned, there are invisible, heat producing rays beyond the red, and invisible rays producing deoxydizement, beyond the violet. Herschel, to whom we are indebted for the discovery of these invisible rays, was of opinion, that the greatest heating and deoxydizing power, existed in them just beyond the limits of the visible spectrum.

From experiments made by Seebeck, and Mellone, it appears that the location of the principal heating power, is dependent on the nature of the refracting medium. A variety of transparent liquid media have been employed, by causing them to occupy the cavities of hollow glass prisms. It was found that when the prism was occupied by water, or alcohol, the maximum of heat was in the yellow rays, when it was filled with sulphuric acid, or solutions of sal ammoniac, or corrosive sublimate, the maximum heat was in the orange; while in the spectrum produced by crown, or plate glass, the principal heat was in the red, and in that procured by flint glass, beyond the red.

Of the coloured rays, the red, being the least bent from their previous course, are obviously the least refrangible; and it is no less obvious that the violet, being the most bent, are the most refrangible; also that those rays, which are found equidistant from the red, and violet, have a mean refrangibility.

An opinion has been entertained by some philosophers that there are only three original and distinct species of light, which seems lately to be sanctioned by one of the most celebrated opticians of modern times. I allude to Sir David Brewster, whose opinions I shall give, by quoting them in his own language, from his Treatise upon Optics, page 68, American edition.

> "With the view of obtaining a complete analysis of the spectrum, I have examined the spectra produced by various bodies, and the changes which they undergo by absorption when viewed through various coloured media, and I find that the colour of every part of the spectrum may be changed not only in intensity, but in colour, by the action of particular media; and from these observations, which it would be out of place here to detail, I conclude that the solar spectrum consists of three spectra of equal lengths, viz. a *red* spectrum, a *yellow* spectrum, and a *blue* spectrum. The *primary red* spectrum has its maximum of intensity about the middle of the *red* space in the solar spectrum, the *primary yellow* spectrum has its maximum in the middle of the *yellow* space, and the *primary blue* spectrum has its maximum between the *blue* and the *indigo* space. The two minima of each of the three primary spectra coincide at the two extremities of the solar spectrum.
>
> "From this view of the constitution of the solar spectrum we may draw the following conclusions:—
>
> "1. *Red*, *yellow*, and *blue* light exist at every point of the solar spectrum.
>
> "2. As a certain portion of *red*, *yellow*, and *blue* constitute *white* light, the colour of every point of the spectrum may be considered as consisting of the predominating colour at any point mixed with white light. In the red space there is more red than is necessary to make white light with the small portions of yellow and blue which exist there; in the yellow space there is more yellow than is necessary to make white light with the red and blue; and in the part of the blue space which appears violet there is more red than yellow, and hence the excess of red forms a violet with the blue.
>
> "3. By absorbing the excess of any colour at any point of the spectrum above what is necessary to form white light, we may actually cause white light to appear at that point, and this white light will possess the remarkable property of remaining white after any number of refractions, and of being decomposable only by absorption. Such a white light I have succeeded in developing in different parts of the spectrum. These views harmonize in a remarkable manner with the hypothesis of three colours, which has been adopted by many philosophers, and which others had rejected from its incompatibility with the phenomena of the spectrum."

75. A TRIANGULAR GLASS PRISM, CONVENIENTLY MOUNTED ON A UNIVERSAL JOINT.

This figure represents a triangular glass prism, mounted upon a universal joint, supported by a brass stand, so as to be well qualified for the dispersion of light, agreeably to the experiments alluded to in the preceding article.

A, the glass prism, supported at each end by a pivot.

B B, Handles by means of which the pivots are turned, so as to make the prism revolve.

C, C, Ball and socket, forming a joint, upon which the plate, D D, may be moved, so as to assume any serviceable position.

OF CERTAIN CHEMICAL EFFECTS OF LIGHT.

I have already adverted to the calorific influence of light, and to its power of producing chemical changes.

Among these, the bleaching power of the solar rays is familiar to every body. In this process the rays appear to exercise that modifying influence on the attraction of ponderable matter alluded to in page 3. Consequently a new arrangement of particles ensues in lieu of that which formed the colouring matter. Certain vegetable leaves, if exposed to the sun in water, have been found to yield oxygen gas. Some metallic salts, especially nitrate of silver, are blackened by a like exposure, owing, as is alleged, to deoxydizement. A mixture of hydrogen and chlorine will, in the dark, remain for a long time, without combining; but in the rays of the sun, will explode.

According to Berzelius, the power of producing this result exists only in the violet rays.

POLARIZATION OF LIGHT.

This name has been given to a property of light, which causes it often to be divided into two portions, one of which is transmitted, the other reflected, by the same pane of glass: or one portion sustains refraction in an ordinary degree, the other in an extraordinary degree. Again, all these properties are found to be commutable, so that the portion of the rays which is reflected in one case, may be transmitted in another; or that which in one case sustains the ordinary refraction, in another may undergo the extraordinary refraction, and vice versa.

These phenomena are ascribed to the different positions, assumed by different sets of rays; by which certain poles, which the particles are supposed to possess, are variously directed at different times, so as to determine their reflection, or transmission, or the degree of their refraction.

OF ATTRACTION BETWEEN INORGANIC PARTICLES, OR CHEMICAL ATTRACTION.

The word chemical has been used to designate the attraction, which takes place between heterogeneous particles only. I object to this restriction of its meaning, because I consider it as affording a natural line of separation, between chemical and mechanical philosophy, to consider the one as treating of masses, or masses and particles, the other of particles only. Besides the process of crystallization, respecting which I shall in the next place treat, arises from the reaction of homogeneous atoms, and it was among chemists that the investigation or observation of the laws and phenomena of crystallization originated. I consider crystallography as a branch of chemistry, and the attraction which causes homogeneous atoms to cohere, whether in the crystalline form or otherwise, is a species of chemical attraction.

The attraction which takes place between homogeneous particles, is designated as attraction of aggregation, attraction of cohesion, or as homogeneous affinity. The attraction which arises between heterogeneous particles, is called chemical affinity, or heterogeneous affinity.

OF ATTRACTION OF AGGREGATION, OR COHESION: ALSO CALLED HOMOGENEOUS AFFINITY.

Of this kind is the force which enables bodies to resist mechanical division. Overcoming it, does not alter the *chemical* nature of a substance. It is the cause of crystallization.

OF CRYSTALLIZATION.

Almost all matter, in passing from the fluid to the solid state, assumes regular forms, called crystals.

As it is difficult to conceive that homogeneous atoms are not exactly similar in size and shape, it is not wonderful that when united by the same attractive force, they should produce regular forms. To produce irregular forms, the atoms, or forces actuating them, should be irregular. In fact, as the deposition of matter from solution, or the evaporation of the solvent, is accelerated or retarded, a corresponding change ensues in the crystalline forms. In this way various deviations arise from that primary form, which is assumed under circumstances which allow the deposition to proceed at the same rate precisely. Those forms which deviate from the primary form are called secondary. The various steps by which they are generated from the primative forms, have been most ingeniously traced, or inferred, by Hauy and others. In some instances, the primitive form has been developed by mechanical cleavage.

It was at one time a general impression that every chemical compound had an appropriate crystalline form. Latterly it has been shown, that certain substances quite different in their nature, as, for instance, phosphoric and arsenic acids, assume the same forms in crystallizing; and are, in consequence, called *isomorphous*.

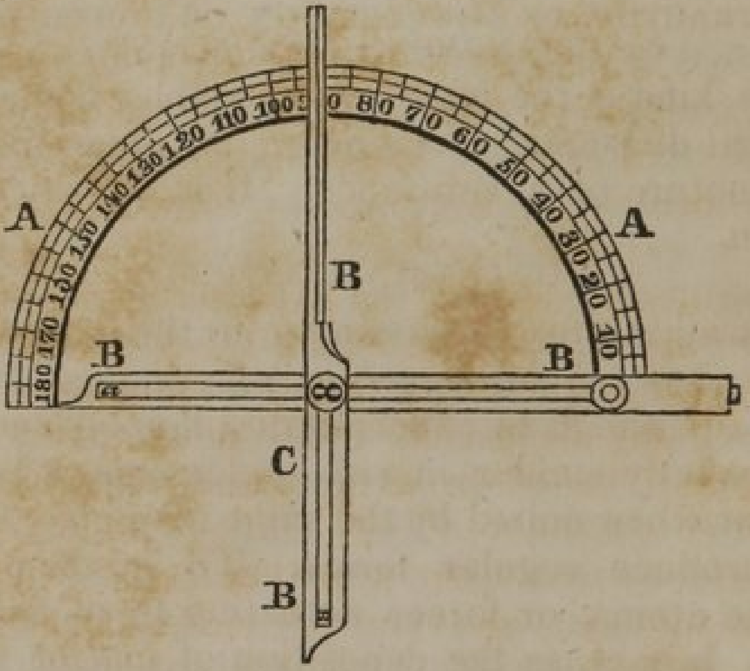
In the introduction to Thomson's Inorganic Chemistry, several groups of isomorphous substances are mentioned.

OF THE GONIOMETER, OR INSTRUMENT FOR MEASURING THE ANGLES OF CRYSTALS.

Crystals may appear to be exactly similar to the eye, which when compared by means of accurate instruments, called goniometers, contrived for that purpose, will be found to differ in their angles. Of these instruments, there are two constructions; one, being more easy to be used, is of more general utility; the other, contrived by Wollaston, is complicated, but when skilfully employed, is capable of giving more accurate results.

The instrument of the easiest application, and which is usually employed, is represented by the following engraving.

OF THE COMMON GONIOMETER.



Its construction is founded upon the 15th proposition of Euclid, which demonstrates that the opposite angles, made by any two lines in crossing each other, are equal. Hence it follows that the angles made by the legs, B B, B C B, of this instrument, above and below the pivot on which they revolve, are equal to each other. Consequently, if they be made to close upon any solid crystalline angle, presented to them at C, they will comprise a similar angle on the other side of the centre about which they turn. This angle is evidently equivalent to that of the crystal, and is ascertained by inspecting the semicircle, A, graduated into 180 degrees precisely in the same manner as a protractor.

The construction of goniometers is usually such as to allow the legs to be detached from the arch, in order to facilitate their application to crystalline angles; and yet, so that they may be reapplied to the semicircle, without deranging them from the angle to which they may have been adjusted.

The piece of brass, in which the pivot is fastened, slides, in a slit in each leg, so as to permit them to be made of a suitable length, on the side on which the crystal is applied.

OF WOLLASTON'S GONIOMETER.

The process by which angles are ascertained by means of Wollaston's goniometer, is as follows:—

The crystal to be examined, is attached to an axis, and so adjusted by means of suitable mechanism, that the image of a window bar may be seen reflected from one of the crystalline faces, so as to coincide with a line (seen directly) drawn on the wall under the window parallel to the window bar. By a partial revolution of the axis, and consequently of the crystal, a similar coincidence of the images of the bar and line is produced by means of another face of the crystal, being the next to that first employed.

Meanwhile the number of degrees of a circle moved through, in changing the crystal from the first to the second position, is measured by an index on a graduated arch, and the degrees of the angle, which the surfaces make with each other, thus ascertained.

SUBJECT OF CRYSTALLIZATION CONTINUED.

Other things being equal, crystals are larger in proportion as their growth is slower. They shoot from extraneous bodies, as the sides of the receptacle, or from strings, or sticks, in preference to crystallizing in an isolated manner. Agitation hastens their production, but confuses them. The crystalline texture of some of the trap rocks, is attributed to slow cooling. The same matter fused, and allowed less time to cool, forms a glass.

Berzelius alleges that if two flasks, both containing a saturated solution of two parts of nitrate of potash, and one of sulphate of soda, be surrounded with ice or cold water, on introducing a crystal of nitrate of potash into one, and a crystal of sulphate of soda into the other, crystals will be formed of the same nature as that of the crystal introduced into each flask. Nitrate of potash will be found crystallized in the flask first mentioned, and sulphate of soda as exclusively in the other.

Crystals are found in nature, and are produced artificially.

The precious stones are native crystals. Carbonate of lime, common salt, gypsum, are native products, often crystalline in form.

THE VARIOUS MEANS OF CAUSING ARTIFICIAL CRYSTALLIZATION.

CRYSTALS ARE PRODUCED BY

Fusion, followed by congelation.—Instances: Crystallized sulphur, bismuth, antimony, zinc.

Solution, followed by evaporation in open vessels.—Exemplified by salts, acids, alkalies, sugar.

Solution with heat, followed by refrigeration.

Most of the substances, which crystallize by evaporation, yield crystals in this way.

Solution, followed by vaporization at the boiling heat.

Crystals may be thus obtained from many salts; but are always minute.

Solution, followed by saturation.—Instances: Potash saturated by carbonic acid, or chlorine.

Sublimation.—This comprises the idea of vaporization and condensation into a state of solidity. Instances: Corrosive sublimate, calomel, iodine, arsenic.

Solution, followed by precipitation, as in the case of the arbor Dianæ, and the arbor Saturni.

76. CRYSTALLINE SPECIMENS EXHIBITED.

A wooden arch, about fifteen inches high, and a foot wide, encrusted with fine blue crystals of the sulphate of copper.

Crystals of corrosive sublimate, and of calomel.

Crystals of sulphur, arsenic, bismuth, antimony, and various other specimens.

OF DECRYSTALLIZATION.

Latterly it has been ascertained by Mr. Daniell, that crystals may be partially developed by solution. When alum is slowly dissolved, its crystalline structure becomes very evident.

OF WATER OF CRYSTALLIZATION.

The well known spiculæ, which, by their appearance on the surface of the water, indicate incipient freezing, are crystals. In fact, it was from the Greek name for ice, κρυσταλλος, that the word crystal was adopted; as crystals were correctly considered as the products of a process analogous to freezing. This is strictly true in the case of crystals resulting from the congelation of matter, from a state of fusion. Water enters into the constitution of many crystals which, when robbed of it by heat or desiccation, lose the crystalline form. The water thus situated, is called water of crystallization. Berzelius alleges, that some substances combine with water in different proportions, consequently assuming different forms; others crystallize either with, or without water; with a corresponding diversity of form. These results are dependent upon variations of temperature in the solvent at the period of the crystallization. At 86° F., sulphate of soda crystallizes without, at 40° F., with water of crystallization. Chloride of sodium, which is ordinarily anhydrous, is made to unite with water of crystallization at 8° below zero, F.

Crystals contain usually more or less of their mother water. Hence the decrepitation of chloride of sodium, and other anhydrous salts, when heated from the vaporization of the water so held in their crevices. The larger the crystals, the more are they subject to this impurity.

OF THE CONSEQUENCES OF EXCLUDING THE AIR FROM A SATURATED SOLUTION OF SULPHATE OF SODA, WHILE BOILING.

Several matrasses are sealed, so as to be air-tight, while containing a *boiling saturated solution of Glauber's salt*. The solution remains liquid, so long as undisturbed; but on the admission of the air, will often become a compact crystalline mass, within a few seconds. In other cases, it will continue liquid for some time, even for 24 hours, and may then crystallize on being poured out of the matrass. Sometimes it crystallizes in the neck of the vessel while the operator is pouring it out; at others, allowing a crystal, or other body, to fall into the solution, causes crystals to shoot. No satisfactory explanation has been afforded of this phenomenon. It seems as if the repulsive and attractive powers were so nearly balanced as to enable a slight external force to determine the preponderancy in favour of the latter. That there is an evolution of caloric, consequent to the congelation, is rendered evident by a rise of temperature.

77. EXPERIMENTAL ILLUSTRATION.

A solution of sulphate of soda, saturated at a boiling heat, and sealed up air-tight in a glass flask, remains liquid until it is opened, and then crystallizes either spontaneously, or from slight causes.

CONCLUDING REMARKS RESPECTING CRYSTALLIZATION.

The details of crystallography, as they have been presented by Hauy and others, are of themselves so copious, as to require greater exertion of the memory than all of the chemistry which I would expect a candidate for graduation to learn. It is one of those subjects of which the acquisition may be advantageously postponed, until much other knowledge has been acquired. Consequently as this preliminary knowledge is more than sufficient to occupy all the time which is allotted to my course of lectures, I have concluded to consign to the Appendix some pages respecting crystallization, which in the last edition of the Compendium, were introduced into the body of the work.

OF THE ATTRACTION, WHICH OPERATES BETWEEN HETEROGENEOUS PARTICLES, CALLED AFFINITY, OR HETEROGENEOUS AFFINITY.

This attraction is never subdued mechanically, unless when nearly balanced by repulsion; as in the case of compounds, which may be exploded by percussion, or elastic fluids combined with liquids. See article 47, page 41.

To sever elements, united by chemical affinity, the finest edge producible by human art, were utterly incompetent. Thus, chalk consists of lime and carbonic acid; vermillion, of sulphur and mercury. Yet when reduced into powders perfectly impalpable, the minutest particle, whether chalk or vermillion, contains the same ingredients as the mass, and in the same proportion.

78. DIFFERENT CASES OF AFFINITY.

1ST CASE—SIMPLE COMBINATION.

A and B, two heterogeneous substances, unite and form the compound A B.

INSTANCES.

Copper with zinc, forms brass.
„ with tin, „ bronze.
Antimony with lead, forms type metal.
Magnesia with sulphuric acid, forms Epsom salt, or sulphate of magnesia.
Soda with sulphuric acid, forms Glauber's salt, or sulphate of soda.
With mercury, various metals form amalgams.

79. EXPERIMENTAL ILLUSTRATION.

A portion of gold leaf being triturated with mercury, disappears, forming a chemical compound with the mercury, in consequence of the inherent attraction or affinity between the heterogeneous particles.

2D CASE OF AFFINITY.

Called simple elective attraction, or affinity.

A and B, two heterogeneous particles, being united in the compound AB,—C, another particle, being blended with them in solution, unites with one of them, as A, to the exclusion of B.

In this case, C is said to decompose AB, and to have a greater affinity for A than for B.

80. EXPERIMENTAL ILLUSTRATION.

OF SIMPLE ELECTIVE AFFINITY.

Potash being added to a solution of sulphate of magnesia, the magnesia precipitates in white flocks. A like result takes place on adding a solution of potash to a solution of sulphate of alumine.

RATIONALE.

Sulphate of magnesia consists, as its name implies, of sulphuric acid and magnesia. The affinity existing between the potash and the acid, being greater than between the acids and the magnesia; the latter is displaced from combination, and being by itself insoluble, precipitates. An analogous explanation will apply in the case of the alumine. In either case, the affinity of the acid for the alkali, predominates over that of the acid for the earth.

3D CASE OF AFFINITY.

Called double elective attraction, or complex affinity.

The compound formed by the particles A and B, being blended in solution with the compound formed by C and D,—A combines with D, and B with C.

81. EXPERIMENTAL ILLUSTRATION.

$$\begin{array}{c}\text{A} \qquad\qquad \text{B}\\ \left.\begin{array}{l}\text{Sulphate of Zinc}\\ \text{being mixed with}\\ \text{Acetate of Lead,}\end{array}\right\}\\ \text{C} \qquad\qquad \text{D}\end{array} \text{forms} \begin{array}{c}\text{A} \qquad\qquad \text{D}\\ \left\{\begin{array}{c}\text{Sulphate of Lead.}\\ \text{and}\\ \text{Acetate of Zinc.}\end{array}\right.\\ \text{C} \qquad\qquad \text{B}\end{array}$$

4TH CASE OF AFFINITY.

A and B, being in union, C added in *excess*, combines with both A and B.

When ammonia is added to certain solutions of metallic salts, those of copper or silver for instance, it operates at first as the potash does in the case of simple elective affinity abovementioned, and the oxide of copper or silver, precipitates. But if the ammonia be added in such quantity, as that after all the acid shall have been saturated there shall be an excess of alkali, this excess will combine with the precipitated metallic oxide, forming with it a soluble compound which dissolves. Hence the menstruum which is at first rendered turbid, afterwards becomes clear, and in the case of the copper, assumes a beautiful and distinguishing blue colour.

82. EXPERIMENTAL ILLUSTRATION.

Liquid ammonia being poured into a solution of copper, at first precipitates the metal in green flocks; but when the alkali is added in excess, these flocks disappear, and a beautiful blue solution results.

83. ADDITIONAL ILLUSTRATIONS OF ELECTIVE AFFINITY.

In order to show the wonderful power of chemical reagents in producing striking changes, some additional exemplifications of chemical affinity, will here be given. This exhibition may excite curiosity in the learner, and afford gratification, although unprepared to understand the intricate play of affinities, by which the results are accomplished.

EXPERIMENTS.

Silver precipitated by mercury, mercury by copper, copper by iron.

Conversion of two liquids into an adhesive mass by mingling sulphuric acid with a solution of muriate or nitrate of lime.

Solution of ferroprussiate of potash, added to solutions of copper and iron.

Solution of bichromate of potash, added to solution of lead, mercury, and silver.

Ammoniacal nitrate of copper, or silver, added to arsenious acid.

ON COHESION AS AN OPPONENT TO CHEMICAL COMBINATION.

There are many substances, among others, carbon, which, under certain forms, in consequence of greater hardness, are much less susceptible of chemical reaction, than under others. Thus the diamond, anthracite, charcoal, and tinder, are varieties of carbon, which are endowed with a susceptibility of combustion inversely as their hardness. Tinder is proverbially ready to take fire, while the diamond is only to be ignited by the aid of extreme heat, and an unusual supply of oxygen. Magnesia and lime, after exposure to the flame of the compound blowpipe, become almost insusceptible of the action of acids, which otherwise would readily combine with them. In these cases, it would really appear that the attraction between the homogeneous atoms counteracts the heterogeneous affinity which would sever them. Yet I conceive it to be an error to confound the obstruction to chemical reaction thus created, with that which arises from the restriction of the surface in contact with the solvent. Other things being equal, there will evidently be more action in proportion as the points of contiguity are multiplied, and vice versa. Thus the action of an acid will be less rapid upon a metallic ball, than upon the same weight of metal in the state of foil, fine wire, or turnings, although the attraction of the homogeneous particles is quite as energetic in the one case, as in the other.

84. EFFECTS OF MECHANICAL DIVISION EXPERIMENTALLY ILLUSTRATED.

If a ball of brass be put into one glass, and only half its weight of brass filings, or turnings, into another, on adding nitric acid to both, a violent effervescence will ensue in the one, while in the other, the reaction will hardly be discernible.

85. INFLUENCE OF SOLUTION IN PROMOTING CHEMICAL REACTION, EXPERIMENTALLY ILLUSTRATED.

Tartaric acid, and a carbonate, although intimately intermingled in a pulverulent state, do not react until moistened; when a lively effervescence ensues.

86. EXCEPTION TO THE LAW, THAT CHEMICAL ACTION REQUIRES FLUIDITY—EXPERIMENTALLY ILLUSTRATED.

If slaked lime and muriate of ammonia, in powder, be mixed, the pungent fumes of ammonia will be perceived.

TABLES OF AFFINITY,

Consist of a series of substances, placed in a column, in the order of their affinity, for any one substance at the head of the column.

AN EXAMPLE.

SULPHURIC ACID.

Barytes,
Strontites,
Potash,
Soda,
Lime,
Magnesia,
Ammonia.

OF DEFINITE PROPORTIONS.

The proportions have been long known to be invariable, in which substances must be mixed, in order to saturate each other; or to produce a compound, in which the peculiar characters, or affinities of the ingredients, are extinguished.

When substances combine in other proportions, than those of saturation, their ratio is no less definite and constant.

There is not, in any case, except the peculiar one of solution, an indefinite gradation in the proportions in which bodies combine. There are rarely more than four gradations.

The number, representing the least proportion, in which a substance is known to combine, will, in a great majority of cases, divide the numbers representing the greater proportions, without a fraction; and where this result is unattainable, it will still be found that the larger proportion may be divided by the half of the lesser, without any remainder.

Let A, B, and C, be certain substances, and let X, Y, and Z, be other substances, severally having an affinity for either A, or B, or C. Let each of the former, and each of the latter, be combined in the least possible proportion. Consequently, the least combining proportion of each substance, will be found three times. It will appear that the proportions of A, B, and C, found by combining them with X, will be in the same ratios to each other, as the proportions found by combining them with Y, or Z; and reciprocally, that the proportions of X, Y, and Z, will have the same ratios, whether ascertained by their combination with A, B, or C.[*]

When instead of ascertaining the least combining proportions of six substances, the experiment has been extended to any larger number, the same uniformity has been found to prevail, in the ratios of the numbers representing those proportions. It has also been found, that when numbers are ascertained, which express the ratio, of the least combining proportions of a variety of substances, to any one substance, as for instance, to oxygen, those numbers will express the ratios, of the least combining proportions of the substances in question, to each other.

Numbers representing *least combining proportions*, are called *chemical equivalents.* As they are merely expressive of ratio, they may be multi-

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[*] That is, as A, in AX, is to B, in BX, or to C, in CX—so is A, in AY, to B, in BY, or to C, in CY:—and so is A, in AZ, to B, in BZ, or to C, in CZ.—Again, as X, in AX, is to Y, in AY, or to Z, in AZ—so is X, in BX, to Y, in BY, or to Z, in BZ:—and so is X, in CX, to Y, in CY, or to Z, in CZ.

Students who have acquired a sufficient knowledge of chemistry to understand the terms employed, may find the following illustration preferable, in which three acids, and three alkalies, are substituted for the letters. Let us suppose the sulphuric, nitric, and phosphoric acids, and potash, soda, and ammonia, to be selected. Let us find the least possible proportions in which each, of the former, will saturate each, of the latter, so as to form neutral salts. It will be found that as the sulphuric acid, in sulphate of potash, is to the nitric acid, in nitrate of potash, or the phosphoric acid in phosphate of potash; so will the sulphuric acid, in sulphate of soda, be to the nitric acid, in nitrate of soda, or the phosphoric acid, in phosphate of soda; and the same language may be used, substituting ammonia, or any other earth, alkali, or oxide, for soda or potash.

And again, as the potash in the sulphates, is to the soda or ammonia in the sulphates, so is the potash in the nitrates, to the soda and ammonia in the nitrates; and the same statement may be made as respects the ratio of the soda, to the potash or ammonia, or of ammonia, to the potash and soda.

The principle, here illustrated, has been found to hold good, universally: not only in the case of acids, and alkalies, but in a vast number of cases, in which it has been tested, by ascertaining the least combining proportions of substances plied, by any common multiplier, or divided, by any common divisor, without affecting their competency.

They are usually so computed, as to make the equivalent of oxygen, or that of hydrogen = 1. As the equivalents of these substances are as 1 to 8, if hydrogen be represented by unity, oxygen will be 8. If oxygen be unity, hydrogen will be 0.125, or one-eighth of 1: consequently, equivalents, formed upon either basis, may be converted into those corresponding with the other, either by multiplying or dividing by 8.

Originally, I gave a preference to the equivalent of hydrogen as the unit, but was induced by the example of Wollaston, Thompson, Berzelius, and others, to make the equivalent of oxygen the standard. But after it was rendered probable that all the equivalents would prove to be multiples of that representing hydrogen, I returned to my first choice. In this I have been supported by the example of many distinguished chemists in Europe, and the opinion of my friend, Dr. Bache, who is very accurate in his knowledge of the subject in question, having for many years given it great attention. Accordingly, I shall employ the numbers founded on the equivalent of hydrogen, as unity.

Upon the results of experiments which he has himself made, Berzelius denies that the equivalents of the other elements are all exactly multiples of hydrogen. Yet the results which he has stated, are as near to those which would be consistent with the existence of that multiple relation, as I think could be reasonably expected, making due allowance for the imperfection of our means of analysis.

It is in some degree upon this ground, that Berzelius gives the preference to oxygen as the standard. He assumes the equivalent of oxygen as 100. By Wollaston, it was assumed as 10, and by Dr. Thomson as 1. The only difference between the equivalents founded upon these numbers, is in the position of the decimal point.

OF TABLES OF CHEMICAL EQUIVALENTS.

In these, the equivalents of all known bodies, so far as ascertained, are arranged alphabetically.

Such tables are of great utility in practical chemistry. The operative chemist may frequently resort to them with advantage. They enable him to store his memory with data adequate to the solution of a great number of questions which must necessarily arise. If he wishes to know how much of any two substances he must take, to form a third, he has only to recollect or look for their equivalents in the table, and seek a solution by the rule of three. For as the equivalents of the substances are to each other, so are the quantities of them to be used. Should it be an object to produce only a certain weight of a compound, then as the equivalent of the compound, is to that of either of the ingredients, so is the weight of the compound required, to the requisite weight of either ingredient.

In order to know how much of the proper materials he must use to effect a decomposition, he has only to employ them in the ratio of their respective equivalents.

Moreover, when the proportions, afforded by analysis, do not harmonize exactly with well ascertained equivalents, we are warned of the existence of some inaccuracy, which in many cases may be safely corrected, so as to make results accord with them.

87. WOLLASTON'S SCALE OF EQUIVALENTS.

This instrument is so constructed, that the computation requisite in using the equivalents, is performed by a slide.

It has been mentioned that the equivalents may be expressed in any numbers having the same ratios to each other as the least combining proportions of the substances which they represent. The slide enables us to adopt any such numbers as may be convenient. Equal distances on the slide, give the same ratios in different numbers. If, by moving the slide, we vary one equivalent to 100 for instance, the other equivalents vary proportionably.

OF THE ATOMIC THEORY.

Extension has been proved to be infinitely divisible, and it is not difficult to suppose that the matter, comprised within any given limits, may be susceptible of as many subdivisions, as the space in which it is contained. On the other hand, it is obvious, that *mechanical* division must be limited by the imperfection of the edges, or surfaces, employed to accomplish it.

Were atoms chemically divisible, ad infinitum, any one substance, however small in quantity, might be diffused, in a state of chemical combination, throughout any other, having an affinity for it, however great: for as no one particle in the latter, would exercise a stronger affinity than another, it would be unreasonable that each should not have its share. That such a diffusion is impracticable must be evident from the smallness of the number of definite proportions to which substances in combining are restricted, as already mentioned in entering upon the subject of equivalents. Hence elementary atoms are not considered as liable to an unlimited subdivision, either by chemical, or mechanical agency.

The ratios of the equivalent numbers are supposed to be dependent on, and identical with, those of the weights of the integrant atoms of the substances to which they appertain. Thus the fact that 32 parts by weight, of soda, will saturate as much of any acid, as 48 parts, of potash, is explained by supposing that the weights of the smallest atoms, of those alkalies, which can exist, are to each other, as 32 to 48.

In like manner it is explained, that when neutral salts are made reciprocally to decompose each other, no excess, of either ingredient, is in any case observable. The lime, in nitrate of lime, is to the potash, in an equivalent weight of the sulphate of potash, as 28 to 48, yet neither is the lime incompetent to take the place of the potash, nor is there too much potash to take the place of the lime. This result is intelligible, if we suppose, that when quantities, just adequate, for reciprocal decomposition, are employed, there is an equal number of atoms, of each salt; the one containing as many atoms of potash, weighing 48, as the other contains atoms of lime, weighing 28.

The same explanation is also applied to explain the fact that while the sulphuric acid in the sulphate of potash is to the nitric acid in the nitrate of lime as 48 to 54, yet neither is there too much of the latter nor too little of the former, to produce neutral compounds with the bases to which they are severally transferred.

On account of the hypothetical association of the numbers, representing the least proportions in which bodies are known to combine, with the supposed relative weight of their atoms, those numbers are as well known by the appellation of atomic weights, as that of chemical equivalents.

A LIST OF THE ATOMIC WEIGHTS OF ALL THE PONDERABLE SUBSTANCES WHICH ARE ELEMENTARY OR INDECOMPOSABLE.

As the atomic numbers are practically useful, enabling us to know the proportions in which substances are combined, or in which they should be used to produce compounds, it is advantageous to commit them to the memory as far as possible. The whole number of substances recognised as elementary, agreeably to the present state of our knowledge, is fifty-four. Of these, little more than half are of sufficiently frequent recurrence either in speculation or in practice, to make it desirable to remember their numbers. I will quote them therefore in two distinct tables. Those of which a knowledge is likely to be rarely in demand, I have subjoined in smaller type.

Aluminum	10
Antimony	65
Arsenic	38
Barium	70
Boron	20
Bromine	78
Calcium	20
Carbon	6
Chlorine	36
Copper	64
Fluorine	18
Gold	200
Hydrogen	1
Iodine	126
Iron	28
Lead	104
Magnesium	12
Mercury	200
Nitrogen	14
Oxygen	8
Phosphorus	16
Platinum	96
Potassium	40
Selenium	40
Silicon	8
Silver	110
Sodium	24
Strontium	44
Sulphur	16
Tellurium	32
Tin	58
Zinc	32

Bismuth	72
Cadmium	56
Cerium	48
Chromium	28
Cobalt	30
Columbium	185
Glucinum	18
Iridium	96
Lithium	10
Manganese	28
Molybdenum	48
Nickel	28
Osmium	100
Palladium	54
Rhodium	45
Thorium	60
Titanium	24
Tungsten	100
Uranium	217
Vanadium	68
Yttrium	32
Zirconium	30

It appears by some experiments made by Messrs. Petit and Dulong, that the capacities for heat, or specific heats, of all elementary atoms are the same; so that if the specific heat of any one congeries of atoms, be less than that of another having the same weight, it is because the atoms of the one, being heavier than those of the other, there are fewer of them in the same weight. Hence as the capacities, or specific heats, of elementary substances are greater as estimated in the mass, the weights of their atoms are less; so that if, in the case of each, its atomic weight be multiplied by its specific heat, the product will in general be so nearly the same, that the difference may be ascribed to the inaccuracy, unavoidable in experimental investigations.

Respecting this highly important and interesting inference of Petit and Dulong, Professor A. D. Bache has endeavoured to show in an article published in the Journal of the Academy of Natural Sciences, that multiplying the equivalents of twelve principal metals into their specific heat, gives results so widely deviating from uniformity as to take all plausibility from the hypothesis that the atoms of simple bodies have the same specific heat.

Dr. Thomson has observed that this law is more likely to be true since it holds good without doubt in the case of the gases, and that if it be true we have only to divide the specific heat of hydrogen by the atomic weight of any body to find its specific heat. Moreover that the specific heats thus found agree very nearly with those ascertained experimentally.

The following remarks are quoted from Turner's Chemistry.

In the new part of his Chemical Philosophy, page 293, Mr. Dalton has made some strictures in reference to this table, tending to show that the opinion of Dulong and Petit cannot be correct, and stands in opposition to their own facts. Mr. Dalton argues that the product of the weight of an atom by the corresponding capacity for caloric, is not a constant quantity; because the capacity of the same substance varies with change of form, or even, according to their own experiments, from variation of temperature without change of form. To the latter part of the criticism, Dulong and Petit are certainly exposed; but they have anticipated the former by remarking, that the law is not affected by change of form, provided the substances compared are taken in the same state. Whether this position is or is not correct, remains to be proved.

ON SPECIFIC GRAVITY.

A clear idea of specific gravity is indispensable to a chemist. *Gravity* and *weight* are synonymous words: but the term *specific gravity* is used to signify the ratio of *weight* to *bulk*. Hence the object of all the processes for ascertaining specific gravities, is either to ascertain the *weight* of a *known bulk*, or the *bulk* of a *known weight;* for whether the substances whose specific gravities are to be found, be reduced to the same weight, and then measured, or be reduced to the same bulk and then weighed, the ratio of their weights, to their bulks, will be discovered. If reduced to the *same bulk*, and *weighed*, their *specific gravities* will be *directly* as the *weights*. If reduced to the *same weight and measured*, their *specific gravities* will be *inversely* as their *bulks* thus ascertained.

Supposing a like bulk of each kind of matter, in nature, to be weighed, the results, numerically stated, would represent their specific gravities. But since it is not possible to procure an exactly similar bulk, of each kind of matter, it is necessary to resort to another mode of reducing their bulks to a common measure. The method adopted, in the case of solids and liquids, is to divide the weight of a given bulk, of each body, of which the specific gravity is to be found, by the weight of a like bulk of water. This in fact may be stated as the general rule for ascertaining specific gravities.

Thus on dividing the weight of any bulk of copper, by the weight of a like bulk of water, the quotient is 9. This, therefore, is received as the specific gravity of copper. By a similar procedure, in the case of silver, the quotient is 10.5, in the case of mercury 13.6, in the case of gold, 19.3: consequently, these numbers are considered as representing the specific gravities of those metals.

If the body be lighter than water, as in the case of cork, which is only about one-fifth as heavy, the quotient, being less than one, is expressed by a decimal fraction. Thus the specific gravity of cork may be stated to be .20.

The gravity of water has been assumed as the standard, because this liquid may always be obtained sufficiently pure; and it is generally easy to ascertain the weight of a quantity of it, equal, in bulk, to any other body.

The weight of a quantity of water, equal to the body in bulk, is equal to the resistance which the body encounters in sinking in water. Hence, if we can ascertain, in weight, what is necessary to overcome the resistance which a body encounters in sinking in water, and divide, by the weight thus ascertained, the weight of the body, we shall have its specific gravity.

In the case of a body which will sink of itself, the resistance to its sinking, is what it loses of its weight, when weighed in water.

In the case of a body which will not sink of itself, the resistance to its sinking, is equivalent to its weight, added to the weight which must be used to make it sink.

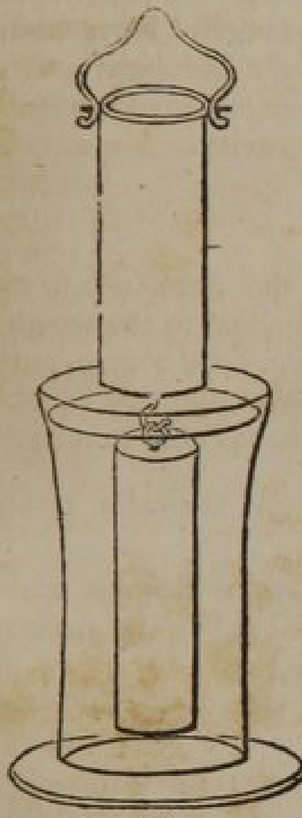
88. EXPERIMENTAL DEMONSTRATION, THAT THE RESISTANCE WHICH A BODY ENCOUNTERS, IN SINKING IN ANY LIQUID, IS JUST EQUIVALENT TO THE WEIGHT OF A PORTION OF THE LIQUID, EQUALLING THE BODY IN BULK.

This proposition may be experimentally demonstrated, by means of the apparatus, represented by the following figure.

The cylinder, represented as surrounded by the water of the vase, (V) is made to fit the cavity of the cylinder suspended over it so exactly, as that it enters the cylinder with difficulty, on account of the included air, which can only be made to pass by it slowly. It must, therefore, be evident, that the cavity of the hollow cylinder, is just equal in bulk to the solid cylinder.

Both cylinders, (suspended as seen in the plate) being counterpoised accurately upon a scale beam; let a vessel of water be placed in the situation of the vase, in the drawing. It must be evident, that the equiponderancy will be destroyed, since the solid cylinder will be buoyed up by the water. If water be now poured into the hollow cylinder, it will be found, that, at the *same* moment *when* the cavity becomes full, the equiponderancy will be restored, and the solid cylinder sunk just below the surface of the water.

Hence it appears, that the resistance which the solid cylinder encounters, in sinking in the water, is overcome by the weight of a quantity of the water equal to it in bulk. It must be evident, that the same would be true of any other body, and of any other liquid.



V

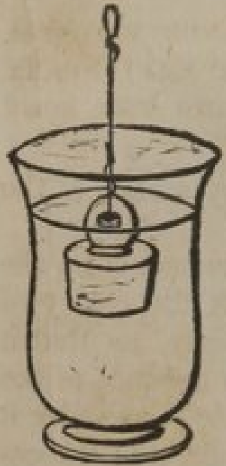
RATIONALE.

When a solid body is introduced into an inelastic solid, on withdrawing it, a hole is left, which remains vacant of the solid matter: but, no sooner is a body, which has been introduced into a liquid, withdrawn, than the liquid is found to fill up the space from which it has been removed.

It is evident, that the force which liquids exert, thus to re-enter any space within them, from which they are forcibly excluded, is precisely equal to the weight of a quantity of the liquid, commensurate with that space; since, when the space is reoccupied by the liquid, the equilibrium is restored. Consequently, every body, introduced into a liquid, experiences from it a resistance equal to the weight of a quantity of the liquid, commensurate with the cavity, which would be produced, supposing the liquid, frozen about the solid mass, split open so as to remove it, and the fragments put together again; and the cavity thus created, must obviously be exactly equal to the bulk of the body. It follows, that the resistance which any body encounters in sinking, within a liquid, is equivalent to the weight of a quantity of the liquid, in bulk equal to the body.

89. TO ASCERTAIN THE SPECIFIC GRAVITY OF A BODY HEAVIER THAN WATER.

Let the glass stopple, represented in the following figure, be the body.

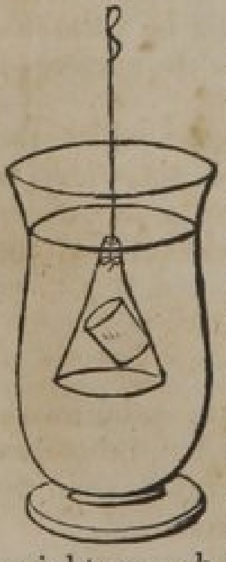


First counterpoise the stopple by means of a scale beam and weights, suspending it by a fine metallic wire. Place under the stopple, a vessel of pure water, at the temperature of 60°, and lower the beam, so that if the stopple were not resisted by the water, it would be immersed in that fluid. Add just as much weight, as will counteract the resistance which the water opposes to the immersion of the stopple, and render the beam again horizontal. Divide the weight, by which the stopple had been previously counterpoised, by the weight thus employed to sink it. The quotient will be the specific gravity.

RATIONALE.

The weight requisite to sink the stopple, measures the resistance to its being sunk in the water, and this it has been shown is equal to the weight of a bulk of water commensurate with that of the stopple. Of course, pursuant to the general rule, it is only necessary to see how often this weight is contained in the weight of the stopple, to ascertain the specific gravity.

90. TO ASCERTAIN THE SPECIFIC GRAVITY OF A BODY LIGHTER THAN WATER.



Let a small glass funnel be suspended from a scale beam, and counterpoised so as to be just below the surface of some water in a vase, as in this diagram.

If, while thus situated, a body lighter than water, a small cork for instance, be thrown up under the funnel, the equilibrium will be subverted. Ascertain how much weight will counteract the buoyancy of the cork, add this to its weight, and divide its weight by the sum—the quotient will be the answer.

RATIONALE.

The force with which the cork rises against the funnel, is equal to the difference between its weight and the weight of the bulk of water which it displaces. Of course, ascertaining the force with which it rises, by using just weight enough to counteract it, and adding this weight, so ascertained, to that of the cork, we have the weight of a bulk of water, equal to the bulk of the cork. By this weight, dividing the weight of the cork, agreeably to the general rule, the specific gravity of the cork will be found.

91. TO ASCERTAIN THE SPECIFIC GRAVITY OF A LIQUID.

Let the stopple be counterpoised, exactly as in experiment 93, excepting that it is unnecessary to take any account of the counterpoising weight.

Having, in like manner, ascertained how much weight will sink it in the liquid, divide this by the weight required to sink it in the water, as above. The quotient will be the specific gravity sought.

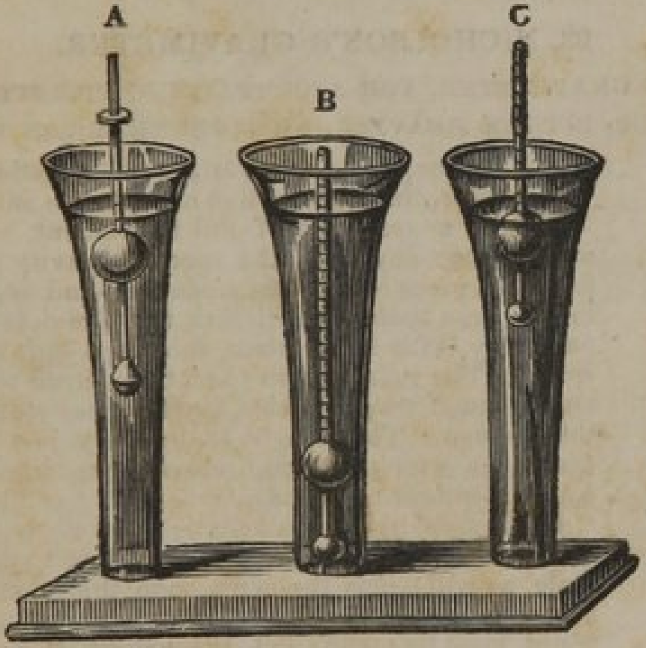
RATIONALE.

It has been proved, that the resistance to the sinking of a body in any liquid, is precisely equal to the weight of a bulk of the liquid, equal to the bulk of the body. Ascertaining the resistance to the immersion of the same body in different liquids, is, therefore, the same as ascertaining the weights of bulks of those liquids, equal to the body, and, of course, to each other. And if one of the liquids be water, dividing, by the weight of this, the weights of the others, give their specific gravities.

If the stopple be so proportioned, as to lose just one thousand grains, by immersion in water, division is unnecessary, as the weight of the liquid will be obtained in grains, which are thousandths by the premises. A metallic mass, of the same weight as the stopple exactly, may be employed as its counterpoise.

In these experiments, the liquid should be as near 60° of Fahrenheit's thermometer as possible.

92. HYDROMETERS, FOR ALCOHOL, AND FOR ACID, SALINE, AND OTHER SOLUTIONS. ALSO, FOR VEGETABLE INFUSIONS.



In these a constant weight is used, (to a certain extent,) and the differences of gravity are estimated, by the quantity of the stem immersed. In those instruments of this construction, where several weights are employed, the effect is the same, as if the stem of the instrument were lengthened as many times, as the number of the weights attached to it.

Above there is a representation of three Hydrometers, A, B, and C, contained in glass vessels. B and C are of glass, and A of metal.

B is intended for liquids heavier than water; C, for those which are lighter. In each, the graduation commences at that point of the stem, to which the instrument sinks in distilled water. It must of course, commence at the top of the stem, for liquids heavier than water; and, at the bottom of the stem, for liquids lighter than water. In the latter case, as in that of spirituous liquors, or of ether, the strength being greater, as the liquid is lighter, more of the stem is immersed, in proportion as the liquid is stronger; but the opposite is true, in the case of acid and saline solutions, or infusions of vegetable matter; the more the stem emerges from these, the heavier, and, of course, the stronger, they are. The instruments are represented as when swimming in pure water.

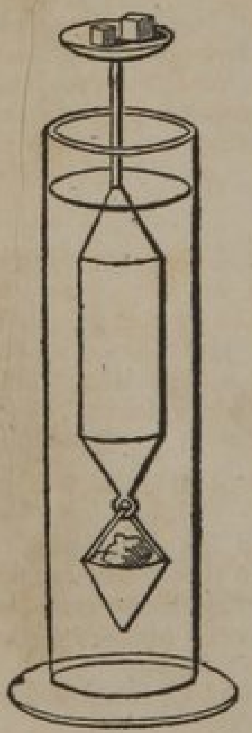
At A is an Hydrometer, of a form much used in this country and in England, both for spirit and infusions of vegetable matter. The stem is virtually lengthened, by the use of several small weights, which may be slipped on and off at pleasure.

The whole difference, between the weight of water and that of the strongest spirit, is equal to about two parts in ten. Of course, an Hydrometer for spirit, should have on its stem a scale of more than two hundred parts, in order to give the specific gravity of any liquid consisting of water and alcohol. To render such graduation sufficiently discernible, the stem would have to be of very inconvenient length. This is obviated, by using different weights. When the heaviest weight is upon the stem, the whole of the stem stands above the surface in distilled water. When the liquid contains enough spirit to allow the whole of the stem to sink in it, while supporting this weight, a lighter weight may be used; and when the stem again would be wholly merged, this last mentioned weight may be exchanged for one still lighter. Supposing the stem graduated into fifty parts, three weights would give fifty degrees each; and the stem, unloaded, fifty more. Were the stem graduated into ten parts, nineteen weights would give one hundred and ninety parts; and the stem, unloaded, ten more.

An instrument, sometimes called Saccharometer, but precisely similar in principle, is used for infusions of vegetable matter, especially for the wort of brewers and distillers—excepting, that the scale begins at the top of the stem, with a line which coincides with the surface of pure water, at sixty degrees Fahrenheit, when the Hydrometer is immersed in it. When the infusion is strong enough to support the whole of the stem above its surface, a weight is to be added, heavy enough to bring the graduated part of the stem into the liquid. And, in like manner, as the infusion is found stronger, weights still heavier must be added, the process being perfectly analogous to, but the converse of that, described in the case of alcohol.

93. NICHOLSON'S GRAVIMETER.

OF NICHOLSON'S GRAVIMETER, FOR ASCERTAINING THE SPECIFIC GRAVITY OF SOLIDS, EITHER HEAVIER, OR LIGHTER, THAN WATER.



The accompanying cut is a representation of Nicholson's Gravimeter, the construction of which is sufficiently obvious.

On the upper scale of the instrument, whilst floating in water, place any body, the specific gravity of which is to be found—a piece of coin, for instance—and add as much weight to the same scale, as will sink the Gravimeter, until a mark, purposely made in the stem, coincides with the surface of the water. The coin is then to be transferred to the lower scale, and as much weight added to the upper one, as compensates this change. This weight is obviously just equivalent to the resistance which the coin encounters, in sinking in water. Let this weight be called A.

In the next place, the body is to be removed from the Hydrometer, and as much weight, B, again added to the upper scale, as will cause the mark upon the stem to coincide with the aqueous surface. Of the weight first employed, no account need be taken; but, the weight, A, and the weight, B, used in the second and third steps of the process, are to be carefully noted, and added together; the sum of A and B is then to be divided by A, the first noted number. This number, A, represents the weight of a bulk of water, equal in bulk to the coin; while the sum of the numbers, A and B, is equivalent to the weight of the coin: since that aggregate weight has been found equivalent to the weight of the coin in sinking the Hydrometer.

94. TO FIND THE GRAVITY OF A BODY LIGHTER THAN WATER, BY NICHOLSON'S GRAVIMETER.

Should the gravity of a light body, as a piece of cork, for instance, be in question, place it on the upper scale of the Gravimeter, load the instrument, so as that the mark on the stem may coincide with the surface of the water, as in the case above stated; a leaden disk being previously laid upon the lower scale. The cork being removed, the weight requisite to compensate its absence, gives the weight of the cork. This weight, being added to that which will compensate its buoyancy, when immersed in water, by being placed beneath the leaden disk in the lower scale, gives the weight of a quantity of water, equal in bulk to the cork. Hence, if the number of grains representing the weight of the cork, be divided by that representing the weight of its bulk of water, the quotient will be the specific gravity; which, in this case, must be expressed in a decimal fraction, as it is less than unity.

OF THE INFLUENCE OF THE AIR ON THE APPARENT WEIGHT OF BODIES.

A pleasant illustration of the loss of weight, and consequent inaccuracy attendant on the ordinary process of weighing, as conducted in the air, is necessarily afforded by means of the apparatus and the process described in this figure.

95. *A pound of Feathers heavier than a pound of Lead.*

If two bodies, one of which is more bulky than the other, be found equiponderant in the ordinary process of weighing by a balance, the larger body is the heavier.

Let the bodies in question, be those represented within the receiver of an air pump, in the subjoined figure. On withdrawing the air, by means of the pump, it will be found, that the larger body preponderates, though previously counterpoised with accuracy.

RATIONALE.

It appears from a preceding illustration, 92, that, when any body is surrounded by a fluid, it is buoyed up with a force in proportion to the weight of the fluid, and the quantity displaced by the body. Of course, the more space it occupies, in proportion to its weight, the more will its weight be counteracted. In the case of the two bodies rendered equiponderant, in air, the weight of the larger is most counteracted by the air. Hence, on exhausting the air from the receiver, the larger body shows a preponderancy over the other, equivalent to the superior support which the air had afforded it.

A similar result may be obtained, if hydrogen be substituted in the receiver for atmospheric air; because, as its specific gravity to that of the air, is only as 1 to 14, nearly each body would lose 13-14ths of the support which the air had afforded; but the larger body having received more, would lose more. It follows, that the common saying, that "a pound of feathers is as heavy as a pound of lead," falls short of the truth, as they would really prove heavier were the air removed.

MEANS OF ASCERTAINING THE SPECIFIC GRAVITIES OF GASEOUS SUBSTANCES.

I shall defer any explanation of the means by which the specific gravities of the gases are ascertained, until the student is better acquainted with them.

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OF PONDERABLE SUBSTANCES.

OF THE ORDER TO BE PURSUED IN TREATING OF PONDERABLE SUBSTANCES.

After having treated of repulsion, as displayed in the phenomena of electricity, caloric and light, and likewise of chemical attraction, whether as existing between homogeneous, or heterogeneous particles, I shall in the next place proceed to the consideration of ponderable substances individually. In the prosecution of this object, various arrangements have been pursued by different writers. Some have preferred to begin with elements, and to proceed to compounds; others to begin with compounds, and to proceed to elements. In favour of the last mentioned method, it may be alleged, that the most interesting substances in nature, become known to us at first, in a state of combination. Thus for instance, the air, water, salts, acids, alkalies, also flesh, sugar, farina, and other organic products essential to our subsistence, are compounds which have been naturally made the object of inquiry; and it may be inferred that the student might with advantage be induced to travel in those paths, of which a successful pursuit has led to that chemical knowledge which it is the object to impart. In this way he proceeds from facts which he knows, to such as he ought to learn, in the order in which he would spontaneously advance as far as he might be competent. But it may be objected, that no sooner are the ingredients of a body stated, than the student is distracted by a plurality of names, of which he is ignorant; and which there is an immediate necessity to explain. Hence it follows that the ingredients of a compound may come to be considered in immediate succession, when they may have no analogy with each other; while it is highly advantageous, after having treated of any one element, to proceed to that which has the greatest analogy with it. In that case, a certain portion of the conceptions which have been formed respecting one element, may be extended to another, with little mental exertion, and without much additional pressure upon the memory.

The method first mentioned of treating of each elementary substance first, and afterwards of compounds, is objectionable, because it cannot be put into practice effectually. To treat of the chemical habitudes of any one element, requires that we should speak of other elements, in reacting with which, those habitudes are displayed, and respecting which a beginner is of course ignorant. In pursuing this course, each substance must be treated of imperfectly, or language and illustrations employed, which the student is unprepared to understand.

The course which I have chosen, is as follows.

I begin with the substance which, of all ponderable matter, has the most important part assigned to it in nature: I mean oxygen. The history, state of existence in nature, means of procuring, and properties of this substance, so far as they can be rendered intelligible to a novice, are stated, or exemplified and explained. In the next place to oxygen, I present chlorine to attention, which has at least as much analogy with oxygen, as any other known substance, and is, at the same time, an agent of high importance. Having treated separately of oxygen and chlorine, as far as may be expedient, the compounds which they form with each other, may, in the next place, to a certain extent, be treated of with advantage. Then, guided by analogy, bromine and iodine, though inferior in importance, may be successively treated of, and subsequently all the compounds which they can form, either with oxygen or chlorine, or with each other.

Fluorine, next presents itself, and might, upon some grounds, have pretensions to precedency over either of the substances which I have mentioned, excepting oxygen; but as fluorine has never been isolated, and of course cannot be exhibited uncombined; and as its most important properties are demonstrated by means of its combinations with substances respecting which, no knowledge can, in this part of the course, be advantageously afforded, a brief mention is all that can, under these circumstances, be expedient.

Cyanogen, is, in its properties, analogous with chlorine, bromine, and iodine, yet being composed of carbon and nitrogen should not be an object of attention, until the pupil is prepared by a knowledge of them. Besides it comes in consistently under the general head of carbon, which, agreeably to my plan, as above explained, comprises the compounds of carbon with all substances previously treated of, among which is nitrogen.

The preceding substances, with the exception of oxygen, are, by Berzelius, classed under the name of halogen bodies, or generators of salts; while oxygen, sulphur, selenium, and tellurium, are classed together under the name of amphigen bodies, or both producers; meaning that they are productive both of acids and bases. For reasons stated in a letter to Professor Silliman, which will be found in the Appendix to this work, I object to this classification. It appears to me, from the facts stated by Berzelius, coupled with his own practice, that the bodies of both of his classes are productive of acids and bases. Influenced by this impression, I would associate them in one class, under the appellation of *basacigen* elements. In honour of Berzelius, I shall, however, retain the terms halogen, and amphigen, in order to designate the elements which he has distinguished by those names. It may be proper to add, that we owe to Berzelius himself the idea, that any other substance besides oxygen could form bases as well as salts. Our knowledge of the existence of this faculty in three of his amphigen elements, sulphur, selenium and tellurium, is, I believe, entirely due to his investigations. If chemists, myself among others, who consider his double salts as consisting of acids and bases, are in the right, it is to the light afforded by the brilliant discoveries of Berzelius that we owe the ability to pursue the true path.

OF PNEUMATIC CHEMISTRY.

It appears from the phenomena of calorific repulsion, that solid ponderable matter, by combining with caloric, first expands, next melts, and finally passes into that elastic state of fluidity, in which the repulsive power so far predominates over the attractive, that the particles recede from each other as far as external pressure will permit. When a substance is naturally aeriform, it is called a gas: when it retains the form of air only, in consequence of extraordinary heat, or a removal of pressure, it is called a vapour.*

The art of procuring, collecting, examining, measuring, and distinguishing gaseous substances, has been called pneumatic chemistry. It is a branch of the science which has existed for little more than half a century.

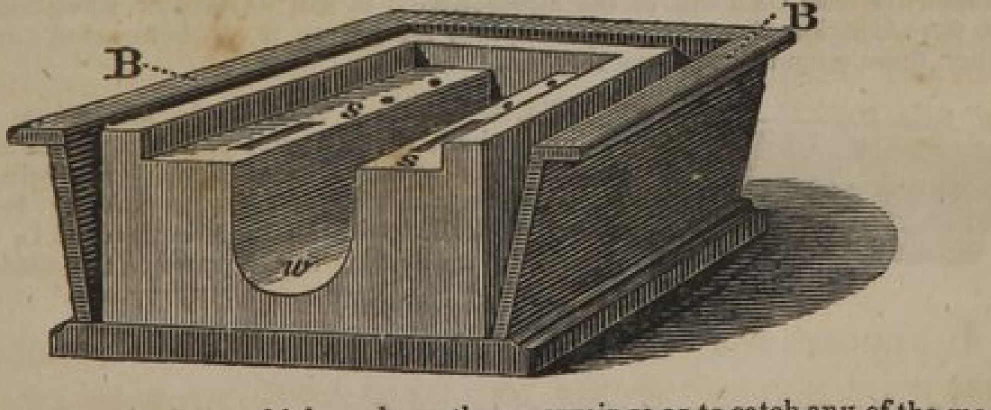
All gases were considered as common air, variously modified by impurities, until Dr. Black ascertained the nature of carbonic acid gas. Incited by this discovery, oxygen, nitrogen, hydrogen, chlorine, and many other substances susceptible of the gaseous state, were discovered, or distinguished, by Scheele, Priestley, Cavendish, and others.

96. ON THE MODE OF COLLECTING, AND PRESERVING GASES IN THE PNEUMATO-CHEMICAL APPARATUS.

Vessels are filled with water, or mercury, in a pneumatic cistern, and inverted; then placed on a shelf, or part of the cistern, purposely kept just below the surface of the water or mercury. As their orifices are not raised above the surface, they remain full of the liquid in consequence of the pressure of the atmosphere (see 14). Any gas emitted under the mouth of a vessel, so filled, and situated, rises and displaces the contained liquid.

97. MERCURIAL PNEUMATIC CISTERN.

The next figure represents the mercurial cistern used in my laboratory. The front is supposed to be removed, that the inside may be exposed to view.



B B, is a wooden box, which encloses the reservoir so as to catch any of the metal which may be propelled over the margin of the cistern. This box is bottomed upon stout pieces of scantling, tenanted together and grooved so as to conduct the mercury towards one corner, where there is a spout to allow it to escape into a ves-

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* See definition of vapour, by Berzelius, page 40: also paragraph 4 and 5, page 59.

sel, situated so as to receive it. The cistern itself, is made out of a solid block of white marble. It is 27 inches long, 24 inches wide, and 10 inches deep.

The ledges, S S, answer for the same purposes as the shelves in the pneumatic cistern described in the next article. The excavation, *w*, constitutes the well. In this well, vessels are filled with mercury, in order to be inverted and placed, while full, on the ledges. There are some round holes in the marble for introducing upright wires to hold tubes, or eudiometers; also some oblong mortices, for allowing the ends of tubes, duly recurved, to enter under the edges of vessels to be filled with gas;—and in cases of rapid absorption, to afford a passage for the mercury, into vessels, from which, it might otherwise be excluded, in consequence of their close contact with the marble of the reservoir.

To fill this reservoir requires nearly 600 pounds of mercury.

98. HYDRO-PNEUMATIC CISTERN.

Fig. 1.

In the Appendix will be found an engraving and description of a pneumatic cistern, which I employed in the experimental illustrations of my lectures for more than ten years; and which I should probably continue to use now, had not the command of water from the public works, put it into my power to dispense with the mechanism for keeping the water at a proper level. As I am now situated, any deficit of water is easily supplied from the pipes known here as the hydrant pipes, by which the city is supplied with water; and any excess is carried off by a waste pipe. Many chemists designate as a pneumatic trough or tube, apparatus for the purposes to which that in question is applied. Neither of these names is in my opinion as applicable to the apparatus which I have hitherto used, as that of cistern, to which I resorted; and although the last term be less suitable to the apparatus I am about to describe, yet I beg leave to adhere to it for want of a better appellation.

A A, a water tight platform, surrounded by a wooden rim, R R R R, rising above it about an inch and a half. B, C, D, three wells or cavities, each in the form of a hollow parallelopiped, with all of which the cavity bounded by the rim communicates, so that when supplied with water to the level of the waste pipe, this liquid fills the wells, and covers the platform to the depth of about ¾ of an inch.

E, F, G, shelves, which severally move in grooves over the wells, so that they may be placed in the most convenient position. Under H is a waste pipe. At I, is a hydrant pipe. K, a pipe for emptying the wells and casks, with all of which it communicates by cocks, when requisite. N, O, casks which act as gas holders, each having a communication with the cistern at Q or *q*, for letting in water from that source; the orifices being controlled by valves. By means of a pipe proceeding from its vertex, each gas holder communicates with a pipe or cock, at S or *s*.

To these gallows screws flexible leaden pipes may be attached, for transferring gas either from one of the holders to a bell glass, or from a bell glass to one of the holders. When a communication is established between the cavities, either of these offices may be performed, accordingly as the pressure within the holder is made greater, or less, than that of the atmosphere. It will be greater when the valve for the admission of water is opened, that for letting it out being shut: and less when these circumstances are reversed.

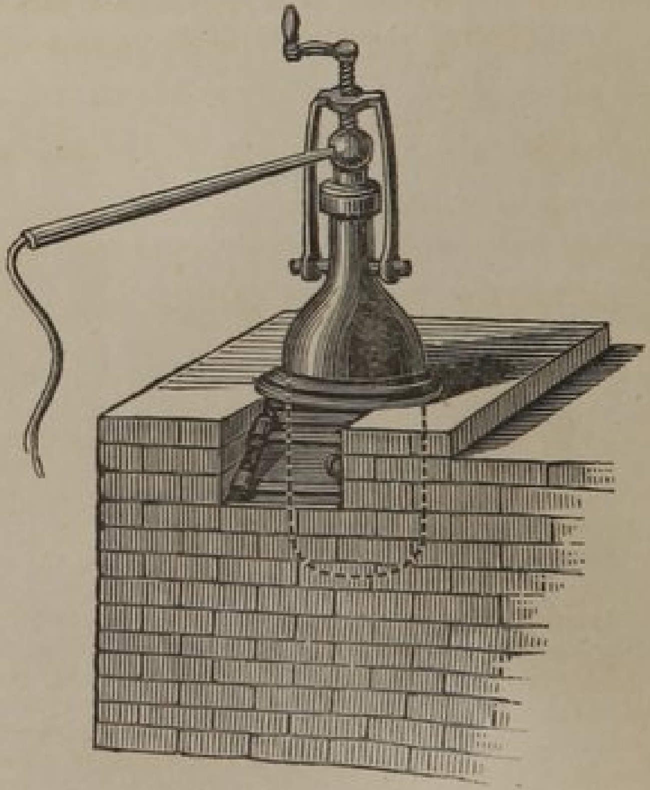
Fig. 2 affords a view of the lower side of the sliding shelf, in the wood of which it will be seen that there are two excavations, converging into two holes, one of which is seen at *h*, fig. 1.—This shelf is loaded with an ingot of lead at L, to prevent it from floating in the water of the cistern.

OF OXYGEN.

In the gaseous state, oxygen forms one-fifth of the atmosphere, in bulk; and it pervades the creation, as a constituent of water, in the ratio of eight parts in nine, in weight. It is a principal, and universal constituent of animal and vegetable matter. Its combinations with me-

A large Cast Iron Alembick for obtaining Oxygen from Nitre or Peroxide of Manganese.

(C. p. 101.)



tals, and various other combustibles, are of the highest importance in the arts. It was called oxygen, under the erroneous impression of its being the sole acidifying principle, from the Greek οξυς, acid—and γινομαι, to generate.

On the means of procuring Oxygen.

It can only be isolated in the form of a gas. It is yielded either by red lead, nitre, or black oxide of manganese, when exposed to a bright red heat in an iron bottle. There are various other means of obtaining oxygen gas. It is generally supposed, that in order to obtain it, in a high degree of purity, chlorate of potash must be employed; but I have found the first portions of the gas, from nitre, quite pure: and Dr. Thomson alleges, that this salt, by exposure to a carefully regulated heat, parts with one-fifth of its oxygen, in a state of purity; or in other words, it gives up an atom of oxygen for every atom of the salt, which is equal to 8 parts in 102 parts, or rather less than one-twelfth.

99. *Apparatus for obtaining Oxygen upon a large scale.*

As nearly as much time and trouble are expended in conducting a chemical process on a small scale, as upon a large one; and as in my experiments I consume large quantities of oxygen gas, I have lately employed the cast iron alembic represented in the figure, for the purpose of obtaining the gas from twelve or fifteen pounds of nitre. When in operation, it is made to occupy a suitable cavity in a brick stack. The neck is so formed as to receive a large hollow knob of iron, from which a gun barrel, B, proceeds at right angles. This knob is secured by a gallows screw, G, embracing the arms, A, A, cast with the alembic. The juncture is to be luted with clay, added dry to a saturated solution of borax. To the orifice of the gun barrel, a flexible leaden pipe is attached, by which the gas is conveyed to the gas holders, or gasometer.

Care is taken to use no more fire than will bring over the gas, and the operation is arrested as soon as the impurity exceeds 20 per cent. By attending to these precautions, the gas is of a better quality; the first portion being nearly pure, and the alembic is less corroded. Besides, the nitrate being converted into nitrate of potash, with the aid of sulphuric acid, answers to excite galvanic apparatus, or by deflagration with charcoal, to produce a tolerably pure carbonate of potash. As the equivalent of nitre, or nitrate of potash, is 102, that of oxygen 8; 12 lbs. of the salt ought to give nearly 1-12th, or 1 lb. of oxygen, by yielding only one atom. One pound of oxygen weighs 7000 grains, which, divided by 33, the weight of 100 cubic inches of oxygen, gives 21,200 cubic inches to the pound of oxygen, or about 12½ cubic feet, equal to 90 gallons.

It follows, that by evolving two atoms of the oxygen of the nitre, we should get about 180 gallons, but of an inferior quality. It is best to keep the product which first comes over, separate from that which is subsequently obtained.

Properties of Oxygen Gas.

The specific gravity of this gas, atmospheric air being 1., is 1.1111. One hundred cubic inches of it, weigh 33 grains. In refracting light, oxygen is inferior in power to any of the other gases.

It is insipid, inodorous, colourless, and transparent. It is but slightly absorbed by water; does not differ from common air in appearance, but is somewhat heavier, and supports life and combustion, more actively. Under a bell glass, filled with oxygen gas, an animal lives, and a candle burns, thrice as long as when similarly situated, with the same quantity of common air.

It is alleged to be the only gas, which when pure, becomes luminous by compression. It was supposed that chlorine had this property, but it has been asserted that it does not produce light in consequence of compression, when the piston of the condenser employed is free from oil.

Oxygen gas is supposed to consist of oxygen, a simple or elementary substance, rendered aeriform by caloric.

The equivalent of oxygen is 8, hydrogen being made unity. See page 86, 4th paragraph.

100. EXPERIMENTAL ILLUSTRATION OF THE PROPERTIES OF OXYGEN GAS.

Several cylindrical glass vessels of an appropriate shape being filled with the gas over one of the shelves of the pneumatic apparatus, and the following illustrations of the energy of oxygen gas in supporting combustion, are afforded.

EXPERIMENTS.

Let a stout wire be made, at one of its ends, to embrace a lighted candle, so that it may be conveniently lowered into the bell, while replete with oxygen. It will be found, that if the flame be extinguished, and the candle lowered into the gas, the inflammation will be renewed, with great energy.

The vessel being replenished with the gas, and a piece of caoutchouc, after being ignited, lowered into it, the generated flame acquires a dazzling brightness.

Let Homberg's pyrophorus, or preferably, such as I have contrived to obtain from Prussian blue, be thrown into the gas. The pyrophorus, in descending through the gas, being spontaneously ignited, appears like a shower of fire.

Charcoal powder, or filings of iron or steel, being made red hot in a crucible, and then be projected into oxygen, in a receiver, a vivid extrication of heat and light ensues.

If the hydrostatic blowpipe be supplied with oxygen, and be made to act upon a lamp flame, an intense heat will be excited, page 61, article 66.

An iron wire being heated in the flame, thus excited by oxygen, takes fire, and continues to burn splendidly, although the lamp be removed.

101. *Combustion of Iron or Steel, in Oxygen.*

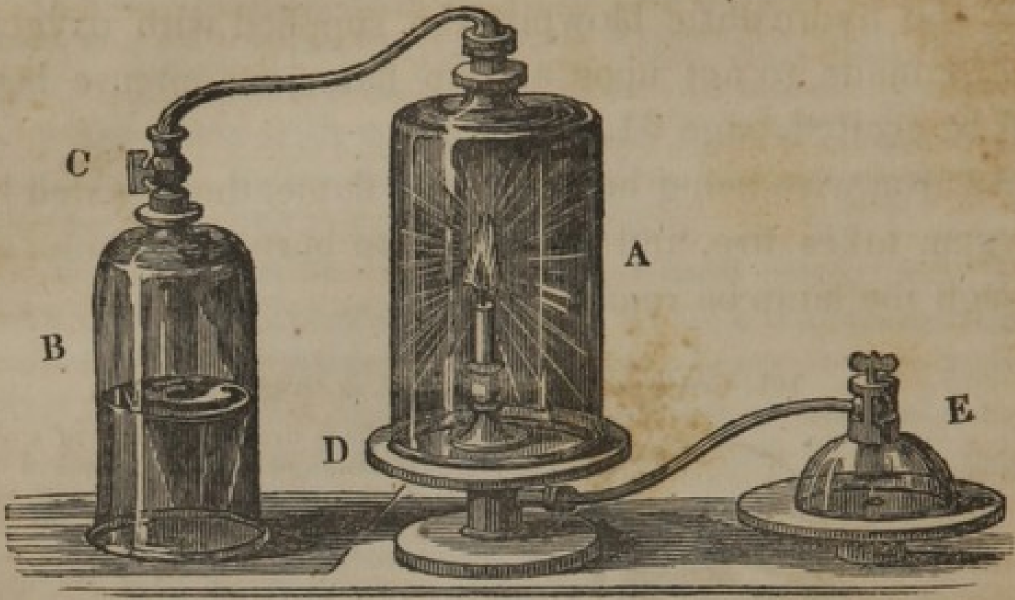
Place over the orifice of a pipe communicating with a cock of one of the air holders supplied with oxygen, a glass vessel, such as is usually employed to shelter candles from currents of air. Let the upper opening of the vessel be closed, by a lid with a central circular aperture, as here represented. Leaving this aperture open, by turning the key of the cock, allow the gas to rise into the vessel from the holder. Next apply a taper to the aperture, and as soon as it indicates by an increased brilliancy of combustion, that oxygen has taken place of the air previously in the vessel, cover the aperture. In the next place, attach a small piece of spunk to one end of a watch spring, or a spiral wire, as in the figure. Ignite the spunk, and removing the cover, plunge the end of the spring associated with the spunk, into the gas. The access of the oxygen causes the spunk to be ignited so vividly, that the spring takes fire and burns with great splendour, forming a brilliant liquid globule, which scintillates beautifully. This globule is so intensely hot, that sometimes on falling, it cannot immediately sink into the water; but leaps about on the surface, in consequence of the steam which it causes the water to emit. If it be thrown against the glass, of the containing vessel, it usually fuses it without causing a fracture, and has been known to pass through the glass, producing a perforation without any other injury.

The phenomena last mentioned, are more likely to be produced when an iron wire is used in this experiment, instead of the steel spring.

101. *Necessity of Oxygen to a candle flame, demonstrated.*

A candle will burn only for a limited time with a limited supply of air; it will not burn in vacuo, but, burns brilliantly in oxygen gas, and much longer than in a like quantity of air.

Let there be two bell glasses, A and B, communicating with each other by a flexible leaden pipe, a cock intervening 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 more dimly, and will at last go out, if no supply of fresh air be allowed to enter the containing bell. If on repeating the experiment, the air be withdrawn by means of the pump, the candle is rapidly extinguished. It is thus demonstrated, that a candle will not



burn in vacuo, and that it can burn only for a limited time, in a limited portion of atmospheric air.

If while the bell, A, is exhausted, the cock at C, be opened, communicating with a receiver, B, filled with oxygen over the pneumatic cistern, the water will rise into and fill the receiver, while the gas will be transferred to the bell. By means of the galvano ignition apparatus, represented page (55,) article (59,) the candle may be again lighted in the oxygen, when it will burn splendidly.

103. *Combustion of Phosphorus in Oxygen Gas.*

A brass plate, which answers as an extra air pump plate, and is of course, ground into a plane as true as possible, is supported on a hollow cylinder of the same metal. Concentric with the axis of this cylinder, and passing up through it, so as to reach about three inches above the plate, there is a tube of about three-fourths of an inch in diameter, open below, but closed above, by a concave copper disk to which it is hard soldered. The tube is fastened into the cylinder by a brass screw plug, in the centre of which the tube is made air tight by solder. Hence although the bore of the tube is accessible, from below, so far up as the concave copper disk, which surmounts it, no air can pass through it, or through the cylinder.

An adequate quantity of phosphorus being placed upon the copper disk, a glass globe is placed over it, upon the plate; and by making one of the pipes which are attached laterally to the cylinder communicate with an air pump, the globe is exhausted. By means of the other pipe, a due quantity of oxygen gas is then let in, from the bell glass, B, to which this pipe is annexed. The apparatus being thus prepared, the end of an iron rod previously reddened in the fire, is passed through the bore of the tube so as to touch the copper disk which holds the phosphorus. The most vivid ignition ensues. The light has at first a dazzling beauty, but is soon "shorn of its beams" by the dense white fumes of phosphoric acid, which the combustion evolves. Hence an effulgence, approaching to solar brilliancy, soon yields to a milder illumination, like that of the moon; which is rendered more pleasing by the contrast.

The globes with which I am accustomed to perform this experiment, contain from 12 to 15 gallons. It is better that the gas in the globe should be in some degree rarefied; otherwise the expansion at first excites a considerable effort in the air to escape. In one instance, a small piece of iron wire, with which the phosphorus was tied, took fire, and falling in a burning globule, on the neck of the globe, caused its fracture. At the same time the expansion was sufficient to throw the pieces to a distance of four or five feet apart.

The enlargement of bulk, arising from the heat, may be provided for by a bag or bladder, a communication with which being opened, a portion of the heated air is enabled to retire till the condensation of the oxygen, with the phosphorus, into phosphoric acid, compensates the expansion.

I have performed this experiment, when the density of the gas was one-half less, than if in equilibrio with the atmospheric pressure. This of course obviated the possibility of any ill consequences from expansion.

It will be shown in a subsequent article, that an apparatus of this kind may be applied to the analysis of atmospheric air.

104. *Combustion of Sulphur in Oxygen Gas.*

Supposing the junctures made by the plates, P *p*, with the receiver, R, to be air tight, and that there is a communication between it and the bell glass, B, by means of a flexible leaden pipe, L: it must follow that whenever the suction pump, from which the recurved pipe, S, terminating with the bell, proceeds, is made to act, the air in B being rarefied, that in R will force its way through L, and the liquid in the vase upon the stand. It must also be evident, that if the pipe and cock, C, communicate, on one side, with the receiver; on the other, with a reservoir of oxygen, this gas will be impelled into the receiver, as soon as the cock is opened, in order to restore the equilibrium destroyed by the suction pump.

The plate, P, with its supporting hollow brass cylinder, has been already described in the preceding article. The tube, surmounted by the disk, used in the combustion of phosphorus, is removed, and in its place a piece of a gun barrel is, in like manner, fastened, so as that the butt-end may occupy the axis of the cylinder. The touch-hole being closed, a perforation, similar in size is drilled in the end of the barrel, at the point from which the flame is, in the figure, represented as proceeding. In order to produce this jet of vaporized sulphur, some cotton wick is wound about the end of a rod, and tied on it. The tuft, thus made, is soaked in melted brimstone. The gun barrel is, during a temporary removal, heated red-hot at the butt-end, where it is perforated. Being screwed into its place again, the rod, armed with the cotton and sulphur, is pushed up into the bore of the barrel. By the heat of the iron, the sulphur is converted into a hot vapour, which issuing in a jet, from the perforation, enters into combustion with the oxygen, in the receiver.

In consequence of the rarefaction of the air, of the bell, B, by the suction pump, the fumes of the burning vaporized sulphur, are drawn through the water, in the vase upon the stand, in which, consequently, a mixed solution of sulphuric and sulphurous acids is produced.

105. LARGE GASOMETER FOR OXYGEN.

The opposite engraving represents a section of my gasometer for oxygen, which is capable of holding between five and six cubic feet of gas. It is represented as it was situated when the drawing was made, in the cellar under my lecture room. It is now placed in the lecture room in front of my table, near one end. The wooden tub, V, is necessarily kept nearly full of water. The cylindrical vessel, T, of tinned iron, is inverted in the tub, and suspended and counterpoised, by the rope and weight, in such manner, as to receive any gas which may proceed from the orifice of the pipe, in its axis. This pipe passing, by means of a water-tight juncture, through the bottom of the tub, is extended to a cock fixed in a cavity made in the plank forming the rim of the pneumatic cistern. Hence by means of this cock, and a leaden pipe soldered to a brass knob, properly perforated, a communication may be established between the cavity of the gasometer, and any other vessel, for the purpose either of introducing or withdrawing gas. In filling this gasometer, the copper vessel and bell glass, used in obtaining nitrous oxide, may be employed advantageously: or the counter-weight being made heavier, than the vessel, by appending additional weight to the ring, K, the gas may be sucked in from a bell glass, (situated over the pneumatic cistern) as fast as it enters the bell, from the generating apparatus.

As the gas displaces the water from the cavity of the vessel, T, the latter becomes more buoyant, and consequently rises. When any gas is withdrawn or expelled, the water resumes its place, and the vesel sinks.

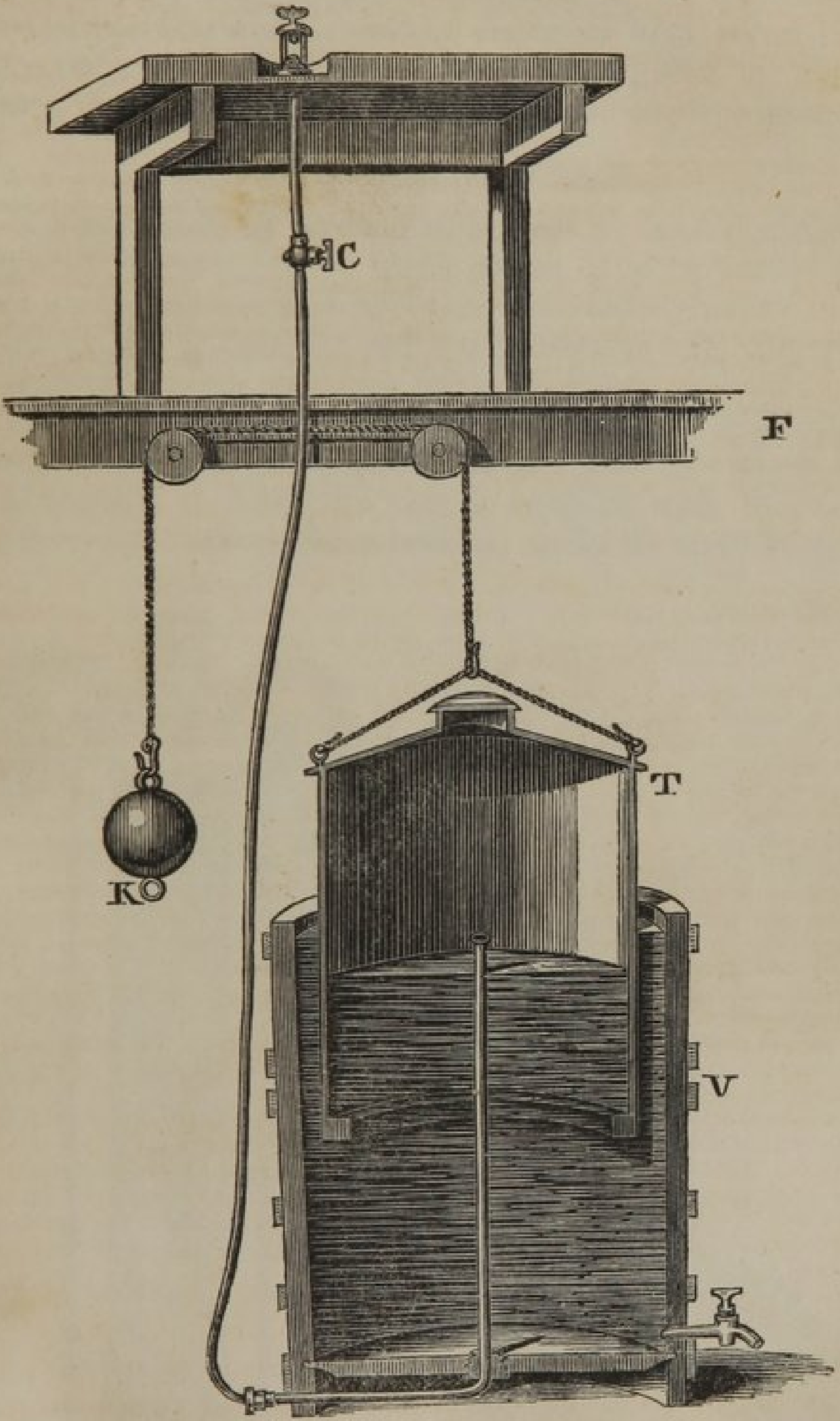
Gasometers which contain 40 or 50,000 cubic feet, have been constructed upon this principle for holding the gas from oil or coal. They are usually hollow parallelepipeds. The upper vessel is generally made of varnished sheet iron, the lower one of brick work or cast iron. The space within the lower vessel, which is included by the upper one, when down, is filled up, so as to lessen the quantity of water required. (See article on carburetted hydrogen.)

OF CHLORINE.

As a gas, chlorine exists only by artificial means; but as an ingredient, in marine salt, in the proportion of three-fifths: it constitutes nearly one-fiftieth of the matter in the ocean; and is widely disseminated throughout the land, as well as the sea. It is also an ingredient in

Gasometer for Oxygen.

(P. 106.)



some of the most active agents, used in chemistry, or medicine. It was discovered by Scheele, and called by him dephlogisticated marine acid. It afterwards received the name of oxygenated muriatic acid, or oxymuriatic acid, from Lavoisier, and the chemists who adopted his nomenclature. Its present name was given by Sir H. Davy, from χλωρος, green—because its colour is greenish.

Means of obtaining Chlorine.

It is obtained by heating in a glass or leaden retort, or alembic, three parts of black oxide of manganese, with four parts of muriatic acid: or the same quantity of the same oxide, with eight parts of common salt, four parts of sulphuric acid, and four parts of water.

Being a gas, it must be received over the hydro-pneumatic cistern, in bell glasses, or bottles. As much of it is absorbed, if it remain long in contact with the water, I generally employ glass bottles, with air tight stopples,

Fig. 1.

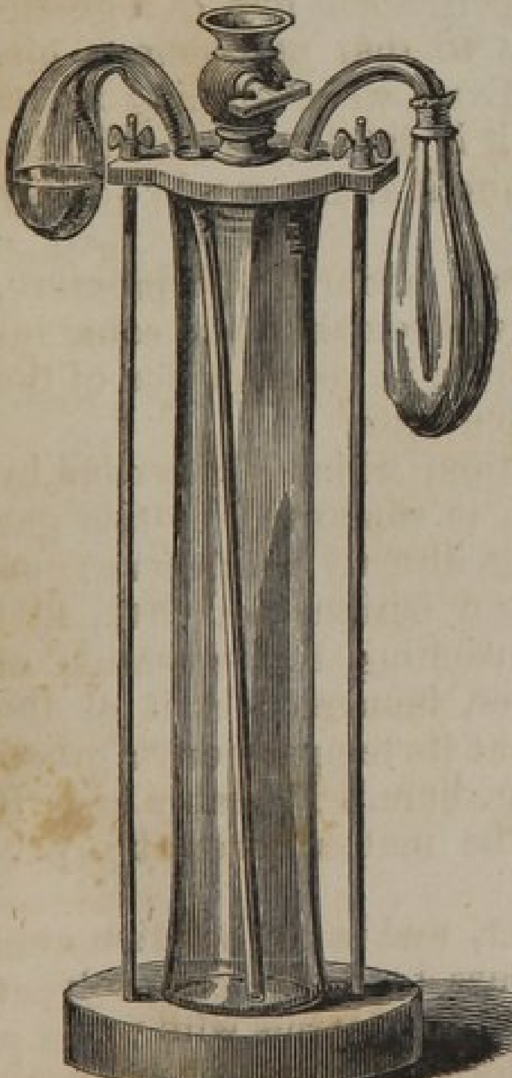


Fig. 2.

in order that they may be removed from the water, as soon as filled.

Berzelius alleges that if the water employed be saturated with salt, there is less absorption.

Jars or bottles may be filled with chlorine gas, by means of a tube or retort beak, as in the figure, reaching from the generating vessel, to the bottom of that into which it is to be introduced. The air is displaced by the chlorine, in consequence of its superior gravity, without any admixture ensuing adequate to interfere with the exhibition of its characteristic properties.

When substances which take fire in the gas, are to be introduced it is expedient that a communication should exist with the inside of a bladder attached as in the preceding figures, which represent apparatus of which fig. 1 may be used for the combustion of metallic powders; fig. 2 for that of phosphorus introduced by means of the ladle, L.

Properties of Chlorine.

When pure and dry, it is a permanent gas, of a greenish yellow colour. Its weight to that of common air, is as two and a half to one. Even when existing in the air, in very small proportion, it is intolerable to the organs of respiration, and to respire it alone, would quickly produce fatal consequences.

Mr. Faraday has shown that, under great pressure, chlorine becomes a liquid. It will remain liquid some instants after all pressure is removed in consequence of the great cold produced by its evaporation.

That species of chemical action, which is attended by the phenomena of combustion, is supported by this gas with great energy. It combines directly with every combustible except carbon. It has a curious property, first noticed by me I believe, of exciting the sensation of warmth—though a thermometer, immersed in it at the same time, does not indicate that its temperature is greater than that of the adjoining medium. Probably heat is produced, by a reaction with the matter insensibly perspired.

Chlorine is absorbed by water, and in the solution acts powerfully on metals. It appears to be the only solvent of gold. At the temperature of 40 it forms with water a solid hydrate, consisting of chlorine 1 atom, of water 10 atoms, of which I shall treat more fully when on the subject of water. Silver, in solution, is the best test for chlorine: and reciprocally, chlorine is the best test for dissolved silver. The compounds of chlorine with mercury, so useful in medicine, will be treated of, when on the subject of that metal. When the aqueous solution of chlorine, is exposed to the solar rays, it forms muriatic acid, with the hydrogen of the water, while the oxygen escapes. It bleaches, by liberating the oxygen of water, and thus enabling it to act on the colouring matter.

Chlorine gas was considered as a compound of muriatic acid and oxygen, and called oxymuriatic acid, till within about 25 years. It is now, generally deemed an elementary substance, rendered gaseous by caloric.

106. EXPERIMENTAL ILLUSTRATIONS OF THE PROPERTIES OF CHLORINE.

Leaves of Dutch gold introduced by means of a glass rod into a bottle of chlorine, take fire.

Effect upon the fingers, compared with that upon a thermometer.

An infusion of litmus whitened in falling through the gas.

A lighted candle introduced.

107. *Combustion of Antimony in Chlorine.*

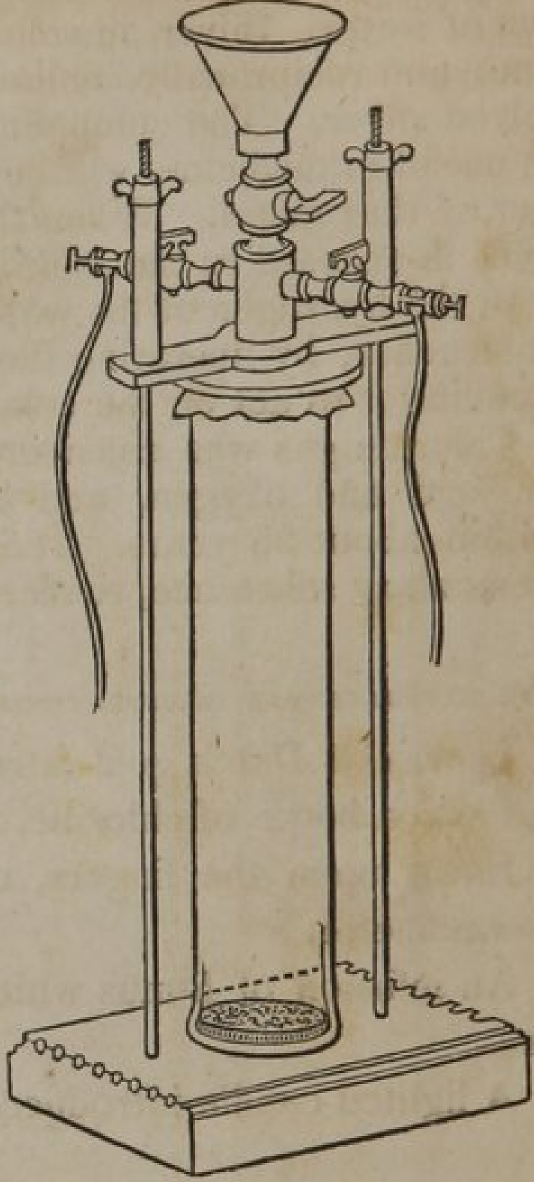
When an air pump is at hand, the following apparatus may be used for the combustion of powdered antimony. It consists of a large jar closed air tight, and supported in the screw rod and plate frame described in article 48, page 41.

By means of one of the flexible pipes and cocks with which the apparatus is furnished, communication may be made with an air pump, and with a large vessel, A B, containing chlorine.

Into the centre of the lid, a cock is fastened, the key of which, instead of being perforated as usual, is drilled only half through, so as to produce an excavation capable of holding a thimbleful of powder.

The cavity in the key of the cock is duly charged with pulverized antimony which, on turning the key half round, falls through the chlorine, and as it falls, assumes the appearance of a shower of fire. The cock being, from its construction, always closed, and the junctures being tight, the spectators are protected from the noxious fumes.

In this experiment, the chlorine forms, with the antimony, a compound, which has less capacity for caloric and light, than its ingredients have separately. Hence, by their combination, the phenomena of combustion are produced.



The antimony is converted into a chloride, called butter of antimony, from its consistence.

108. *Combustion of Metallic Leaf* in Chlorine.*

The apparatus used in this experiment differs but little from the one above represented, being the same as that described in article 41, page 42, excepting the funnel which is unnecessary in this case. See Fig. 1.

Into the lower end of the cock, a rod of iron is screwed fast. This rod is of such dimensions, as to extend from the top to the bottom of the receiver, and is supported within it, so as to be in its axis, or every where equidistant from the surface.

Before fastening the plate into the situation in which it is represented in the figure, it must be lifted in order to attach the leaf metal to the rod, with the aid of gum arabic.

The arrangements being so far completed, the cylindrical receiver having been exhausted by means of the air pump, the cock regulating the communication with that instrument, is to be closed; and the other, which controls the entrance of the gas, is to be opened. By these means, the

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* The metal usually employed is the Dutch gold leaf of the shops, an alloy of copper and zinc principally.

leaves burn splendidly, being simultaneously enveloped in an atmosphere of the chlorine, which rushes in to supply the vacuum caused by the air-pump.

Another method of performing this experiment is illustrated by Fig. 2.

Fig. 1.

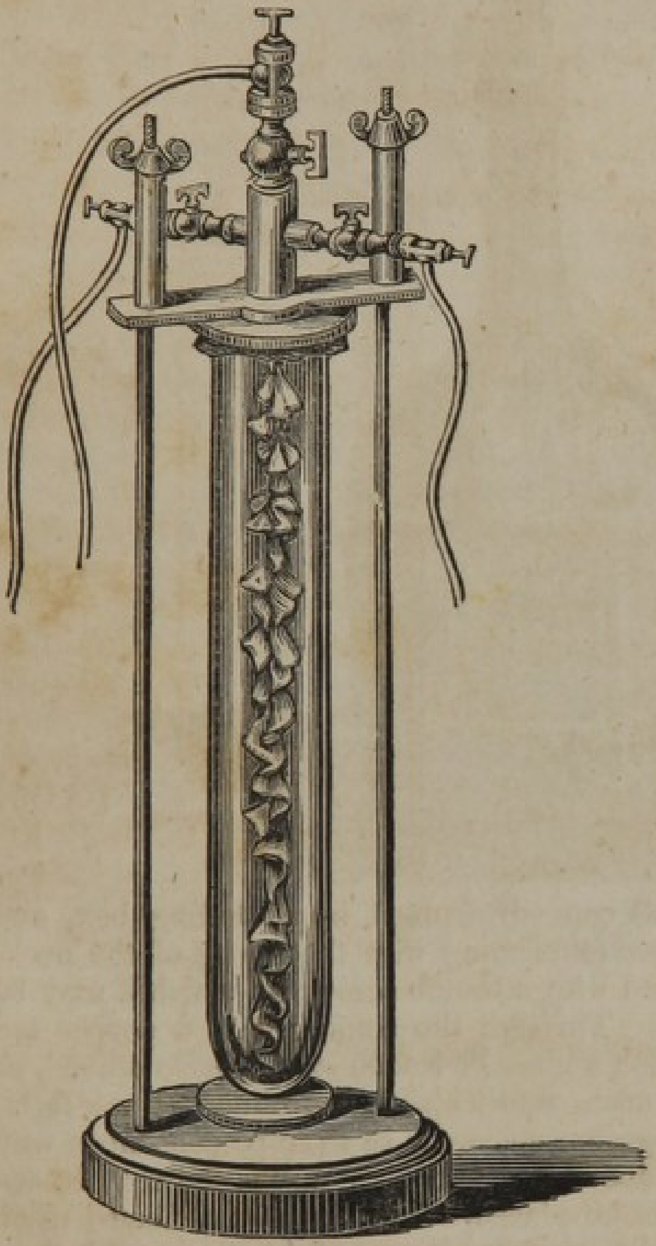

Fig. 2.

The metallic leaves being suspended from the plate which closes the bell, B, and this bell being exhausted of air by means of the pump, chlorine is suddenly admitted into it by the glass cock from the bell glass, A, previously supplied with the gas.

109. SPONTANEOUS COMBUSTION OF PHOSPHORUS IN CHLORINE.

The following figure is intended to convey an idea, of the spontaneous inflammation of phosphorus with chlorine, by means of an apparatus, which enables the lecturer to perform the experiment, without exposing spectators to the fumes.

Let there be a cylindrical glass vessel, (see following figure) eight or nine inches in diameter, and about a foot in height, with a neck about four inches high, and one and a half inches in bore; the whole resembling a large decanter, without a bottom. About the orifice of the neck, let there

be cemented air tight, a brass cap surmounted by a stuffing box, and having on one side a hole communicating with the cavity of the neck. This aperture must be furnished with a thumb screw, by which it may be opened or closed at pleasure. Through the stuffing box, a copper rod passes, at the lower end of which a glass or leaden stopple is so affixed, as to close the lower part of the neck, into which it is ground to fit air tight. Over this stopple, a cup of copper is soldered, so as to be concentric with the rod. The rod terminates above in a handle. Within the cup, let ten or fifteen grains of phosphorus be placed. This is easily effected when the cup and plug are depressed into the lower part of the cavity of the vessel, by a suitable movement of the sliding rod. In the next place draw up the cup and plug into the neck so as nearly, but not entirely to close the neck, and sink the vessel into the water of the pneumatic cistern until all the air below the neck is expelled through the hole in the side of it, which is then to be closed by means of the screw, and the plug twisted and drawn into its place, so as to be air tight. After filling the body of the vessel thus, with water, place it upon the shelf of the cistern. Chlorine may now be allowed to occupy three-fourths of the space within the vessel below the plug. The process being so far advanced, it is only necessary, at the moment when it is desirable to produce the combustion, to depress the plug, and of course the cup associated with it, containing the phosphorus, into the cavity supplied with the chlorine. The phosphorus soon burns actively, although with a feeble light.

The increased temperature consequent to the combustion, causes the gas to expand, but not so much as to become too bulky to be retained

In this case, the chlorine forms a chloride of phosphorus, which meeting with water is decomposed into phosphoric and muriatic acids. By transferring the vessel after it is supplied with chlorine, to a clean porcelain or glass dish, covered by pure water, the products of this combustion might be saved, and would of course increase in proportion to the quantity of phosphorus and chlorine employed. On a larger scale, this process might be resorted to advantageously for the generation of phosphoric acid, which is produced when the proportion of chlorine is sufficient; say four cubic inches for every grain of phosphorus.

*Of the Nomenclature of the Compounds of Oxygen, Chlorine, &c.**

Consistently with the French nomenclature, the combinations formed by oxygen, chlorine, bromine, iodine, and fluorine, with other elements, have been distinguished as *acids*, or characterized by a termination in "*ide*," or in "*ure*," which last monosyllable, when there has been no intention of altering the meaning, has, by the British chemists, been translated into *uret*. The termination in *ide*, which is common to both languages, is, by Thenard, and other eminent French authors, restricted to the binary compounds of oxygen, which are not acid. Analogous compounds formed with the "*halogene*" elements, chlorine, bromine, fluorine, iodine, cyanogen, &c., have by the same writer been designated by the termination in *ure*. Thus we have in his work, chlorures, bromures, fluorures, iodures, cyanures. Some of the most eminent chemists in Great Britain, have distinguished the elements called halogene, by Berzelius, together with oxygen, as supporters of combustion; and have designated the binary compounds made with them, when not acid, by the same termination as the analogous compounds of oxygen. Accordingly in their writings, instead of the names above mentioned, we have chlorides, bromides, fluorides, iodides. In Henry's Chemistry, cyanure is represented by cyanide; in Thomson's, by cyanodide, and in Brande's and Turner's by cyanuret. I shall follow the practice of the British chemists.

The term *uret*, equivalent as above mentioned to the French *ure*, is restricted by the English chemists to the compounds formed by non-metallic combustibles, either with each other, or with metals. Hence we have in English, sulphurets, phosphurets, carburets, borurets, for sulphures, phosphures, carbures, borures, in French.

COMPOUNDS OF CHLORINE WITH OXYGEN.

1 atom or 1 volume of chlorine equivalent 36, forms	With 1 atom, or ½ volume of oxygen, euchlorine or the protoxide of chlorine, - - -	44
	With 3 atoms, or 1½ volumes of oxygen, chlorous acid, - - - - - - -	60
	With 5 atoms, or 2½ volumes of oxygen, chloric acid, - - - - - - -	76
	With 6 atoms, or 3 volumes of oxygen, oxychloric acid, - - - - - - -	84

Some chemists give 4 atoms of oxygen to chlorous acid, and 7 to oxychloric acid.

OF EUCHLORINE, OR PROTOXIDE OF CHLORINE.

Means of obtaining Euchlorine.

It is obtained by heating gently, in a small glass retort, equal parts of

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* Quoted from my letter on the Berzelian nomenclature. See Appendix.

strong muriatic acid, water, and chlorate of potash. The retort should only be subjected to the flame of a small spirit lamp, or an inflamed jet of hydrogen, which should be so situated as not to heat the body of the retort above the part containing the liquid; as this may cause an explosion. It is advantageous to interpose as a support for the retort, a plate of tin, having a circular aperture of about an inch and a half in diameter. By these means, the application of the heat may be sufficiently restricted.

The gas may be received over mercury, although not without inconvenience; since either by its decomposition, or in consequence of some free chlorine with which it is accompanied, the mercury is partially converted into a chloride; or, as it would seem from its dark hue, a subchloride. The compound thus formed, by adhering to the glass, obscures it so that the colour of the gas is seen with some difficulty.

The method, mentioned in the case of chlorine, of conveying the gas into a jar or bottle, through a tube descending to the bottom, whence by its inferior weight the air is displaced, is recommended by Professor Silliman in the case of the gas under consideration; and latterly I have myself resorted to this method with advantage.

RATIONALE.

It may be supposed that in this case the chlorate of potash is converted into a chloride of potassium, and that all the oxygen of the acid and alkali is liberated, making six atoms of oxygen. These six atoms may form three atoms of water with the hydrogen of the muriatic acid, and three atoms of protoxide, with the three atoms of the chlorine of the same acid.

Properties of Euchlorine, or Protoxide of Chlorine.

Euchlorine has a peculiar and suffocating odour, which in some degree resembles that of chlorine, mingled with that of burnt sugar. Its colour is an orange yellow, with a slight tinge of green. It first reddens, and then whitens litmus paper. At the temperature of 100°, its elements separate with great violence, and with the disengagement of light and heat. After explosion, according to Sir Humphry Davy, it occupies one-fifth more space than before. Berzelius, however, alleges that a partial decomposition must have taken place in the experiments of Davy, before the explosion. He estimates the expansion, at one-half the previous volume of the gas.

When mingled with muriatic acid gas, and subjected to a high temperature, it is resolved into chlorine and water. When brought in contact with phosphorus, it explodes. The same effect is produced, after some time, by sulphur. Antimony, or arsenic, in powder, or Dutch leaf, frequently causes it to explode; this effect, however, may be due to the presence of uncombined chlorine.

Incandescent coals, plunged into euchlorine, burn vividly at first, but are afterwards extinguished. This gas is slowly absorbed by mercury. Water absorbs eight or ten times its bulk, acquiring an acrid and almost acid taste, and a yellow colour.

Doubts are entertained whether this gas be not a mixture of chlorous acid with chlorine. Berzelius and Thenard, however, consider it as a distinct gas.

110. EXPERIMENTAL ILLUSTRATIONS.

Euchlorine is generated by the process abovementioned, and collected over mercury. Portions of euchlorine are exploded by Dutch gold, antimony, or arsenic previously heated, and especially by phosphorus.

111. EXPLOSION OF EUCHLORINE.

A convenient and safe method, which I have employed, of effecting the explosion of euchlorine, is represented in the preceding figure. The gas being introduced into a strong tube of about $\frac{4}{8}$ of an inch, in diameter, and fifteen inches, in length, over mercury; on applying a heated metallic ring, an explosion ensues. The gas at the same time loses its greenish yellow colour, and increases in bulk, being converted into half a volume of oxygen, and one volume of chlorine.

The chlorine is subsequently absorbed by the mercury.

Thenard advises the application of a spirit lamp to produce the necessary temperature. It is easier, and more safe, to use the hot ring. The tube must be supported by an iron wire, which has been overlooked in sketching the figure.

RATIONALE.

Agreeably to the idea that aëriform fluids owe their repulsive power to caloric, there ought, after an evolution of heat, to be a reduction of volume in any gaseous compound, but by the decomposition of euchlorine, although caloric is evolved with explosive violence, the volume of the gaseous matter is increased.

The only explanation, which I can give, is that the capacity for caloric of the compound in this case, as in others, is greater than the sum of the capacities of the constituents. Why the capacity of the compound should be greater, and wherefore caloric should be more forcibly attracted by an atom of oxygen and an atom of chlorine when united, than when separate, I cannot explain. This and other analogous mysteries, are no doubt connected with those of electricity, galvanism, and electro-magnetism.

OF CHLOROUS ACID, HERETOFORE CALLED THE TRITOXIDE, QUADROXIDE, OR PEROXIDE OF CHLORINE.

It is obtained over mercury by distilling one part of chlorate of potash, fused into a mass, at the bottom of a small glass retort, with about 3½ parts of concentrated sulphuric acid. The evolution of the gas takes place without heat at first, but to be completed requires a temperature near to 140° F. This should not be exceeded, and the heat should be restricted to the bottom of the retort as in the case of euchlorine. The process is replete with danger, as from slight causes this gas explodes with surprising force.

RATIONALE OF THE EVOLUTION OF CHLOROUS ACID.

By the action of sulphuric acid on chlorate of potash, two compounds are produced, chlorous and oxychloric acid. The former is evolved in the gaseous state, the latter remains in union with the potash. It would seem as if one portion of the chloric acid were displaced from its union with the potash, by the superior affinity of the sulphuric acid, and then relinquished a part of its oxygen to another portion of the same acid, still in union with that alkali. The chlorate of potash is thus partially converted into an oxychlorate. The deoxidized chloric acid constitutes a compound which was heretofore called either a tritoxide, a quadroxide, or a peroxide of chlorine, but which is now, by Berzelius, designated as chlorous acid. It combines when nascent with bases, forming the bleaching or disinfecting salts, heretofore known as chlorides of soda, potash, or lime, and which must now be called chlorites.

Chlorous acid gas has a yellow colour, which is deeper than that of chlorine. Its odour is somewhat aromatic, and bears no resemblance to that of chlorine. It whitens a solution of litmus, without reddening it. When subjected to an electric spark, or at a temperature of 212°, it explodes with great violence, giving out light and heat, and being converted into chlorine and oxygen. Agitating the gas with mercury, will sometimes produce the same result.

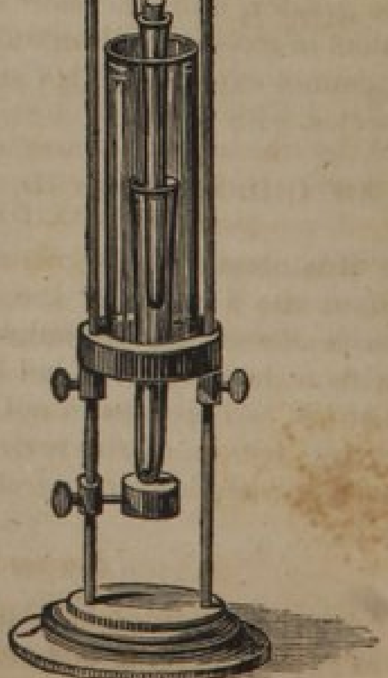
Water absorbs seven times its volume of chlorous acid gas, acquiring a deep yellow colour, and a peculiar acrid taste, which is nevertheless not at all acid. The aqueous solution, when added in small quantities, possesses the power of reddening litmus, and when exposed directly to the sun's rays evolves chlorine, while oxychloric acid remains in solution. In a diffuse light it takes several weeks to effect this decomposition, and it does not take place at all in the dark. Faraday has found that chlorous acid gas may be liquefied by subjecting it to a great pressure. The resulting liquid is of a yellow colour. When this acid is brought in contact with a base, a portion of it is decomposed, and a chlorate, a chlorite, and a chloride are formed.

112. APPARATUS FOR EXHIBITING SAFELY, THE EXPLOSION OF CHLOROUS ACID.

The adjoining figure represents an apparatus for exhibiting, without danger to the spectators, the detonation of chlorous acid.

Into a tube of nearly $\frac{5}{8}$ths of an inch in diameter, and sealed at one end, about as much chlorate of potash is introduced, as will rise above the bottom about one inch. The mass thus situated is to be fused by means of a spirit lamp, or a chauffer.

The tube being thus charged, it is corked gently, and suspended within a stout glass cylinder, as in the drawing. It is then surrounded, near the bottom, by another tube, supplied with boiling water. At first, the hot water is applied only to that part of the tube which contains the salt; but, as soon as the inner tube is pervaded by a greenish-yellow colour, demonstrating the evolution of the chlorous acid, the outer tube containing the water is to be raised, so that the gas may be generally heated by it. An explosion soon



follows, from the influence of which spectators are protected by the glass cylinder.

OF CHLORIC ACID.

Means of obtaining Chloric Acid.

It may be obtained by passing chlorine through water, containing oxide of silver in suspension.

It is also procured by precipitating the potash from the chlorate, by fluohydrosilicic acid, and filtration and evaporation. Should any chlorate remain, it may be removed by alcohol, which afterwards spontaneously evaporates. It was in the first instance discovered by precipitating barytes from the chlorate of barytes by sulphuric acid. In that way it cannot be obtained free from sulphuric acid, as it forms with this acid a compound more difficult to decompose than pure chloric acid. From this it differs also in reddening, without whitening litmus.

Of the Properties of Chloric Acid.

It is an oleaginous liquid—colourless, sour, and astringent. It is inodorous—first reddens and then whitens litmus. It does not precipitate solutions of lead, mercury, or silver. It is partially decomposed by distillation. With muriatic acid, it produces water and chlorine. It dissolves either zinc or iron with a disengagement of hydrogen gas.

Chloric acid is decomposed by a number of combustible bodies, and likewise by sulphurous and phosphorous acids, and sulphuretted hydrogen. Many bodies which do not act upon it in the dark, decompose it in the solar rays.

OF OXYCHLORIC OR PERCHLORIC ACID.

The latter of these names was given by the discoverer, Count Von Stadion, to a compound, containing more oxygen than chloric acid. In the first edition of the Compendium, I mentioned my opinion that oxychloric would be a name more consistent with the received nomenclature. Dr. Bache had expressed the same opinion previously in his Chemistry. Accordingly I find that it is now designated as oxychloric acid by the celebrated Berzelius.

Means of obtaining Oxychloric Acid.

After the chlorous acid has been liberated from chlorate of potash, agreeably to the explanation given, page 115, a portion of oxychlorate of potash remains. This is mingled with the bisulphate of potash formed at the same time, but may be extricated by repeated solution and crystallization, as the bisulphate is more soluble. When the oxychlorate has been thus depurated, the acid may be obtained by a distillation of the oxychlorate in a retort, with its own weight of sulphuric acid diluted with a like weight of water at the temperature of 280° F. It is rendered more pure by carefully precipitating the sulphuric acid which comes over with it by means of barytic water, and redistillation.

Properties of Oxychloric Acid.

According to Berzelius, it exists only as a liquid in combination with water, being limpid, colourless, and having a lively acid taste. It reddens, but does not subsequently bleach an infusion of litmus. It is decomposed neither by the solar rays, sulphurous acid, nor sulphuretted hydrogen. It dissolves zinc and iron with a disengagement of hydrogen. It exercises strong affinities, and is the most enduring of the combinations of chlorine with oxygen; which is the more surprising, as it is in general true that in proportion as any one ingredient predominates in a compound, it is the more easily separated in part.

OF BROMINE.

This name has been given to a substance analogous to chlorine, from the Greek βρωμος, fetidity.

Bromine was discovered by Balard in 1826, in the mother water of marine salt, at the salt works of Montpellier in France. Since then it has been found in the water of the Dead Sea, and in the greater part of the salt springs of the continent, especially those of Germany. In those of Theodorshalle near Kreuznach, a sufficient quantity has been found, to make it profitable to effect the extraction.

Common salt in its natural state often contains traces of the bromides of sodium or magnesium.

Means of procuring Bromine.

The mother water of marine, or common salt, is impregnated with chlorine, until it acquires a hyacinth red tinge. The chlorine combines with the hydrogen and earth of a hydrobromate of magnesia, which exists in that water. The bromine, thus displaced, mingles with the water, which is to be washed with ether. The resulting ethereal solution of bromine, being treated with potash, a bromide of potassium is produced; which heated in a retort, with diluted sulphuric acid, and manganese, yields bromine, as chlorine is obtained from a chloride by like treatment.

The following process is recommended by Desfosse.

The mother waters containing bromine are to be digested with hydrate of lime, so as to transfer the bromine from the magnesium to the calcium, from which it is less prone to separate during the concentration of the liquid by evaporation. The precipitated magnesia is to be separated by filtration. When sufficiently concentrated, the liquid yields bromine by distillation with manganese and muriatic acid, without resorting to ether.

Properties of Bromine.

Bromine is a liquid, and is so volatile, that a single drop is sufficient to fill a flask with its red brown vapour. The specific gravity of bromine is 2.966, being nearly three times the weight of its bulk of water. It freezes at a temperature of from 7° to 12° below zero. It has, when frozen, a crystalline and leafy texture, with a lead gray colour, and a lustre almost metallic. It boils at the temperature nearly of 89° F., forming a vapour resembling that of nitrous acid, and more than five times as heavy as atmospheric air. It does not conduct electricity. Flame is extinguished in the vapour of bromine, acquiring a greenish colour previous to extinction. Bromine is slightly soluble in water, and its solubility is not sensibly augmented by heat. The solution has an orange colour, and emits red fumes. It is more soluble in alcohol than water, and in ether still more so than in alcohol.

It acts upon vegetable colours like chlorine, and indeed has a similar influence upon organic products generally; as it decomposes them in consequence of its affinity for hydrogen. Bromine combines with starch, producing a yellow compound. It corrodes the skin, producing a yellow tinge, which continues till the skin is renovated. In its habitudes with oxygen, hydrogen, sulphur, and phosphorus, it has a great analogy with chlorine, but generally its affinities are not so strong. When taken internally, bromine acts as a virulent poison. A single drop placed on the beak of a bird has produced death.

Bromine is supposed to be one of the active substances in mineral springs, especially in those which contain common salt. By means of nitric acid bromine may be obtained from the mother water in which it exists as above stated, in the form of a deep brown precipitate; but there is much lost by its solution, and subsequent volatilization, during the evaporation of the solvent.

EXPERIMENTAL ILLUSTRATION.

Bromine exhibited as a liquid and in vapour.

COMPOUNDS OF BROMINE WITH OXYGEN AND CHLORINE.

OF BROMIC ACID.

Bromine forms but one compound with oxygen, called bromic acid, which was discovered by Balard.

Means of obtaining Bromic Acid.

When sulphuric acid is added to bromate of barytes dissolved in water, a sulphate of barytes is precipitated, and bromic acid remains in solution, which may afterwards be concentrated by evaporation. See chlorates.

Properties of Bromic Acid.

Bromic acid thus obtained, is a liquid of the consistence of syrup. If we endeavour to remove any farther portion of the water, the acid is decomposed into oxygen and bromine.

Bromic acid first reddens, and then whitens litmus paper. It has a strong taste, acid but not caustic. Its odour is hardly perceptible. Sulphurous and phosphorous acid, and all the acids which have hydrogen for their radical, decompose it by removing the oxygen. Concentrated sulphuric acid produces the same effect by removing the water, without which bromic acid cannot exist.

Bromic acid is composed of one atom of bromine, 78, and five of oxygen, 40. Its equivalent therefore is 118.

Of Chloride of Bromine.

When a current of chlorine is passed through fluid bromine, a liquid compound is produced of a reddish yellow colour, but not so deep as that of bromine. This liquid is volatile, of an intolerable smell, producing tears; has an excessively disagreeable taste, and a colour resembling that of euchlorine.

Water dissolves this chloride, acquiring the power of bleaching litmus. Bases produce with its ingredients, a bromate, a bromide, and a chloride.

OF IODINE.

It will be seen by the subjoined quotation from Thomson's Inorganic Chemistry, that this element is widely though not copiously disseminated throughout nature.

"Iodine has been detected in various sea plants by Gaultier de Claubry. He found it in fucus saccharinus, fucus digitatus, fucus vesiculosus, fucus serratus, fucus siliquosus, and fucus filum. Davy found indications of the presence of iodine in the ashes of fucus cartilagineus, fucus membranaceus, fucus rubens, fucus filamentosus, ulva pavonia, and ulva linza.

Dr. Fyfe informs us that he found it in the ashes of fucus nodosus, fucus palmatus, fucus digitatus, the ulva umbilicalis, and the common sponge. But he could not detect it in sea water, nor in any land vegetable.

Dr. Carter found it in the sulphureous mineral waters of *Castelnovo d'Asti*, in Piedmont, so celebrated for curing the goitre and other glandular affections. M. Angelini had previously detected it in the mineral waters of Sales, in the same country. M. Boussingault detected it in a yellowish liquid brought from the province of Antioquia in South America, and employed successfully as a cure for the goitre. M. Krüger of Rostock, found it in the mother ley of the Sülzer salt spring in Mecklenburg Schwerin. Dr. Tucker found it in the mineral spring of Bonnington near Leith; and Dr. Daubeny, Professor of Chemistry in Oxford, found it in various salt springs in England.

Iodine exists also in the mineral kingdom. Vauquelin found an iodide of silver in a mineral from Mexico which he analyzed. But he has given no description of the mineral, nor did he determine the proportion of the constituents."

From the experiments of Dr. Steele, it appears that iodine exists in the mineral waters of Saratoga.

Of the means of obtaining Iodine.

It is obtained from the lixivium of kelp, from which carbonate of soda is manufactured. After all the soda has been crystallized, the residuum is concentrated, and being heated with sulphuric acid, in a retort, the iodine passes over, and condenses in shining crystals of an intense purple, or black, colour.

The rationale of this process, is analogous to that for obtaining chlorine by salt and sulphuric acid, excepting that the presence of manganese is not indispensable, sufficient oxygen being imparted in the case of iodine, by the partial decomposition of sulphuric acid into sulphurous acid. But it will be more proper to recur to this subject hereafter, in treating of the chlorides and chlorates, and ioidides and iodates. Although not absolutely necessary, the presence of about one-sixth part of manganese prevents the contaminating evolution of sulphurous acid.

Iodine may be precipitated from the mother water of salts, with which it is naturally associated, by a mixture of eight parts of sulphate of copper, and one of green sulphate of iron. From this precipitate iodine may be obtained by intense ignition in a retort, with an equal quantity of dry peroxide of manganese.

Of the Properties of Iodine.

When solid it is of a bluish-black colour, friable, and almost insoluble. It stains the skin yellow. It fuses at 225° F. and volatilizes at 350° in a beautiful violet vapour, whence it derives its name of iodine from the Greek ιωδης, violet coloured. Its taste is acrid and hot, and continues for a long time in the mouth. According to Orfila, when taken internally it acts as a poison. Iodine is considered as an element. It is incombustible either in oxygen, or atmospheric air; but forms acids severally with oxygen, chlorine and hydrogen, called iodic chloriodic—iodohydric* *acids*. In its habitudes with the

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* The term hydriodic has hitherto been applied to this acid, but Thenard, as well as myself, for reasons which will be given hereafter, calls it iodohydric acid.

Voltaic pile, it is more electro-negative, than any other matter, excepting oxygen, chlorine, and probably fluorine. With starch, (fecula,) iodine produces an intensely blue colour; so that these substances are reciprocally tests for each other. When moistened it vaporizes perceptibly, producing an odour similar to that of chlorine, but which yet has a peculiar character. The specific gravity of iodine, in a state of solidity, is 4.946.

The vapour of iodine is the heaviest aeriform substance known, being 8.716 or nearly nine times as heavy as atmospheric air. In condensing it is peculiarly prone to crystallize, assuming the form of an elongated octaedron, with a rhomboidal base. Water does not dissolve more than $\frac{1}{7000}$ of its weight, acquiring a russet colour, but no taste. When the water has a salt added to it, especially muriate, or nitrate of ammonia, it dissolves a larger quantity of iodine. The aqueous solution does not give out oxygen in the solar rays, nor destroy vegetable colours. It has in other respects a great analogy to chlorine, and bromine, though more feeble in its affinities than either.

Soubeiran recommends, that in order to apply starch as a test for iodine, the liquid to be essayed should be rendered slightly acid by means of nitric acid. After this addition, and that of the starch, it will in the course of an hour, acquire successively a reddish tint, a brownish red, a blue, and finally a black colour; or, in other words, the blue by its intensity, becomes equivalent to black.

It has been alleged that in this way iodine may be detected in a liquid of which it forms only the $\frac{1}{45000}$th part.

Another mode is to include the liquid to be tested in a bottle made air tight by means of a cork, from which is suspended a piece of moist paper sprinkled with starch finely powdered. If iodine be present, it will tinge the starch. It is alleged by Baup that iodine may be thus discovered, when existing in a liquid, in a proportion no greater than that of a millionth.

Balard recommends that after boiling the liquid with a small quantity of starch, a solution of chlorine in water be added, by means of a tube descending to the bottom. The chlorine, at the line of contact, disengages the iodine from its combinations and enables it to act upon the starch. I resorted to a similar process, fifteen years ago, using sulphuric acid in the manner in which the chlorine is employed by Balard.

113. EXPERIMENTAL ILLUSTRATIONS.

A glass sphere, containing iodine, on being warmed, appears filled with a violet coloured vapour.

To a large glass vessel, containing some boiled starch diffused in water, a small quantity of iodine being added, the fluid becomes intensely blue.

PROCESS FOR THE EXTEMPORANEOUS EVOLUTION OF IODINE.

Heat to the temperature of ebullition nearly, about two ounces of concentrated sulphuric acid, in a glass globe like that represented in the following figure.

It is preferable to have the whole of the globe heated by suspending it, with due caution, over a large charcoal fire. Then quickly transferring it to the iron tripod, previously heated, and furnished with a small bed of hot sand, throw into the acid about half a drachm of iodide of potassium, or sodium, sometimes called hydriodate of potash or soda. Instantaneously the cavity of the globe will become replete with the splendid violet vapour of iodine, which will soon after condense on those portions of the glass which are first refrigerated, in crystals symmetrically arranged, of great beauty, and unusual size.

It is perhaps more convenient, as respects the manipulation, to have the globe suspended by a crane like that used for the suspension of large kettles, rendering it easy by a circular motion to swing them on or off the fire. By similar management the globe may be first kept over the fire till sufficiently hot, and then swung off to receive the salt. A method more attainable in the small way, is that of placing the vessel employed in a small iron skillet, in which it may be made steady by sand. Thus prepared, it may in the first place be conveniently held over the fire, and afterwards transferred to a table and supported without removing it from the skillet.

OF IODIC ACID.

When iodine is subjected to a current of chlorous acid gas, previously dried by passing over chloride of calcium, the gas is absorbed, and a yellow liquid produced. From this, heat expels all the chlorine of the acid, while its oxygen uniting with the iodine forms with it iodic acid.

Of the Properties of Iodic Acid.

Iodic acid is an inodorous crystalline solid, much heavier than water, with an acid and astringent taste. It deliquesces in moist air, but remains unaltered when the air is dry. In water it is soluble, but is precipitated from it by alcohol, in which it is insoluble. Its aqueous solution first reddens and then whitens litmus.

Salts are formed by it with a great number of salifiable bases, which detonate if mingled, and ignited with any dry combustible matter. In common with bromic acid, it is decomposed by those acids which have hydrogen for their radical, and by many others which have not their highest proportion of oxygen. It contains one atom of iodine, and five of oxygen.

OF HYPERIODIC, AND IODOUS ACID.

An acid containing more oxygen than iodic, has been recently discovered by Magnus, to which the name of hyperiodic has been given. But little has been ascertained respecting its properties. Sementini has asserted that he has discovered two additional compounds of oxygen with iodine, one of which he calls oxide of iodine, the other iodous acid. Their existence, however, requires farther confirmation. Consistently, the name of the acid called hyperiodic, should be oxyiodic acid.

OF THE CHLORIDES OF IODINE.

According to Thenard, chlorine forms with iodine a protochloride and a perchloride. The former contains one atom of each ingredient, the latter consists of five atoms of chlorine and one of iodine.

The protochloride is the chloriodic acid of Davy.

To the perchloride the name of perchloriodic acid may be due. Thenard awards the appellation of acid to neither.

Chloriodic acid is obtained by subjecting iodine in excess to the action of chlorine. A liquid is produced of a deep reddish-brown colour, much heavier than water, and having in its mechanical properties a great analogy to bromine. It has an acid taste, and reddens litmus. Water dissolves it without sustaining or causing any decomposition; but abandons it to sulphuric ether. If the abovementioned process be so varied, as to have an excess of chlorine, perchloriodic acid is produced, which is a crystalline and volatile substance of a yellowish-white colour, and emitting an effluvium so irritating, as to produce tears and a sense of suffocation.

OF THE BROMIDES OF IODINE.

Bromine combines with iodine in two proportions. A protobromide is obtained when this last mentioned substance is subjected in excess to the action of bromine. It is solid, and when warmed affords reddish-brown vapours, which condense into crystals of the same tinge, in shape resembling fern leaves. By the same process, when the proportions are reversed, a perbromide results; which is a liquid. Both of these bromides are soluble in water, and bleach without reddening litmus. Subjected to the action of the Voltaic pile, bromine goes to the positive, iodine to the negative pole.

OF FLUORINE.

By many chemists, the existence is inferred of a principle, called fluorine, which is conceived to be very analogous to chlorine, and even more active in its properties. I have no doubt of the existence of fluorine.

Fluorine exists in small proportions in mica, hornblende, paranthene, and in almost all the native phosphates. Traces of it are found in the teeth and bones of animals. It is capable of combining with phosphorus and sulphur. These combinations are obtained by distilling fluoride of mercury, or lead, with sulphur or phosphorus in vessels of platinum. A sulphuret or phosphuret of mercury or lead, and a fluoride of sulphur or phosphorus, are produced. These are fuming liquids.

The fluoride of phosphorus is capable of combustion in oxygen; in which case phosphoric acid and gaseous fluorine, have been supposed to result. Sir Humphry Davy supposed that fluorine might be isolated by these means.

I shall however defer, for the present, giving any farther account of this principle; as the intricate combinations in which it exists, will be more easily understood, when the student has acquired a knowledge of the substances with which it is united.

OBSERVATIONS RESPECTING NOMENCLATURE AND ARRANGEMENT.

It has been mentioned* that chlorine, bromine, iodine, fluorine, and cyanogen, are by Berzelius classed as halogen or salt-producing bodies; while oxygen, sulphur, selenium, and tellurium, are classed as amphigen bodies, or such as produce both acids and bases. Moreover, in explaining the order to be pursued in treating of ponderable substances, I manifested my disapproval of that classification,* my objections being given more fully in a letter on the Berzelian nomenclature, which will be found in the Appendix. I have also suggested, page 98, and in that letter, that it would be preferable to associate as basacigen bodies, or such as produce both acids and bases, all that are comprised in both of the classes above mentioned.

Having commenced with a basacigen body, oxygen, I have proceeded to others of the same character, in obedience to considerations which have been stated.* The analogy which caused them to be associated, also renders it advantageous to treat of them in immediate succession.

Agreeably to the order prescribed by analogy, cyanogen might in the next place be an object of attention, but is postponed for reasons already given. I have mentioned sulphur as one of the bodies, which I would

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* Page 98.

comprise in the basacigen class. Both on account of this, of its analogy with oxygen, and with the halogen bodies of which I have been treating, and in consideration of the importance and variety of its combinations, I shall treat of sulphur next. Afterwards I shall proceed with selenium and tellurium, in consequence of their analogy to sulphur.

The rules of nomenclature quoted, page 113, from my letter on the Berzelian nomenclature, and observed in treating of the compounds of oxygen and of the halogen bodies, will be considered as extending to all the basacigen class. Of course the compounds of sulphur, selenium, and tellurium, when not acid, should have appellations terminating in ide. In lieu therefore of sulphuret, selenuret, or telluret, I shall employ the words sulphide, selenide, and telluride.

I will here quote another passage from the letter on nomenclature in the Appendix, hoping that it will be intelligible to the student who shall have read the preceding part of this work, and serviceable in making him acquainted with the definition of acids and bases, which I believe to be correct.

"Berzelius classes as electronegative, 'all those substances which go to the positive pole when isolated, or *when in union with oxygen;*' while all substances are by him treated as electropositive which go to the negative pole, either when isolated, or when in union with oxygen.

"According to his nomenclature, when both the ingredients in a binary compound* belong to the class of bodies, by him designated as electronegative, the termination in ide, is to be applied to the more electronegative ingredient; but where one of the ingredients belongs to his list of electropositive bodies, the termination in ure, (uret, in English) is to be applied to the electronegative ingredient. As, agreeably to the prevailing nomenclature, which in this respect, the great Swedish chemist has not deemed it expedient to change, the electropositive compounds of oxygen with radicals, forming electropositive bases, have each a termination in ide, it seems that consistency requires us, conformably with the English practice, to designate in like manner analogous electropositive compounds of the electronegative elements called by him '*halogen.*' But especially it would be inconsistent not to put the same mark upon the compounds of substances which from their analogy with oxygen are placed in the same '*amphigen*' class. If there were insuperable reasons for retaining the term oxide, as a generic name for the electropositive compounds of oxygen, it seems to me inexpedient not to employ the words sulphide, selenide, and telluride, to designate the electropositive compounds of sulphur, selenium, and tellurium. And since the three last mentioned elements when united with hydrogen, form electronegative compounds which act as acids, why not treat them as such, under appellations corresponding with those heretofore used for that purpose?

"I conceive the following definitions to be justified by the practice of modern chemists in general, as established in the case of oxacids and oxibases. *When two compounds capable of combining with each other to form a tertium quid, have an ingredient common to both, and one of the compounds prefers the positive, the other the negative pole of the Voltaic series, we must deem the former an acid, the latter a base.* And again, all compounds having a sour taste, or which redden litmus, should be deemed acids in obedience to usage."

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* Berzelius considers a body containing only two elements a binary compound.

OF SULPHUR.

Sulphur is a mineral production, well known in commerce under the name of brimstone. It is sold both in rolls and in flowers. It is found pure in the vicinity of volcanoes, of which it is a product. In combination with metals, it is widely disseminated. From some of its metallic compounds, which are known under the name of sulphurets, or pyrites, it is sublimed by heat, and in condensing, assumes the pulverulent form, to which the name of flowers has been given.

Properties of Sulphur.

Sulphur is yellow, odorous, and insipid; becomes electric by friction, and when warmed within the hand, is fractured with a slight noise. It evaporates and burns with a feeble flame at 180°, and melts at 225°, and by pouring out the liquid portion, after the mass is partially congealed, it may be obtained in crystals. In close vessels at the temperature of 600° it vaporizes, and condenses in the well known form of flowers. The flowers are by the microscope ascertained to be crystalline, and are generally contaminated by a minute portion of sulphurous acid, which may be removed by repeated washing.

All the metals when presented, in thin leaves or powder, to the vapour of sulphur without access of air, enter into combustion with it, forming compounds which have been designated as sulphurets; but which, as I have stated, ought to be called sulphides. Combustion also ensues when the metals in a divided state are heated with sulphur. The sulphides formed with the metals of the earths and alkalies, are soluble in water. From the resulting solution the sulphur is thrown down by acids. Like phosphorus, sulphur is susceptible of a slow, as well as quick combustion. In consequence of the low temperature at which it is capable of becoming converted by combustion into sulphuric acid, sulphur may be burned out of gunpowder without causing it to flash. If raised to the temperature of 369°, it enters into a more active reaction. The products of the combustion of sulphur are sulphurous acid, mingled with a small portion of *anhydrous* sulphuric acid. Berzelius alleges that when sulphur is rubbed on any body, a brick for instance, which has been previously warmed, though not sufficiently to inflame the sulphur, an extremely feeble blue flame is produced with a peculiar odour. This flame he conceives to be the effect of the evaporation unaccompanied by any combustion, "since a cold body held above it is covered with the flowers of sulphur unchanged." This reason, however, appears insufficient; since the sublimation of one portion of the sulphur does not demonstrate that another is not oxydated, any more than the deposition of carbon upon a cold body exposed to a smoky flame, proves that another portion of carbon arising from the same source, cannot at the same time be converted into carbonic acid, as is known to be the fact.

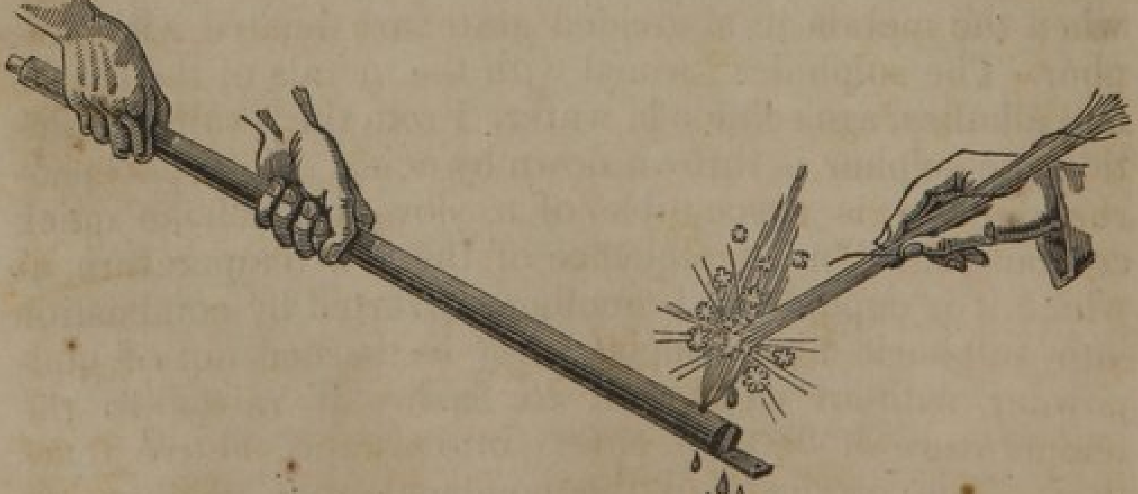
Some very curious anomalies have been observed, respecting the phenomena of sulphur when kept over the fire after fusion, which the limits prescribed to this work, will not allow me to introduce.*

EXPERIMENTAL ILLUSTRATIONS.

Sulphur exhibited in flowers, and in rolls, also crystallized, as above mentioned.

Combustion of Dutch gold leaf, and of an iron bar, by sulphur. Iron wire converted into a sulphide, by the vapour of sulphur emitted in a jet from the touch-hole of a gun barrel, made red hot in the vicinity of the aperture.

114. THE COMBUSTION OF IRON, BY A JET OF VAPORIZED SULPHUR, ILLUSTRATED.



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* Berzelius, Vol. I. p. 250.

If a gun barrel be heated red hot at the but-end, and a piece of sulphur be thrown into it, on closing the muzzle with a cork, or blowing into it, an ignited jet of vaporized sulphur will proceed from the touch-hole. Exposed to this, a bunch of iron wire will burn as if ignited in oxygen gas, and will fall down in the form of fused globules, in the state of protosulphuret. Hydrate of potash, exposed to the jet, fuses into a sulphuret of a fine red colour.

COMPOUNDS OF SULPHUR WITH OXYGEN.

One atom of sulphur, 16,	With one atom of oxygen, forms hyposulphurous acid, equivalent - - - - - - - -	24
	With two atoms of oxygen, forms sulphurous acid, equivalent - - - - - - - -	32
	With three atoms of oxygen, forms sulphuric acid, equivalent - - - - - - - -	40
Two atoms of sulphur, 32,	With five atoms of oxygen, form hyposulphuric acid, equivalent - - - - - - -	72

OF HYPOSULPHUROUS ACID.

This acid exists only in combination with salifiable bases, and of these, I believe no useful application has been made. Any attempt to explain the method in which hyposulphites are produced, will be deferred until I reach the subject of the compounds formed by acids, with metallic oxides.

OF SULPHUROUS ACID.

Means of obtaining Sulphurous Acid.

It is formed by the ordinary combustion of sulphur, or by boiling sulphuric acid on sulphur, on mercury, or on any other substance by which it may be partially deoxidized.

Properties of Sulphurous Acid.

Sulphurous acid is a colourless gas, producing the well known odour of burning sulphur. It is incapable of supporting combustion, and is deleterious to life, a spasmodic closure of the glottis following any attempt to respire it.

It first reddens, and then bleaches litmus; and destroys vegetable colours generally. It is used on this account, to bleach silk and wool. Sulphurous acid is soluble in water, which absorbs 43 times its bulk. When a solution of this gas is exposed to the air, it absorbs oxygen, and is converted into sulphuric acid. This acid, with four times its bulk of water, forms a crystalline hydrate, which melts under 40°, disengaging the greatest part of the acid. When exposed to a temperature of 12°, sulphurous acid gas condenses into a colourless, transparent liquid, having the specific gravity of 1.45. When dropped in vacuo on the bulb of a spirit thermometer, previously at 50°, and surrounded with cotton, the intense cold of — 90° will be indicated. It is even said, that alcohol has been frozen in this manner. Sulphurous acid gas is decomposed at a red heat, by hydrogen and carbon. It is displaced from its combinations by all the acids except cyanhydric (prussic) and carbonic acid.

115. *Impregnation of Water with Sulphurous Acid, by Means of an appropriate Apparatus.*

Into the open neck of a tall receiver, a recurved pipe is fastened, so as to descend a few inches below the neck. The other end of the pipe terminates in a brass socket, into which is inserted the stem of an inverted glass funnel. The receiver is placed over the shelf of the pneumatic cistern, covered about an inch deep with water, and includes a stand supporting a tumbler of the same liquid. A pipe, extending from a suction pump, rises within the receiver, nearly as high as the stand. If, under these circumstances, the pump be put into action, the consequent exhaustion of the air, from the receiver, causes a rise into it of the water from the cistern, until the resistance which this water opposes to a further elevation is greater than that opposed by the water in the tumbler, to the entrance of air from the recurved pipe communicating with the funnel. The air of the funnel will then be drawn into the receiver, through the liquid in the tumbler; and, if sulphur, carbon, phosphorus, a candle, lamp, or any inflammable gas, be placed while burning under the funnel, the fumes may be made to pass through the water, which may be coloured by litmus, or may contain lime, ammonia, barytes, or any other desirable agent, which it may be capable of dissolving or suspending.

OF HYPOSULPHURIC ACID.

This acid is obtained by passing sulphurous acid gas through peroxide of manganese suspended in water in a finely divided state. If the mass be kept cold, the peroxide is reduced to the state of protoxide, while the oxygen forms with the sulphurous acid, hyposulphuric acid. This, with the protoxide, produces a salt, which, remaining dissolved, may be purified by crystallization. By the addition of sulphuret of barytes, to a solution of the resulting crystals, the manganese is precipitated, and a hyposulphate of barytes is obtained. From this salt the hyposulphuric acid may be separated by sulphuric acid, and concentrated by evaporation in vacuo, till it acquires the specific gravity of 1.347. By heat or farther concentration, it is decomposed into sulphurous and sulphuric acid.

Hyposulphuric acid is a colourless, inodorous liquid, which reddens litmus, has an acid taste, and dissolves zinc, with a disengagement of hydrogen.

OF SULPHURIC ACID.

Sulphuric acid has been known since the close of the

15th century, when it was obtained by Basil Valentine, by the distillation of green vitriol, or sulphate of iron.

Means of obtaining Sulphuric Acid.

This acid may be obtained, by burning sulphur and nitre, in chambers lined with lead, or by the process abovementioned, by which it was originally obtained; whence the almost obsolete name, oil of vitriol. It is best purified by distillation.

I shall defer for the present the illustration of the process for procuring sulphuric acid, by sulphur and nitre; also any exemplification of its habitudes with other bodies.

Properties of Sulphuric Acid.

It is a liquid, oleaginous in its consistency—caustic, when concentrated—intensely acid, when dilute. When three parts are added to one of water, a boiling heat is produced. (See 61.) Hot water explodes with it as with a melted metal. It is diluted by the absorption of moisture, when exposed to the air. No acid equals it in the power of reddening litmus. When pure it is colourless, and has but little smell.

OF THE SULPHURIC ACID OF NORDHAUSEN, AND OF ANHYDROUS SULPHURIC ACID.

The sulphuric acid of Nordhausen, differs from that in use in this country, in containing a portion of acid free from water, and therefore called anhydrous. This anhydrous portion being volatile, assumes the form of vapour; and meeting consequently with the moisture of the air condenses, producing white fumes.

Of the means of obtaining, and of the Properties of the Sulphuric Acid of Nordhausen; and of Anhydrous Sulphuric Acid.

The fuming acid of Nordhausen, is obtained by calcinement and distillation from sulphate of iron, (known also by the name of green vitriol) by means of retorts of stone ware. It may be obtained also from white vitriol, or sulphate of zinc, by similar treatment. The anhydrous acid may be separated from the other portion, by gentle distillation, with the aid of a refrigerated receiver, previously well desiccated. It is a crystalline body resembling asbestos, and may be rubbed between the fingers like wax, without their being attacked. In the air it emits thick fumes having an acid smell. At a temperature above 64° it is liquid. Once congealed it cannot be fused without great care, as the temperature at which it is vaporized, is but little above that at which it liquefies. Hence it is apt to undergo a sudden enlargement of bulk which causes it to be thrown out of the containing vessel. When vaporized it forms a colourless gas. Neither in this state nor in its crystalline form, has it any effect on litmus paper rendered perfectly dry. When passed through a red hot tube of porcelain, it is resolved into oxygen, and sulphurous acid.

Either caustic lime, or barytes, enters into a species of combustion with this gas, forming with it a sulphate.

The solid anhydrous acid thrown into water, produces a commotion resembling the effect of a hot iron, and when mingled with an equivalent proportion of water, explodes with a force sufficient to fracture a glass vessel.

The fuming acid of Nordhausen is of use for the solution of indigo used in dyeing, as the anhydrous acid answers better for this purpose than the aqueous.

It combines chemically in four different proportions with water. The compound containing the least water, is formed in some of the processes for producing the acid of Nordhausen. It is a crystalline body, which probably consists of 2 atoms of anhydrous acid and 1 of water. Four parts of the anhydrous acid and about 1 of water, form the concentrated acid of the shops of a specific gravity of 1850; and which is considered as containing 1 atom of water to 1 of acid. When the acid is to the water as 4 to 2 a compound results of which the density is greater than that of the mean density of the constituents, which probably consists of 2 atoms of water to 1 of acid, and which crystallizes at 40°. A similar alteration of the density follows the addition of water until the specific gravity of 1632 is attained. Thus the fourth compound is designated, since beyond that point no condensation takes place by further dilution, it may be inferred, that the water subsequently added, merely acts in the capacity of a solvent.

OF THE CHLORIDES OF SULPHUR.

According to Thenard there are two chlorides, which are both liquids. One contains 2 atoms of sulphur to 1 of chlorine; the other an atom of each ingredient. The protochloride is a yellow viscid oleaginous liquid, heavier than water, and which boils at 280°. The other is reddish brown, volatile, fuming and acrid, and boils at 147°. Both are decomposed by water and alcohol.

OF THE BROMIDE AND IODIDE OF SULPHUR.

The flowers of sulphur dissolve in bromine, producing a reddish oleaginous fuming liquid. When iodine is heated gently with sulphur, it forms a brilliant crystalline iodide, of a steel gray colour.

[illegible] On Object of Scientific

OF SELENIUM.

In 1817, Berzelius, examining, in concert with Gahn, the old method of preparing sulphuric acid, as practised at Gripsholm, in Sweden, a sediment was found in the acid, partly red, partly brown, which treated by the blowpipe, produced the odour of a rotten radish, and left a minute portion of lead. The odour thus evolved, had been by Klaproth, treated as an indication of tellurium. In consequence, Berzelius took care to collect all the deposition produced by the manufacture of sulphuric acid, during some months; no other sulphur than that of Falun, being employed. The discovery of a new substance resulted, to which he gave the name of

Selenium, from a Greek word σεληνη, the moon, suggested by its analogy with tellurium, named from tellus, the earth.

Selenium seems much distributed throughout nature. In Sweden, it has been found combined sometimes with copper and silver, sometimes with copper only. A small quantity has been detected in cubic galena. In Norway, it has been discovered united with tellurium and bismuth; in the Hartz, combined with lead, copper, and mercury. Stromeyer has found it in the Lipari Islands, combined with sulphur.

Means of obtaining Selenium.

From the deposition in which it exists, as above stated, selenium is extricated by solution in aqua regia, precipitation by sulphuretted hydrogen, solution in the same solvent, precipitation by potash, filtration and evaporation of residual liquid, desiccation of resulting mass, and sublimation with the addition of sal ammoniac. Selenic acid is produced by the action of the oxygen in the aqua regia, is saturated by the potash, and afterwards deoxydized by the hydrogen of the ammonia in the sal ammoniac employed, the selenium being sublimed by the heat.

Properties of Selenium.

On cooling, after distillation, it assumes a shining surface of a deep reddish brown, with a metallic brilliancy resembling that of the bloodstone, (hæmatite.) Its fracture is conchoidal, vitreous, of a lead gray, with metallic lustre. Very slowly refrigerated after fusion, its surface becomes granulated and uneven, of a reddish gray, devoid of lustre. By quick refrigeration, the characters above indicated result. Selenium has little tendency to crystallize, yet it is capable of separating in a crystalline pellicle, or of forming in a vegetation upon the sides of the vessel from its solution in the state of a selenhydrate. When precipitated cold, from a diluted solution, whether by zinc or sulphuretted hydrogen, it is red, like cinnabar. But if this precipitate be boiled, it turns black, and consolidates, becoming heavier. When pulverized, selenium becomes of a deep red, and likewise when in very thin layers. With heat it softens, and at the boiling point of water, acquires a semifluidity, becoming completely fluid at a temperature somewhat higher. In cooling it remains soft for a long time, and may, like heated sealing wax, be drawn out into filaments. These, by reflected light, are gray, with some metallic brilliancy, but by transmitted light, are transparent and of a ruby red.

When selenium is heated nearly to redness, in a distillatory apparatus, it assumes with ebullition, the form of a vapour of a yellow colour, deeper than the hue of chlorine, yet lighter than that of sulphur. This vapour condenses in the neck of a retort, in black drops, which coalesce like those which are formed by the condensation of mercury. When condensed with access of air, selenium appears like a red fume, and is deposited in a state analogous to the flowers of sulphur, but of a cinnabar red colour. The smell of a radish is only perceived, when the heat is sufficient to be productive of oxidation.

Its specific gravity, is from 4.3, to 4.32.

Compounds of Selenium with Oxygen.

Selenium has but a feeble affinity for oxygen; yet forms a volatile oxide, which has the smell either of radish, or decayed radish. It forms also two acids, the selenious and selenic. The latter of these is isomorphous with sulphuric acid, so that the crystals formed by the one, cannot be distinguished from such as are formed by the other, either by ocular inspection, or the goniometer. See page 78.

The selenious acid is procured by the combustion of selenium in oxygen gas, or by the action of nitric, or nitromuriatic acid.

The selenic acid is obtained by the deflagration of nitre with selenium in a hot crucible; a seleniate of potash results, which is decomposed by a nitrate of lead, and the resulting seleniate of lead is decomposed by sulphuretted hydrogen. The sulphuret of lead precipitates, while selenic acid is dissolved in the water employed. When heated to 280 degrees, it attains its highest concentration; and at 290 degrees, is decomposed into oxygen and selenious acid.

The highest specific gravity of selenic acid is 2.6. It resembles sulphuric acid in its consistency, in its evolving heat by dilution with water, and in the power of dissolving iron, or zinc, with the evolution of hydrogen. It cannot be rendered anhydrous. When its density is at a maximum, it contains 16 per cent. of water. With the aid of heat, it oxydizes and dissolves copper and even gold, but not platinum. With chlorohydric acid, it constitutes a sort of aqua regia, which dissolves both platinum and gold. Its salts cannot be distinguished from the sulphates, unless by the property of detonating with carbon at a red heat, and that of causing an evolution of chlorine, when boiled with muriatic acid. Selenic acid may be separated from sulphuric acid, by saturation with potash, and ignition with sal ammoniac. The selenic acid is decomposed into selenium by the hydrogen of the ammonia.

Selenium combines with chlorine, and bromine, and with sulphur in every proportion.

ON THE QUESTION WHETHER SELENIUM IS A METAL.

As there is not one of those substances which have decided pretensions to the metallic character, which is not an excellent conductor of both heat and electricity, and as metallic brilliancy is another striking attribute of the metallic genus, I cannot understand wherefore selenium, which is admitted to be destitute of the two first mentioned characteristics, and to possess the last imperfectly, should be received into the class of metals; while carbon, which in the form of plumbago, is endowed with them all, is excluded. I cannot consider selenium as a metal. It is stated to have the brilliancy of hæmatite, which is, I conceive, inferior to that of plumbago, which Berzelius considers as pure carbon.

OF TELLURIUM.

A metal has been found in the veins of auriferous silver in the mines of Transylvania, which has been called tellurium. It is found also in small quantities in Norway, united to selenium. Tellurium has likewise been discovered in Connecticut.

Tellurium displays a metallic brilliancy, and is of a colour between that of tin and antimony, and of a lamellated structure. It is found chiefly in the state of an alloy with gold and silver. It fuses below a red heat, and above that temperature is volatilized. When heated before the blowpipe, it takes fire, and burns with a blue flame bordering on green, and is dissipated in gray pungent fumes, which have sometimes the smell of horse radish. This smell is ascribed by Berzelius to the presence of selenium.

Tellurium may be oxidized, either by combustion or nitric acid. The oxide exposed before the blowpipe, upon charcoal, is decomposed with explosive violence.

Berzelius alleges that it will dissolve in concentrated sulphuric acid without being oxidized, in which it differs from other metals. The colour of its solution in the acid is purplish red. Tellurium is more especially entitled to our notice by its great analogy to sulphur and selenium, and by its forming both acids and bases which, uniting, form telluri-salts. This is the ground upon which it has been included in his amphigen class by Berzelius, and upon which I have included it among the basacigen bodies.

Basacigen Elements all treated of—Consideration of Basacigen Compounds deferred—Reasons for giving attention to Hydrogen in the next place.

The student will observe that, with the exception of such *halogen* and *amphigen* bodies as are compounds, I have now treated of all comprised by Berzelius in those classes; and which I comprise in the *basacigen* class. There are perhaps two compounds entitled to be considered as basacigen bodies; I mean cyanogen, and sulpho-cyanogen. These will be noticed as compounds, in due time.

Nitrogen, an elementary substance of which I shall soon treat, has some pretensions to be viewed as a basacigen body. I deem it better, however, to defer any explanation of the grounds upon which I entertain this opinion.

It might seem of little importance whether in the next place I proceed with hydrogen, or nitrogen; since neither is by any striking analogy entitled to follow the ponderable substances of which I have been treating, while both, by the importance of their associations with them, and especially with oxygen, have pre-eminent claims to be the next objects of attention. From an indisposition to deviate unnecessarily from the order heretofore pursued in the Compendium, I shall give precedency to hydrogen.

OF HYDROGEN.

In its gaseous state, it is the principal constituent of all ordinary flame. Combined with oxygen, or carbon, or both, it is found in water, and all vegetable and animal substances. It derives its name from υδωρ, water, and γινομαι, to produce.

Means of procuring Hydrogen.

Per se, hydrogen exists only in the gaseous state. In this form it may be obtained by the reaction of diluted sulphuric, or muriatic acid, with zinc, or iron; or of steam with iron turnings, made red hot in a gun barrel. It may be evolved in a state of purity, and consequently destitute of odour from pure water by voltaic agency, or by reaction with an amalgam of potassium; but if an acid or a salt be added, the gas acquires the usual odour.

116. *Self-regulating Reservoir, for Hydrogen and other Gases.*

The following figure, represents a self-regulating reservoir for hydrogen gas.

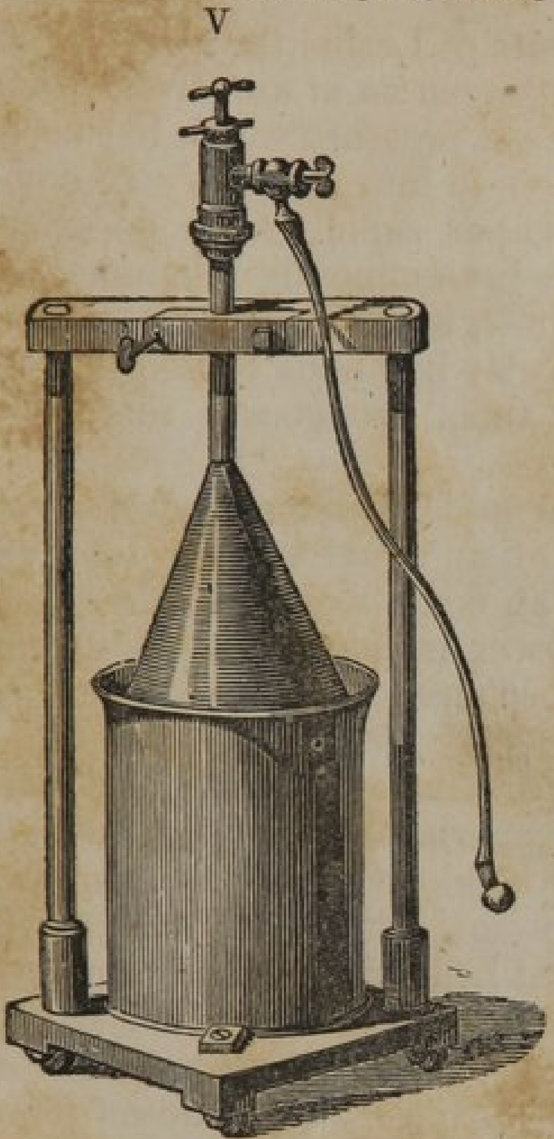
This very perspicuous engraving can require but little explanation. Suppose the glass jar without, to contain diluted sulphuric acid; the inverted bell, within the jar, to contain some zinc, supported on a tray of copper, suspended by wires, of the same metal, from the neck of the bell. The cock being open, when the bell is lowered into the position, in which it is represented, the atmospheric air will escape, and the acid, entering the cavity of the bell, will, by its reaction with the zinc, cause hydrogen gas to be copiously evolved. As soon as the cock is closed, the hydrogen expels the acid from the cavity of the bell; and consequently, its reaction with the zinc is prevented, until another portion of the gas be withdrawn. As soon as this is done, the acid re-enters the cavity of the bell, and the evolution of hydrogen is renewed, and continued, until again arrested, as in the first instance, by preventing the escape of the gas, and consequently causing it to displace the acid from the interior of the bell, within which the zinc is suspended.

The principle of this apparatus is analogous to that which was contrived by Gay-Lussac. I had employed the same principle, however, when at Williamsburg, to moderate the evolution of carbonic acid, before I had read of Gay-Lussac's apparatus.

I prefer the modification above described. In the first place, it is internally more easy of access, for the purpose of cleansing; secondly, it is much better qualified for containing sulphuret of iron, or marble, for generating sulphuretted hydrogen, or carbonic acid gas; and thirdly, by raising the bell glass, the pressure may be removed.

In the other form, the pressure on the gas is so great, that, unless the tube, the cock, and their junctures, be perfectly tight, there must be a considerable loss of materials; since the escape of gas, inevitably causes their consumption, by permitting the acid to reach the zinc, or other material, employed.

117. *Large Self-regulating Reservoir for Hydrogen.*



This figure represents a self-regulating reservoir, for hydrogen, constructed like that described in the preceding article; excepting that it is about fifty times larger, and is made of lead, instead of glass.

This reservoir is attached to the compound blowpipe, in order to furnish hydrogen; and may, of course, be used in all experiments, requiring a copious supply of that gas. When this is to be applied to the hydro-oxygen, or compound blowpipe, the knob at the end of the pipe, which has an orifice on one side, is placed under the gallows, G, and fastened air-tight to the pipe of that instrument, by the pressure of the screw of the gallows. See fig. of the compound blowpipe, 67.

The gas is retained, or allowed to flow through the pipe, by means of the valve cock, V, which is much less liable to leak, than one of the common form. See Appendix for an account of the valve cock and gallows screw.

Of the Properties of Hydrogen Gas.

It is the lightest of all ponderable substances. One hundred cubic inches weigh only 2.11 grains. Its weight to that of oxygen is as 1 to 16. Its specific gravity, the gravity of air being assumed as 1, is 0.0694. It is about 200,000 times lighter than mercury, and 300,000 times lighter than platinum. In its ordinary state, it smells unpleasantly. When pure, it is without odour.

The respiration of hydrogen mixed with the same proportion of oxygen as exists in atmospheric air, is not attended by any oppressive sensations; yet a profound sleep is said to have been induced in animals surrounded by such a mixture. When breathed either in this way, or unmixed, it will be found to produce a ludicrous alteration in a man's voice, making it shrill and puerile, and so out of character as not to be recognised. Sound is said to move in this gas with a velocity three times as great as in the atmosphere.

According to the experiments of Leslie, the sound of a clock bell was as feeble in hydrogen as in air rarefied one hundred times. By no degree of pressure which has been tried, can hydrogen be condensed into a liquid. In consequence of its levity, it escapes rapidly from an open vessel, unless inverted. It is pre-eminently inflammable, yet a taper when immersed in it, is extinguished. A jet of it ignited, appears like a feebly luminous candle flame; and if surrounded by a glass tube, produces a remarkable sound.

The specific heat of hydrogen is greater than that of any other gas, being to that of an equal weight of air as 13.08 is to 1, and to that of an equal weight of water as 3.88 to 1. Its refracting power is ten and a half times greater than that of the atmosphere. It is considered as an elementary substance.

When mixed with oxygen or atmospheric air and subjected to a flame, an electric spark, or a wire ignited by galvanism, it explodes. With chlorine it explodes under like circumstances, and likewise in the solar rays. In burning it disengages sufficient heat to melt 315 times its weight of ice. Dobereiner discovered that platina sponge, a cold metallic congeries, becomes ignited on entering a mixture of hydrogen with oxygen gas, and causes it to inflame by an agency which has not been satisfactorily elucidated. It has since been discovered that palladium, rhodium, and iridium, possess this property in nearly the same degree. I have ascertained that if asbestos, charcoal or clay be soaked in chloride of platinum and afterwards desiccated and heated red hot, the property of inflaming a mixture of hydrogen and oxygen is acquired.

EXPERIMENTAL ILLUSTRATIONS OF THE PROPERTIES OF HYDROGEN.

Levity of the gas demonstrated by the ascension of a balloon, or by the effect of filling, with hydrogen, a glass globe balanced upon a scale beam, 11. Effect upon the voice shown. Inflammation of a gaseous mixture of hydrogen with atmospheric air by platinated asbestos, or platina sponge. Apparatus for lighting a candle by a jet of hydrogen from a self-regulating reservoir, either by the electric spark or platinum. Cannon, charged with a mixture of hydrogen and oxygen fired by a galvano ignition apparatus, 58.

118. *Candle extinguished and relighted by Hydrogen.*

If a lighted candle be introduced into a wide mouthed inverted phial, filled with hydrogen gas, the flame of the candle will be extinguished from the want of oxygen. Meanwhile, at the mouth of the bottle, where there is a sufficient access of air, the gas will have taken fire, and will burn with a lambent flame scarcely visible in daylight. Hence if the candle be slowly withdrawn, it will be relighted as it passes through the flame.

119. *Philosophical Candle.*

Granulated zinc, or turnings of iron, being introduced into a glass flask, so as to occupy about one-fourth of its capacity; provide a suitable cork, so perforated as to receive a glass tube terminating in an orifice just large enough to admit a common brass pin. Pour upon the zinc five parts of water, and adding one of sulphuric acid; fasten the cork, with its tube inserted, into the mouth of the flask. After all the atmospheric air has escaped from the vessel, on applying the flame of a candle to the orifice of the tube, it will be surmounted by an inflamed jet of hydrogen, which has been called the philosophical candle.

The light given out by the flame of pure hydrogen, is, nevertheless, wholly incompetent to answer the purpose of candle light; but I have ascertained, that the addition of one-seventh of spirit of turpentine, to the materials, obviates this defect.

APPLICATION OF HYDROGEN AND OXYGEN IN EUDIOMETRY.

The explosive union of hydrogen with oxygen, has been much resorted to in the analysis of gaseous mixtures containing either.

For this purpose a stout tube, sealed at one end, at the other shaped like a trumpet, has holes drilled into it, near the sealed end, for the introduction of metallic wires, the ends of which approach near enough to each other, within the tube, for the passage of an electric spark. A known volume, of the explosive mixture, being introduced into the tube and ignited by a spark from an electrophorus or an electrical machine; and the residual air, being transferred to a graduated tube, the deficit caused by the process is ascertained.

The glass tube, employed in this experiment, with its appurtenances, is called a eudiometer.

This appellation was at first applied to the instruments used in the analysis of atmospheric air, of which one-fifth part is oxygen gas; but has since been applied to all instruments, employed in measuring the results of pneumato-chemical analysis.

120. OF THE VOLUMESCOPE.

Experiments performed with eudiometers such as I have been mentioning, do not serve to make the steps of the process evident to a numerous class so as to enable them to judge of the result by inspection. In order to attain this object, I have contrived the apparatus represented on the opposite page; which I have called a volumescope, as I find it very inconvenient not to have a name for every variety of apparatus.

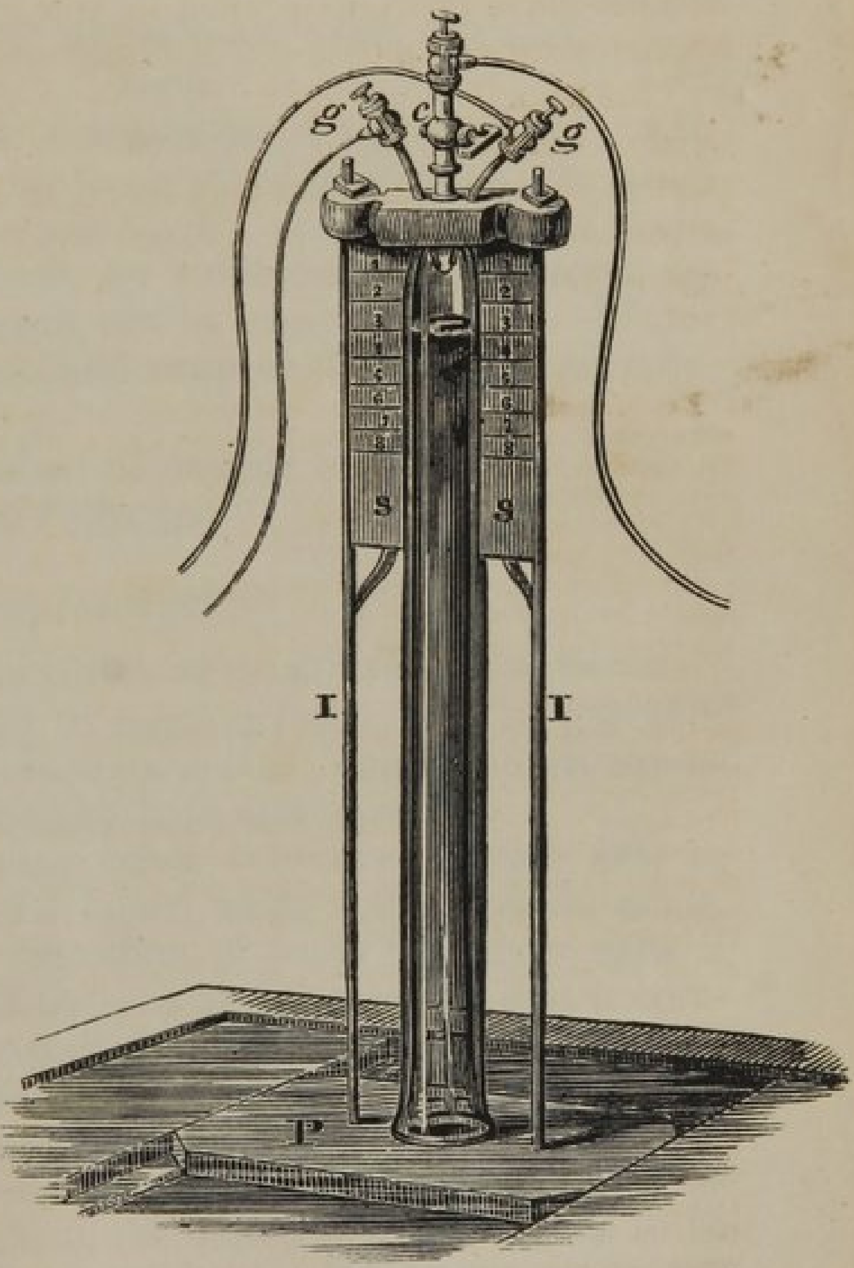
It consists of a very stout glass tube, of 36 inches in height, and tapering in diameter inside from 2 1-8th to 1 1-8 inches. The least thickness of the glass is at the lower end, and is there about 5-8ths of an inch. There is an obvious increase in thickness, towards the top, within the space of about 6 inches. The tube is situated between the iron rods, I I, which are riveted, at their lower ends, to a circular plate of the same metal let into the lower surface of a square piece of plank. This piece of plank supports the tube, so as to be concentric with an aperture corresponding with the bore of the tube, and constituting effectively its lower orifice. The upper orifice of the tube is closed by a stout block of mahogany, which receives a disk of gum elastic in a corresponding hollow, made, by means of a lathe, so as to be of the same diameter as the end of the tube. Into a perforation in the centre of the mahogany block, communicating with the bore of the tube, a cock, C, furnished with a gallows screw, is inserted. Through the block on each side of the perforation, wires are introduced, so as to be air tight.

To the outer ends of these wires two gallows screws, G G, are soldered, to the inner ends a platina wire so as to form a galvano ignition apparatus analogous to that already described and illustrated page 55, article 58.

The apparatus being so far prepared, let it be firmly fixed over the pneumatic cistern, so that the water may rise about an inch above the lower extremity of the tube. To the gallows screws, *g g*, attach two leaden rods, severally proceeding from the poles of a calorimotor. By means of a leaden pipe, produce a communication between the bore of the cock, and an air pump, so that by pumping the air from the cavity of the tube, the water of the cistern may be made to rise into the space thus exhausted of air. On each side of the tube, and between it and each iron rod, there is a strip of wood scored so as to graduate about seven inches of the tube into eight equal parts. These parts were measured by introducing into the tube, previously filled with water, exactly the same bulk of air eight times, and marking the height of the water after each addition. By these means the instrument is graduated into eight parts of equal capacity, and we are by aid of it, enabled to measure the gases, and notice the diminution of volume resulting from their spontaneous reaction, or that which may be induced by the ignition of the wire.

The apparatus being so far prepared, and the tube exhausted of air so as to become full of water, close the cock leading to the air pump, introduce two volumes of pure hydrogen, and one volume of pure oxygen, which may be most conveni-

Volumescope.
(P. 140.)



ently and accurately effected by the sliding rod gas measure. The plates of the calorimotor being in the next place excited by the acid, the ignition of the platina wire ensues, and causes the hydrogen and oxygen to explode. When they are pure, the subsequent condensation is so complete, that the water will produce a concussion as it rises forcibly against the gum elastic disk, which, aided by the mahogany block, has been represented as closing the upper orifice of the tube.

If the preceding experiment be repeated with an excess of either gas, it will be found that a quantity, equal to the excess, will remain after the explosion. This is very evident when the excess is just equal to one volume, because, in that case, just one volume will remain uncondensed. By these means, a satisfactory illustration is afforded of the simple and invariable ratio in which the gaseous elements of water unite, when mixed and inflamed; which is a fact of great importance to the atomic theory, and to the interesting theory of volumes which ere long I shall have occasion to notice.

COMPOUNDS OF HYDROGEN WITH OXYGEN.

WATER

Is produced by the combustion of hydrogen gas with oxygen gas. It may be decomposed by passing it in steam over iron, ignited in a gun barrel; also by the aid of acids, by the alkaline metals, by sulphurets, phosphurets, by electricity, by galvanism, and by vegetable leaves. Water is vaporizable by heat, and evaporable, by the joint influence of heat and air.

The equivalent of oxygen being	8
And that of hydrogen	1
Water is represented by	9

ON SOME PECULIAR AND IMPORTANT CHARACTERISTICS OF WATER.

Water is necessary to some crystals, and to galvanic processes. Its powers, as a solvent, are peculiarly extensive, and are increased by heat and pressure.

Water is one, among other substances, which acts as an acid with powerful bases, while with powerful acids, it acts as a base. Berzelius, in some instances, calls it hydric acid. It will be seen as we proceed, that it combines with various metallic oxides, especially those which constitute the alkalies, and alkaline earths. With the latter especially, it produces much heat in combining, as exemplified in the slaking of lime, and in several of its combinations with them, its affinity is too energetic to be overcome by any degree of heat. Excepting acids, any compound in which water exists as an essential constituent, is called a hydrate. Thus slaked lime is an hydrate of lime; but this term is inappropriate to the compounds which it forms with acids. To them the term aqueous is applied by Berzelius. The absence of water in any substance in which it is liable to be present, is signified by the word anhydrous.

121. EXPERIMENTAL ILLUSTRATIONS OF THE AGENCY OF WATER.

No reaction ensues between tartaric acid and carbonated alkali, until water is added, when a lively effervescence arises.

In like manner, concentrated sulphuric acid and zinc remain inactive, until water is added; when a copious evolution of hydrogen follows.

If nitrate of copper be rolled up in tinfoil without moisture, the mass will remain inert; but if moistened before it be rolled up, ignition will be produced.

122. DECOMPOSITION OF WATER.

Steam decomposed by Ignited Iron.

Having introduced some turnings of iron, or refuse card teeth, into an old musket barrel, lute into one end of it, the beak of a half-pint glass retort, about half full of water; into the other end, a flexible leaden tube. Lift the cover off the furnace, and place the barrel across it, so that the part containing the iron turnings, may be exposed to the greatest heat. Throw into the furnace, a mixture of charcoal, and live coals. The barrel will soon become white hot. In the interim, by means of a chauffer of coals, the water being heated to ebullition, the steam is made to pass through the barrel in contact with the heated iron turnings. Under these circumstances, the oxygen of the water unites with the iron, and the hydrogen escapes in the gaseous state through the flexible tube.

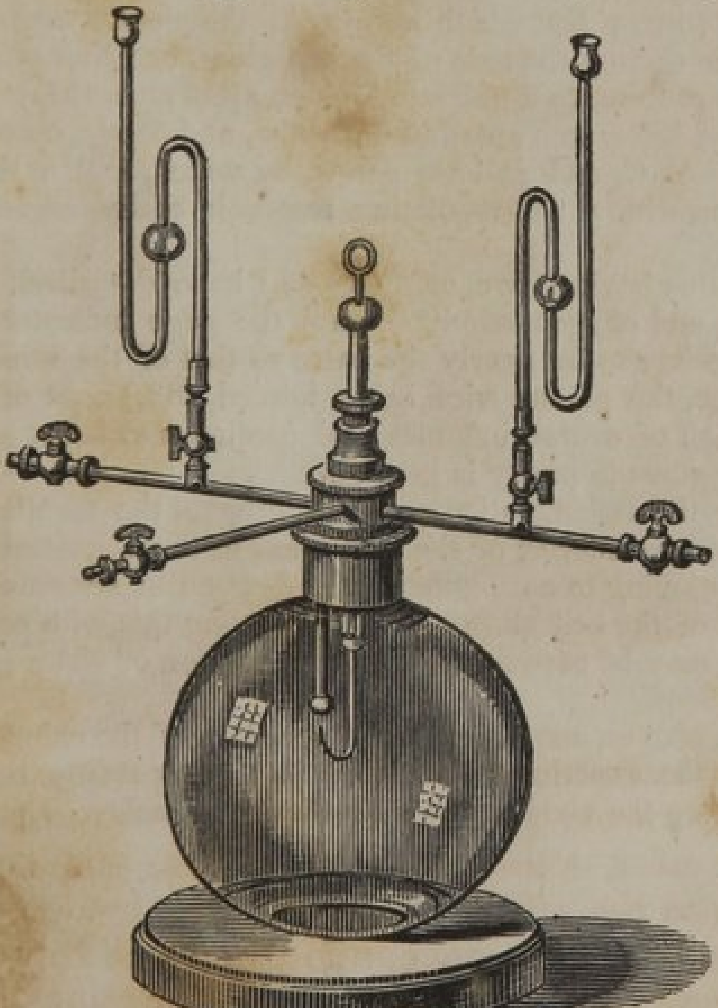
The decomposition of water, by sulphurets, phosphurets and the alkaline metals, will be illustrated in due time.

SYNTHESIS, OR RECOMPOSITION OF WATER.

123. *Water produced by an inflamed jet of Hydrogen.*

The recomposition of water may be rendered evident, by means of the philosophical candle, 139, or any other inflamed jet of hydrogen, situated within a large glass globe. The glass becomes immediately covered with a dew arising from the condensation of aqueous vapour, produced by the union of the oxygen of the air with the hydrogen.

124. *Of Lavoisier's Apparatus for the Recomposition of Water.*



This apparatus consists of a glass globe, 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, then supplied with oxygen to a certain extent. In the next place, hydrogen is to be allowed to enter it in a jet, which is to be inflamed by an electric spark. As the oxygen is consumed more is to be admitted.

I have employed a wire ignited by galvanism, to inflame the hydrogen in this apparatus, and conceive it to be a much less precarious method than that of employing an electric machine, or electrophorus.

125. *Description of an improved Apparatus for the recomposition of Water.*

An inverted bell glass with a conical neck, is so closed at the apex in the making, as to form a transparent converging cavity, suitable to render the presence of a very small quantity of any contained liquid, perceptible to the eye.

By means of the screw rod and plate frame, (48,) this bell glass is secured in an inverted position, and is made air tight. With the aid of three valve cocks, and as many leaden pipes, communications with an air pump, a barometer gage, and a receiver sufficiently supplied with oxygen, may be severally opened or closed at pleasure.

Through a stuffing box which surmounts the plate, a copper pipe, P, is so passed as to occupy the axis of the bell glass, and that of a coil of platina wire appertaining to a galvano ignition apparatus, (58.) The copper pipe terminates below in a small platina tube, and above, outside of the receiver, in a cock C, and gallows screw, by which, and a leaden pipe, a communication with a self-regulating reservoir of hydrogen, is at command.

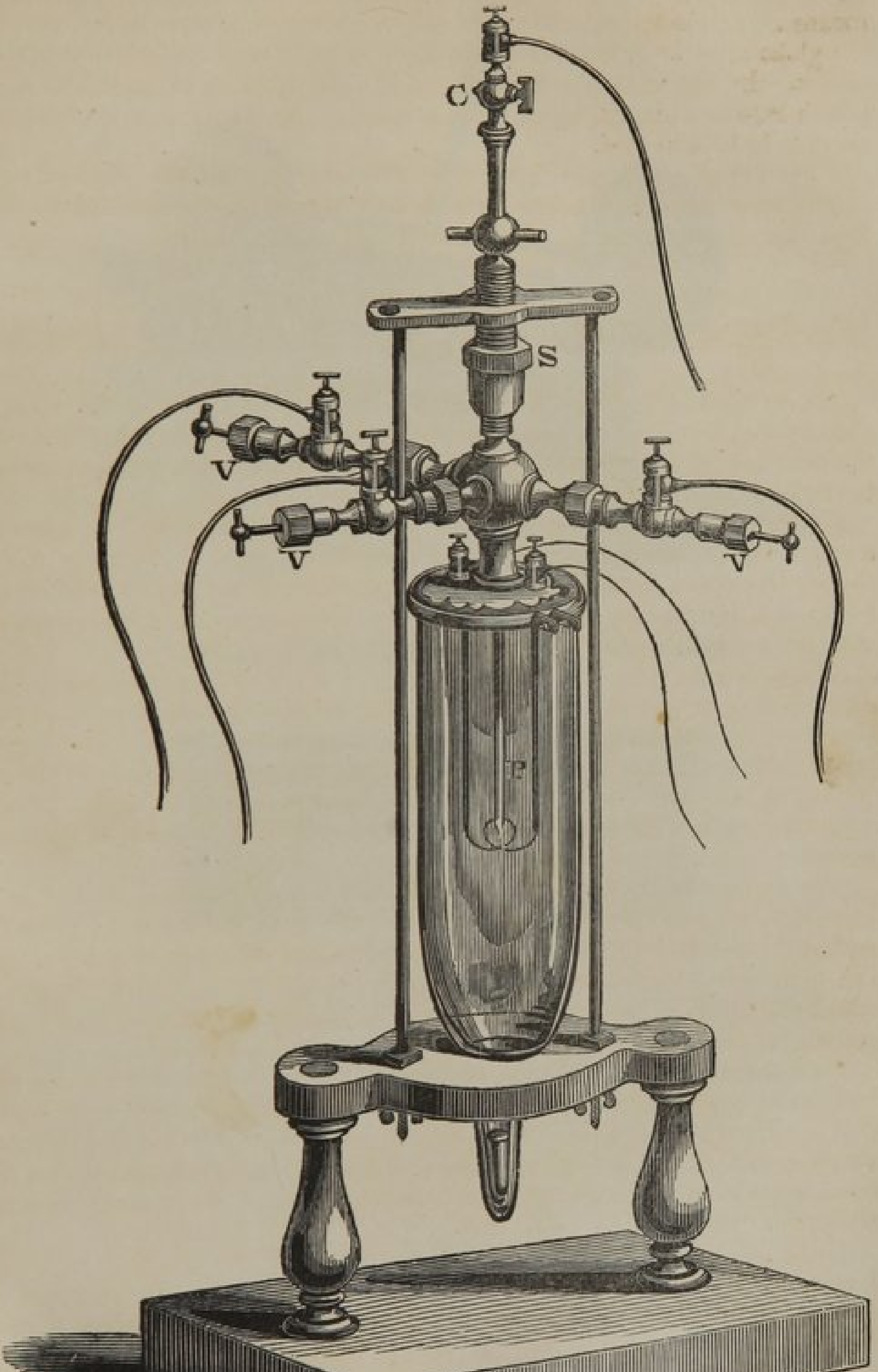
The apparatus having been arranged as I have described, the bell is to be exhausted, and oxygen admitted, until the gage indicates the pressure within the receiver to be nearly the same as that of the atmosphere. In the next place, the platina wire being ignited, (58,) a jet of hydrogen is admitted, which of course inflames and continues to burn, so long as the supply of the gases in purity is kept up.

Soon after the inflammation of the hydrogen, the resulting water will be seen to coat the interior of the bell glass in drops, resembling a heavy dew, and continuing to accumulate, will descend in streams into the converging neck of the bell glass. By surrounding this with cold water, the condensation may be expedited, and the deposition of water soon rendered strikingly evident.

I will here give an engraving and description of the calorimotor, which I employ in the experiment described in the preceding article, and in others requiring the vivid ignition of about two inches of platina wire of No. 24.

Apparatus for the Decomposition of Water.

(C. p. 144.)



126. *Description of a Galvanic Machine for producing ignition.*

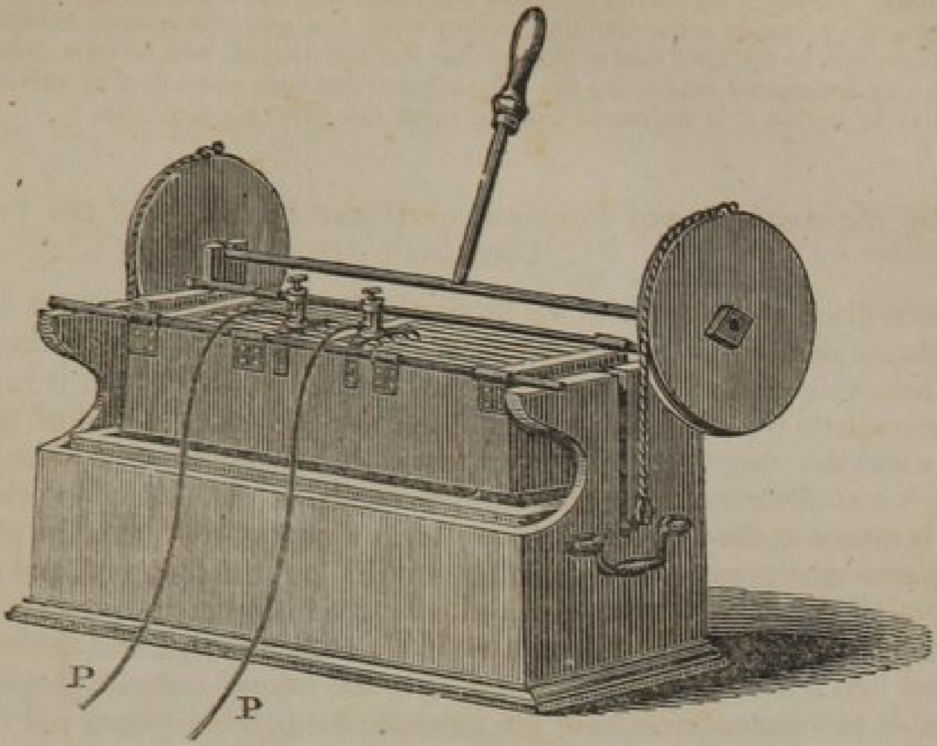
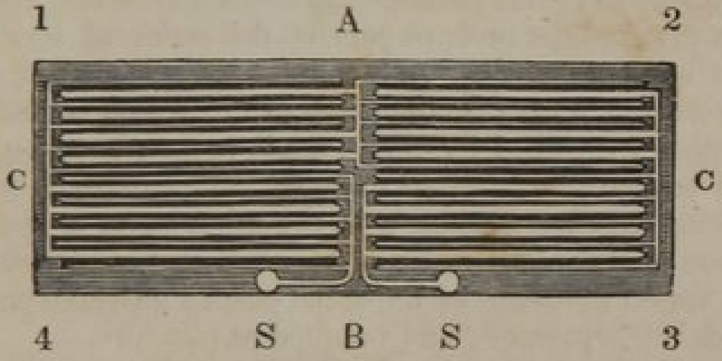


Diagram illustrating the arrangement of the Plates



This machine consists of sixteen plates of zinc, and twenty plates of copper, each twelve inches by seven, arranged in four galvanic pairs. The plates are supported within a box with a central partition of wood, A B, dividing it into two compartments. Each of these may be considered as separated into two subdivisions, by four plates of copper between the letters C C. Of course the box may be considered as comprising four distinct spaces, No. 1, No. 2, No. 3, and No. 4. The circuit is established in the following manner. Between the zinc plates of compartment No. 1, and the copper plates of compartment No. 2, a metallic communication is produced, by soldering their neighbouring corners to a common mass of solder with which a groove in the wooden partition between them is filled. With similar masses of solder, two grooves severally made in the upper edges of each end of the box are supplied. To one of them, the corners of all the copper plates of space No. 1, and the zinc of space No. 4, are soldered. To the other the zinc plates of space No. 2, and the copper plates of space No. 3, are soldered in like manner. Lastly the zinc plates of No. 3 are connected by solder in a groove, and the copper plates of No. 4 are in like manner connected by solder in another groove. Upon the ends, S S, of the solder just mentioned, the gallows screws are severally soldered, and to these the rods, P P, called poles, are fastened.

RATIONALE.

The zinc and copper surfaces of No. 1 and No. 2, communicating, have their naturally opposite electric powers exalted, and induce in the plates with which they are alternated, a like exaltation, still higher. By the communication of the latter with the surfaces in No. 3 and No. 4, a similar effect is induced, and again by induction the electric powers of the plate alternating with those last mentioned are augmented. Hence a discharge between the latter will have a quadruple intensity, and hence the poles, or rods, communicating with the gallows screw, soldered as above described to the zinc and copper plates last mentioned, will make a discharge through any conductor whenever the apparatus is put into operation by raising the acid, so as to enable it to surround and act upon the galvanic surfaces.

127. *Of the Analysis and Synthesis of Water by means of the Voltaic Circuit.*

A stout glass cylinder about 3½ inches in diameter and about 25 inches in height, is secured in the *screw rod and plate frame* (48) over the mercurial reservoir (96). By means of an air pump with which it is made to communicate by the usual means, it is exhausted of air, and of course filled with the mercury from the reservoir whenever desirable (27). Through a stuffing box in the centre of the metallic plate by which the cylinder is closed at the upper end there passes a copper rod. Into the plate a stout platina wire is screwed so as to be parallel to the copper rod, and to the lower end of this as well as that of the rod, two fine platina wires are separately soldered. These wires are bent into a zigzag shape, and flattened at each end into a sharp edge so as to multiply the minute metallic projections favourable to the transmission of the galvanic fluid. This copper rod is surmounted by an iron cup containing mercury, into which an iron rod enters communicating by a copper wire with the negative pole of the series.* The other wire being affixed to the metallic cap and a conducting communication made between this and the positive pole of the series as soon as the acid is made to act upon the plates, an evolution of gas commences. Upon the upper rod there is a spur of the same metal, which is sufficiently long to reach the other wire when the rod is made to turn upon its axis. Hence when the gas has accumulated in quantity sufficient to reach below the spur, by bringing this into contact with the other wire, a spark is elicited and the gaseous mixture is immediately ignited and condensed.

Thus by a varied influence of the same electro galvanic power, the elements of water are separated, and reunited at pleasure.

In order to expedite the process the water may have about half its bulk of a saturated solution of borax added. This salt is not liable to decomposition, but aids in the transmission of the galvanic influence.

When this experiment is performed by means of wires terminating in separate receivers the gases are more slowly cooled, but the ratio in volume in which they combine is rendered perceptible to the eye, and fully accords with the results obtained by the synthesis in my eudiometrical illustrations, 120.

OF THE AIR IN WATER.

Water, naturally, contains air. It is to receive the influence of the oxygen of the air thus existing in water, that fishes are furnished with gills, which perform to a certain extent the office of lungs in decarbonizing the

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* The copper rod is made negative, as otherwise it would be oxydized. To avoid this a rod of platina is employed for the positive pole.

blood. Fishes cannot live in water, which, either by boiling or exhaustion, has been entirely deprived of air.

The habitudes of other gaseous substances, with water, will be more advantageously described, or illustrated, when those substances are under consideration.

121. EXPERIMENTAL PROOF OF THE PRESENCE OF AIR IN WATER.

Water exposed to the action of an air pump, or otherwise subjected to exhaustion, becomes replete with air bubbles.

OF THE MOISTURE IN AIR.

Air is not more invariably *attendant* upon water, than water is upon air; nor is the air, in water, more necessary to fishes, than the water in the air, to animals and vegetables.

The well known deleterious influence of the winds which blow from the African deserts, arises probably from their aridity. The desiccating power of air is directly as its temperature, and inversely as the quantity of moisture previously associated with it.

There is a certain proportion of moisture, relatively to the temperature, which is most favourable to our comfort. If the moisture be increased without raising the temperature, or the temperature be increased without an accession of moisture, we are incommoded. In the one case, the skin becomes unpleasantly dry; in the other, the air is too much encumbered with aqueous vapour, to allow perspiration, whether sensible or insensible, to proceed with sufficient freedom.

Stove rooms are oppressive, on account of the too great aridity of the air in them; and hence, the well known remedy of a basin of water, placed upon the stove, to furnish moisture by its evaporation.

HYGROMETRIC PROCESS OF DALTON.

DANIEL'S HYGROMETER.

The dew which is observable on vessels containing cold water, in warm weather especially, arises from the condensation of the aqueous vapour in the air.

According to Mr. Dalton, the less the degree of cold requisite to produce this phenomenon, the greater the quantity of moisture in the air. Hence, by ascertaining the highest temperature at which the water is capable of producing the condensation, the quantity of moisture may be known from a table, which he has constructed.

Mr. Daniels has contrived an hygrometer upon the principle thus suggested by Dalton. Vaporization is ingeniously applied to *produce* cold, in one bulb of the instrument, in consequence of the cold produced by the evaporation of ether in another bulb, as in the cryophorus, 71. Two thermometers accompany the instrument, one within the bulb refrigerated by the vaporization; the other so situated as to indicate the temperature of the atmosphere. As the quantity of aqueous vapour in the air diminishes, the depression of temperature necessary to the precipitation of moisture on the refrigerated bulb, increases. The extent of the depression is ascertained by the thermometers, the quantity of water in the air, by reference to a table.

ORGANIC SENSIBILITY TO MOISTURE, EXEMPLIFIED IN THE BEARD OF THE WILD OAT.

Hygrometers have been made which are dependent upon the contraction or dilatation which catgut, whalebone, and other substances of a like nature, undergo, in proportion to the quantity of moisture in the air. Among instruments of this kind, that formed by means of the beard of the wild oat, is pre-eminent for its susceptibility to the influence of moisture. Breathing on it, causes the index to be moved instantaneously. The indications of hygrometers thus constructed, are not referrible to any standard, agreeably to which, a comparison can be made between the dryness of the air in different places at the same time, or in the same place, at different times.

HYGROMETRIC PROCESS BY MEANS OF A BALANCE.

It may be presumed that the quantity of moisture in the air, is inversely as the weight of water, which will in a given time evaporate from a moist surface. If this presumption be correct, the little square dish here represented, may with the aid of a delicate scale beam, be used as an hygrometer. If it be suspended to the balance and equipoised, the counter-weight will, in a few minutes preponderate, in consequence of the loss by evaporation.

The loss of weight in any known period being determined, the evaporating power of the air will be as the loss of weight, but as the evaporation is more or less rapid in proportion as there may be more or less agitation, it will not be right to infer that quantity of aqueous vapour in the atmosphere, is inversely as the rate of evaporation, unless the process were uninfluenced by the wind.

COMPOUNDS OF CHLORINE WITH WATER.

HYDRATE OF CHLORINE.

Berzelius observes that chlorine furnishes the only instance of an elementary substance capable of entering into combination with water. I allude here to a crystalline compound formed on passing the gas through that liquid at a temperature below 40° F. The hydrate thus formed is capable of being sublimed from one part of the containing vessel to another, in consequence of a slight diversity of temperature. It consists of one volume of chlorine, and twenty volumes of aqueous vapour.

SOLUTION OF CHLORINE IN WATER.

Berzelius alleges, that in order to obtain a saturated solution of chlorine in water, it is necessary, in the first instance, to expel from the latter all the atmospheric air.

He does not consider that water will hold this principle simply in a state of solution, but that muriatic acid is formed by the union of chlorine with the hydrogen of the water, while its oxygen, combining either with chlorine or water, generates chlorous acid, or deutoxide of hydrogen.

These substances are, he believes, formed only in small quantities at first; yet it is from these that the extrication of oxygen gas is effected in the solar rays, and that oxygen is imparted to colouring matters bleached by the operation of this liquid. The muriatic acid created at the same time, is prone to injure fabrics subjected to it; and hence in bleaching, the solutions of the chloride of lime, or of the fixed alkalies, are preferred. These are by Berzelius considered as chlorites, consisting of the chlorous acid, and the oxybase employed, whether lime, potash, or soda.

DEUTOXIDE, OR BIOXIDE, OF HYDROGEN, OR OXYGENATED WATER.

In 1818, Thenard discovered that water might be made to receive an additional quantity of oxygen, by dissolving deutoxide of barium in liquid muriatic acid, precipitating the barytes, by sulphuric acid, and the chlorine by silver.

This process will be again noticed in a more advanced part of the course, when the nature of the substances employed, shall have been explained.

Properties of Deutoxide of Hydrogen.

The deutoxide of hydrogen is as liquid, and as devoid of colour, as water. It is nearly inodorous, whitens the tongue, inspissates the saliva, and tastes like some metallic solutions. Applied to the skin, it creates a smarting sensation, more durable, in some persons, than in others. Its specific gravity is 1.452. Hence when poured into water, it descends through it like a syrup, but is dissolved by agitation.

As it is less easy to vaporize than water, it may be separated from that liquid, by exposure in vacuo over sulphuric acid, 69. In its most concentrated form, it has not been congealed by any degree of cold, to which it has been subjected.

The most interesting property of this substance, is that of giving off oxygen, explosively, on being brought into contact with substances, which do not unite with either of its ingredients. Thus it explodes, by contact, with finely divided silver, platina, or gold, and still more actively with oxide of silver, or peroxide of lead.

The difficulty of explaining these phenomena, has already been noticed. See the article on the states in which caloric exists in nature, page 70.

When mingled with the mineral acids, its liability to decomposition is diminished.

If exposed to heat, in its most concentrated state, a few grains create a violent explosion. When by dilution with 20 parts of water, and exposure to heat, it loses all the oxygen which it holds, beyond the quantity necessary to the composition of water, as much oxygen is found to be evolved, as the hydrogen, in the residual water, retains. Hence it is generally supposed to consist of one atom of hydrogen, and two of oxygen, though some distinguished chemists conceive it to be a protoxide, and of course consider water as a suboxide, containing two atoms of hydrogen, and one of oxygen.

ON NOMENCLATURE.

I shall here as in some other instances, quote from my letter on the nomenclature of Berzelius, such appropriate suggestions, as the student who has accompanied me thus far ought to be capable of understanding.

In common with other eminent chemists, he* has distinguished acids in which oxygen is the electronegative principle, as *oxacids*, and those in which hydrogen is a prominent ingredient as *hydracids*. If we look for the word radical, in the table of contents of his invaluable Treatise, we are referred to p. 218, vol. 1st., where we find the following definition, "*the combustible body contained in an acid, or in a salifiable base, is called the radical of the acid, or of the base.*—In the second vol. page 163, he defines hydracids to be "those acids, which contain an electronegative body, combined with hydrogen;" and in the next page it is stated, that "hydracids are divided into those which have a simple radical, and those which have a compound radical. The second only comprises those formed with cyanogen and sulphocyanogen." Again, in the next paragraph, "no radical is known that gives more than one acid with hydrogen, although sulphur and iodine, are capable of combining with it in many proportions. If at any future day more numerous degrees of acidification with hydrogen, should be discovered, their denomination might be founded on the same principles as those of oxacids." Consistently with these quotations, all the electronegative† elements forming acids with hydrogen, are radicals, and of course by his own definition, combustibles; while hydrogen is made to rank with oxygen as an acidifying principle, and consequently is neither a radical nor a combustible. Yet page 189, vol. 2d, in explaining the reaction of fluoboric acid with water, in which case, fluorine unites both with hydrogen and boron, it is mentioned as one instance among others in which fluorine combines with *two combustibles*.

I am of opinion that the employment of the word hydracid, as co-ordi-

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* Berzelius.

† See page 126.

nate with oxacid, must tend to convey that erroneous idea, with which, in opposition to his own definition, the author seems to have been imbued, that hydrogen in the one class, plays the same part as oxygen in the other. But in reality, the former is eminently a combustible, and of course the radical, by his own definition.

Dr. Thomson, in his system, does not recognise any class of acids, under the appellation of hydracids; but with greater propriety, as I conceive, places them under names indicating their electronegative principles. Thus he arranges them as oxygen acids, chlorine acids, bromine acids, iodine acids, fluorine acids, cyanogen acids, sulphur acids, selenium acids, and tellurium acids. Those appellations might, I think, be advantageously abbreviated into oxacids, chloracids, fluacids, bromacids, iodacids, cyanacids, sulphacids, selenacids, telluracids.

I had formed my opinions on this subject, before I was aware that Dr. Thomson had resorted to this classification.

As respects the acids individually, I conceived that it would be preferable, if the syllable indicating the more electronegative element had precedency in all, as it has in some cases. The word hydrofluoric does not harmonize with fluoboric, fluosilicic, fluochromic, fluomolybdic, &c. Fluorine being in each compound the electronegative principle, the syllables indicating its presence, should in each name occupy the same station. These remarks will apply, in the case of acids formed with hydrogen, by all principles which are more electronegative. Hence we should use the terms chlorohydric, fluohydric, bromohydric, iodohydric, cyanhydric, instead of hydrochloric, hydrofluoric, hydrohromic, hydriodic, hydrocyanic.

These opinions, conceived during the preceding summer, were published by me in the Journal of Pharmacy for October 1833. Since then, I find that in the late edition of his Traité, Thenard has actually employed the appellations above recommended.

As by the British chemists the objectionable words have not been definitively adopted; the appellations muriatic and prussic, being still much employed, it may not be inconvenient to them to introduce those which are recommended by consistency. In accordance with the premises, the acids formed with hydrogen by sulphur, selenium, and tellurium, would be called severally sulphydric, selenhydric, and telluhydric acid. Compounds formed by the union of the acids thus designated, with the bases severally generated by the same electronegative principles, would be called sulphydrates, selenhydrates, and telluhydrates, which are the names given to these compounds in the Berzelian nomenclature. Influenced by the analogy, a student would expect the electronegative ingredient of a sulphydrate to be sulphydric acid, not a sulphide. The terminating syllable of this word, by its associations, can only convey the conception of an electropositive compound.

OF THE COMPOUND FORMED BY HYDROGEN WITH CHLORINE.

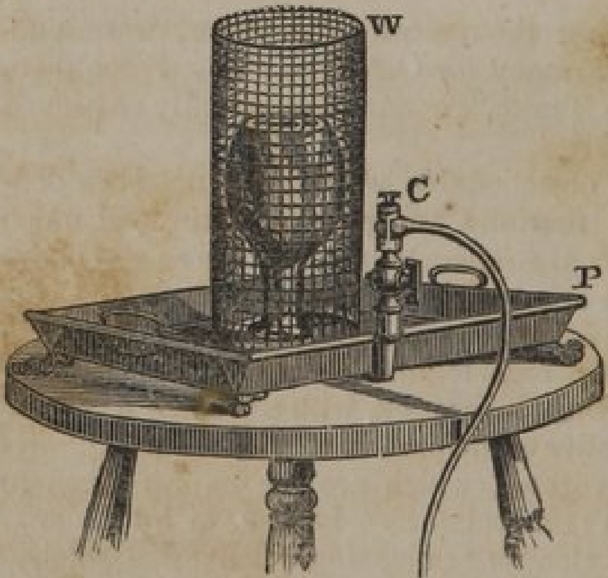
OF CHLOROHYDRIC OR MURIATIC ACID GAS.

When hydrogen and chlorine gas are mixed in equal volumes, they combine spontaneously. In the dark, or where the light is feeble, the union is slowly accomplished; but in the solar rays, takes place explosively. According to Silliman, the direct rays of the sun are not necessary to produce this result. The mixture may also be exploded by the electric spark, or by contact with any ignited matter. However the union may be effected, chlorohydric or muriatic acid gas is produced, without any reduction of volume, if no water be present.

Synthesis of Chlorohydric Acid Gas.

In order to demonstrate the ratio in which chlorine and hydrogen combine, it is only necessary to introduce and ignite in the volumescope equal measures of each gas. If they be pure there will be a complete condensation. The experiment is conducted precisely as in the case of oxygen and hydrogen, 120, excepting that chlorine is substituted for oxygen in a double proportion.

Explosive Reaction of Hydrogen with Chlorine, under the Influence of the Solar Rays.



A flask is half filled with chlorine over the pneumatic cistern, in the usual way, and then transferred to the pan P, so as to have its orifice exactly over that of the orifice of a pipe which, at the other end, communicates with the cock, C, to which is annexed a flexible pipe extending to a self-regulating reservoir of hydrogen, 117.

The flask is surrounded by a wire gauze, and just before the explosion is desired, hydrogen from the reservoir is allowed to occupy that portion of the cavity which was previously unoccupied by the chlorine. It should be understood that the pan, during this operation, retains a sufficient stratum of water to cover the mouth of the flask, and that this is occupied with the same liquid in part until it is displaced by the hydrogen.

The preliminary arrangements being made, a mirror must be placed in a situation to receive the solar rays directly, and reflect them upon the flask. The result is an explosion, from the effects of which the spectators are protected by the wire gauze.

It must be obvious that this experiment can only succeed, when the sun is unobscured.

It should be understood that the condensation arises altogether from the absorption of the gas by the water.

130. *Means of procuring Chlorohydric or Muriatic Acid Gas.*

Into a tubulated retort, introduce about as much chloride of sodium (common salt) as will occupy nearly one-third of the body, A. Lute a glass funnel, furnished with a cock, into the tubulure. Let the orifice of the beak, B, be so depressed below the surface of the mercury in the cistern, as to be under a bell glass, filled with, and inverted over the mercury; and properly situated for receiving any gas which may escape through the beak. Prepare about three-fourths as much strong sulphuric acid by weight, as there may be salt in the retort. After pouring about one-third of the acid into the retort, close the cock of the funnel: the mixture will rise in a foam, and a portion of gaseous matter will pass into the bell. As soon as the foam subsides, add more of the acid, until the whole is introduced. Then as soon as the foam again subsides, apply the chauffer, C, and chlorohydric acid gas will continue to be copiously evolved.

Explanation of the Process.

The water combined with the sulphuric acid, is decomposed; its oxygen unites with the sodium, forming soda, with which the sulphuric acid combines, forming sulphate of soda. The hydrogen of the water, and the chlorine, escape as chlorohydric acid gas.

Properties and Composition of Chlorohydric Acid Gas.

It has all the attributes of a gas. It is colourless; and although less active than chlorine gas, is, to the organs of respiration, intolerably irritating, and, if not very dilute, deleterious to life. On escaping into the air, it produces white fumes, from its meeting with moisture. Its affinity for water, is so great, that this liquid will take up 420 times its bulk—and ice melts in it, as if surrounded by fire. When brought in contact with the metals which decompose water, its hydrogen is liberated, while the chlorine unites with the metal. Equal weights of potassium separate the same weights or volumes of hydrogen from chlorohydric acid and from water, a result conformable with the inferred atomic composition of both. Presented to the metallic oxides, a reciprocal decomposition ensues; the hydrogen unites with the oxygen, generating water, the chlorine with the metal, producing a chloride. If mingled with oxygen and exposed to the action of heat or a succession of electric sparks, a small portion of chlorohydric acid gas is decomposed. This result cannot be extended to more than $\frac{1}{35}$th of the whole volume of the gas. At the temperature of 50°, and under a pressure of forty atmospheres, it becomes a colourless liquid.

Its specific gravity is 1.28, a mean between that of its constituents. The weight of 100 cubic inches is 39 grains.

One atom of chlorine, equivalent	36
And one atom of hydrogen, equivalent	1
Constitute one atom of chlorohydric acid gas, equivalent	37

131. EXPERIMENTAL ILLUSTRATIONS.

Equal volumes of hydrogen and chlorine, being mixed and subjected to the solar rays, or galvanic ignition, explode, and form chlorohydric acid gas.

Gas collected over mercury in tall jars. Water, coloured by litmus, being introduced, rapidly changes to a red colour, and causes the disappearance of the gas. Same effect produced by ice, which is rapidly melted.

Means of obtaining Liquid Chlorohydric or Muriatic Acid.

It may be obtained by saturating water with the gas, in Woulfe's apparatus.—See fig. The solution is nearly pure in all the receptacles excepting the first. The liquid acid is also procured by distilling a solution of common salt with diluted sulphuric acid, and condensing the product in a receiver. In this case, the aqueous vapour proceeding from the water employed to dilute the acid, rises with the gas, in a quantity adequate to cause its condensation, when refrigerated, into a liquid compound of water and acid.

The apparatus described in the following articles, may be employed in procuring chlorohydric acid, and generally where liquids are to be impregnated with any gas.

132. *Woulfe's Apparatus.*

This figure is intended to convey an idea of Woulfe's apparatus. The gas evolved in the retort first passes into the globe where any vapour which may accompany it condenses.

It then proceeds along the tube which establishes a communication with the bottle next to the globe. As the mouth of this tube which is within the bottle, is below the surface of the liquid, placed there to absorb it, the gas has to bubble up through the liquid, so as to promote its own absorption, by the agitation thus induced. It then rises above the surface of the liquid, where a further absorption takes place. The excess of gas, beyond the quantity absorbed by the liquid in the first bottle, passes, by means of the connecting tube, to the second bottle, and what is not there absorbed, reaches the third bottle, where the process proceeds, as in the two first. Should any of the gas escape the whole series, it may, by lengthening the last tube, be conducted under a bell glass filled with water on the shelf of the hydro-pneumatic cistern, so as not to annoy the operator. But this never takes place in the case of chlorohydric acid gas, until the water is nearly saturated.

Supposing the extrication of gas to cease, before the liquid in the first bottle is saturated, the absorption continuing, the liquid in the second bottle might be transferred to the first, in consequence of the rarefaction of the residual gas, rendering it incompetent to resist the atmospheric pressure. In like manner the contents of the third bottle might be transferred to the second. To prevent these inconveniences, there is in each bottle a straight tube fastened air-tight into an intermediate neck, and descending into the liquid. By these means an adequate pressure is opposed to the escape of gas, and yet any diminution of pressure arising from absorption, will be compensated by the ingress of atmospheric air, ere the liquid can be drawn over from the next bottle. To prevent absorption from the first bottle into the globe, it is best to use for the introduction of the acid a trumpet-mouthed tube, of a small bore, passing through and luted to the tubulure by a cork, with lead and a gum elastic bandage; and terminating in a small orifice near the bottom of the retort inside.

133. *Vases tightened by Screws, substituted for Woulfe's Bottles.*

In the apparatus represented in this figure, the vessels, containing the liquid to be impregnated, are, by the pressure of screws, made tight against leaden plates, which they are ground to fit, and which are cemented and nailed to the wooden cross-piece, under which the vessels are situated.

Into the cross-piece two horizontal holes are bored, from a common orifice, so as to enter, severally, other holes bored vertically, of which one communicates, internally with the first, the other with the second vessel. The external orifice being closed, by a screw, a communication is established between the cavities of the vessels, which obviates the necessity of tubes. The second vessel communicates with the third vessel, in the same way as with the first.

The hole over either vessel, which communicates with the inside of the preceding vessel, is furnished with a tube passing downwards, a few inches, so as to enter any contained liquid. The tube, thus immersed in the first vessel, rises into and communicates with the cavity of the globe. This globe is pressed by screws against a leaden plate, which it is ground to fit, so as to make an air tight juncture, in the same way, as already described, in the case of the vessels below the cross-piece.

Hence the first tube establishes a communication between the globe, and the liquid in the first vessel, below the surface of which its trumpet-shaped orifice reaches. The second tube, communicating by means of the perforations made in the wood, with the cavity of the first vessel, descends into the liquid contained in the second vessel. The third tube, in like manner, communicating with the cavity of the second vessel, descends into the liquid of the third vessel.

The gas, extricated from the retort, passes into the receiver, where it deposits any condensable matter, and proceeds down the tube into the first vessel. Whatever gas is not there absorbed, proceeds through the perforations, in the wood, to the tube in the second vessel, escaping from that into the liquid. The excess of gas beyond what is there taken up, will reach the third vessel from the second, as it reached this from the first.

It may be proper to mention, that the perforations, in the wood, are charred by means of a red hot iron; and, while hot, soaked with bees wax. By these means, they are rendered impervious to any gas.

On the top of the wooden cross-piece, there are some holes which, it may be observed, are represented as if closed with corks. These are for the introduction of safety tubes, as in the Woulfe's Bottles described in the preceding article, when they may be deemed necessary.

Properties of Liquid Chlorohydric or Muriatic Acid.

When concentrated, it produces suffocating fumes, from an escape of gas. When pure, it is colourless—though usually straw coloured, from a minute portion of iron. Chlorohydric acid *can be said to combine with those alkalies, earths, and oxides only, which form, with it, soluble salts.* It is doubtful whether when presented to such compounds it is not always resolved into a chloride and water. Berzelius conceives that it cannot exist as an acid, in combination with oxides. It is certain that its combinations are, for the most part, by heat and desiccation, convertible into chlorides. Muriate of magnesia, and muriate of alumine, are exceptions. I shall notice this question again in treating of the reaction of chlorine with the metals of the earth and alkalies.

Dr. Thomson informs us that the strongest acid, which he could obtain, consisted of one atom of acid, equivalent 37, united with six atoms of water, which being equivalent to 54, the proportion of acid to water by weight, was as those numbers, or nearly as 2 to 3.

134. EXPERIMENTAL ILLUSTRATION.

Chlorohydric acid exhibited, also its reaction with other bodies.

OF THE OLD THEORY OF THE NATURE OF CHLORINE AND CHLOROHYDRIC ACID.

Chlorohydric acid was deemed to be a compound of oxygen with some unknown radical. When distilled from red oxide of lead, or black oxide of manganese, it was supposed to combine with a portion of the oxygen of those oxides, forming oxygenated muriatic acid, the name then given to chlorine. To the oxygen thus imagined to exist in it, the activity of chlorine, as a supporter of combustion, or as a solvent of metals, was ascribed. It has since been proved, that neither charcoal, nor the metals, when intensely ignited by the Voltaic pile in dry chlorine, are oxydized. They are converted into substances, now called chlorides. The chloride of sulphur, and bichloride of phosphorus, which result from saturating these substances with dry chlorine, are devoid of acidity, but the addition of water converts the one into muriatic and phosphorous acid, the other into muriatic and hyposulphurous acid.

If chlorine be muriatic acid oxygenated, the discovery of the protoxide and peroxide of chlorine, and of chloric and oxychloric acids, must establish this anomaly, that the radical of muriatic acid, by successive additions of the same acidifying principle, gains, loses, and regains acidity, forming first an acid, then three oxides, and finally two acids. I have said it forms *three* oxides, because chlorine must be deemed an oxide, having no acid properties.

It has been stated, page 149, that Thenard oxygenated the water in liquid muriatic acid; yet this did not convert it into a solution of chlorine.

Agreeably to the doctrine now universally sanctioned by chemists, chlorohydric acid, consisting of chlorine and hydrogen, is deprived of hydrogen, in all those processes in which it was formerly supposed to be oxygenated.

OF BROMOHYDRIC, AND IODOHYDRIC, ACID.

Neither with iodine nor bromine does hydrogen directly combine, yet phosphorus combines with them spontaneously.

The resulting compounds have upon water an effect quite analogous to that produced by the chlorides of that substance; producing phosphoric acid, by a union between the phosphorus and oxygen, and bromohydric, or iodohydric acid, by a combination of the hydrogen of the water, with bromine or iodine.

OF BROMOHYDRIC ACID.

To obtain bromohydric acid, Berzelius recommends that phosphorus should be placed in contact with bromine under water. The resulting bromide is resolved into phosphoric acid, and bromohydric acid gas. The latter may be collected over mercury, or made to produce liquid bromohydric acid by union with water, exactly by the same means as have been illustrated in the case of chlorohydric acid, which the bromohydric acid much resembles. Bromohydric acid is a colourless gas, in smell similar to chlorohydric acid. It has a specific gravity of 27.31. When brought in contact with the air it produces a thick fume. It is decomposed in passing through a tube heated red hot. It is composed of one atom of hydrogen, and one of bromine.

OF IODOHYDRIC ACID.

According to Berzelius, in order to procure iodohydric acid, nine parts of iodine, and one of phosphorus, should be placed in contact at the bottom of a tube or small matrass, and protected from the air by powdered glass. Iodide of phosphorus is formed, which is resolved into phosphoric acid and iodohydric acid gas, by the gradual affusion of a small quantity of water. The gas can neither be collected over water, nor mercury, as it acts on the one, and is absorbed by the other. Hence it must be collected in bottles by means of tubes descending through their orifices to their bottoms; which is analogous to the mode already illustrated on a large scale, in collecting chlorine, page 107. This process is even more practicable in the case in point, since iodohydric acid is the heaviest gas known; having a specific gravity of 4.3847, more than four times as great as atmospheric air. In composition and general properties it resembles chlorohydric, and bromohydric, acid.

OF THE COMPOUNDS OF HYDROGEN WITH SULPHUR.

It appears probable that hydrogen and sulphur may combine in various proportions. Only two compounds however have been sufficiently distinguished, to be worthy of a place in this work. One of these is a definite compound of hydrogen and sulphur, containing an atom or volume of each; and has hitherto been called sulphuretted hydrogen, especially by the British chemists. The other contains one atom of hydrogen, with a plurality of atoms of sulphur; which according to Thenard, may extend to the proportions of 4, 6, or 8 atoms to one. To this he has accordingly given the name of polysulphuret of hydrogen.

I have already stated my objections to the termination *ide* to designate electronegative substances performing the part of acids. Pursuant to the nomenclature in which that mode of designation is adopted, all the electronegative compounds of sulphur are called sulphides, and are designated by attaching, as an adjective, their radical with the last syllable changed into *ique* in French, or *ic* in English; as, for instance, sulphuretted hydrogen is called in French, sulphide hydrique, which is in English represented by hydric sulphide. This gas has, by some chemists, especially the French, been called hydrosulphuric acid by analogy with hydrochloric acid. The term hydrosulphuric is objectionable from its conveying the idea of aqueous sulphuric acid, *hydro* being used as implying the presence or influence of water. I have already pointed out the inconsistency of designating some acids by giving a precedence to the syllables representing their radical, as in hydrochloric, hydriodic; while in others, the syllable indicative of their electronegative ingredient has the precedence, as in fluosilicic, fluoboric, chlorocarbonic and chlorocyanic. If sulphuretted hydrogen is to receive a new name, I would prefer to call it sulphydric acid, as already suggested.

OF SULPHYDRIC ACID OR SULPHURETTED HYDROGEN.

Designated as Hydric-Sulphide in the Berzelian nomenclature.

Few persons are unacquainted with the unpleasant odour which results from the washings of a gun barrel, made foul by the explosion of gunpowder, or that produced by putrid eggs. This odour arises from a compound consisting of one atom, or one volume of hydrogen, and one atom or one volume of sulphur. The celebrated sulphur springs of Virginia are indebted for their odour, and mainly for their efficacy to this compound, to which the celebrated Thenard, has given the name of sulphydric acid. No doubt he was actuated by the same views as myself; when without any knowledge of his opinions, I published my impressions on this subject, in the Journal of Pharmacy for October, 1833.

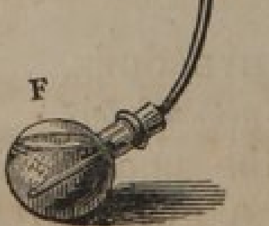
Means of obtaining Sulphydric Acid.

This gas is copiously evolved by the reaction of diluted sulphuric acid with sulphuret of iron. In order to have a supply of it at command, it is only necessary to substitute this last mentioned substance for zinc in the self-regulating apparatus employed for hydrogen, and already described, 116.

As it is absorbed by water, and gradually decomposed by mercury, Berzelius recommends that sulphydric acid should be received over brine. Its purity is demonstrated by its complete absorption by a solution of caustic potash, and by its not rendering lime water milky.

He also advises that the gas should be passed through water, as otherwise it is liable to be contaminated by the generating materials. When the acid is sufficiently diluted, the action in the apparatus above described is so gentle, that I am confident from my experience the gas comes over sufficiently pure for ordinary purposes.

135. *A convenient method of Impregnating Liquids with Sulphydric Acid.*



Suppose the little flask, F, to contain the liquid to be impregnated, and the flexible pipe, one end of which is inserted into the orifice of the flask, to proceed from a self-regulating reservoir of sulphydric acid: it must be evident that the gas, flowing into the cavity of the flask from the orifice of the pipe, must enter the solution. If not absorbed as rapidly as it may be yielded, the excess must bubble up through the solution; the cork being meanwhile loosened, to allow the atmospheric air to escape. The expulsion of the atmospheric air having been completed, and the cork inserted into the neck of the flask, so as to prevent the gas from escaping, it will continue to enter the flask, as fast as absorbed. But if it be generated in the reservoir more rapidly than the solution can absorb it, the excess must remain in the reservoir, and contribute to depress the acid so low in the bell glass, as to diminish the quantity of the sulphuret on which it can act. Finally, when the solution becomes saturated, the gas, generated in the bell, must fill it, and thus, by usurping the place of the acid, cause its reaction with the sulphuret to be suspended.

Of the Properties of Sulphydric Acid.

It is a permanent gas with the odour of rotten eggs, absorbable by water, inflammable, and explosive, forming, by combustion with air or oxygen gas, water, and a mixture of sulphurous and sulphuric acids. Its aqueous solution reddens litmus. Metals are tarnished by it, especially preparations of lead, of which it is a test, and by which it may be detected. It is evolved from privies; blackening the ceruse or carbonate of lead in paint. It may be decomposed by various substances, having some affinity for one or both of its constituents, as for instance, by chlorine, potassium, sodium, sulphurous acid, and ignited carbon, also by successive electric explosions.

Sulphydric acid decomposes all metallic solutions, except those of iron, nickel, cobalt, manganese, titanium, and molybdenum, in consequence of the attraction between hydrogen, and either oxygen or chlorine, and between the metals and sulphur. Metals which in the metallic state yield hydrogen during their reaction with diluted sulphuric or muriatic acid, when subjected to those acids in the state of a sulphide or sulphuret, afford sulphydric acid. According to Berzelius, some sulphides act as acids, others as bases, and unite with each other in a manner analogous to that in which the oxacids and oxybases combine. The resulting compounds he calls sulpho salts. Some sulphides are liable to be reduced by exposure to pure hydrogen in a way analogous to that in which oxides are decomposed by the same agent. But the number of sulphides which may be thus decomposed, is much smaller. Neither the sulphide of copper, nor that of any metal, not having a higher affinity for sulphur than copper, can be thus reduced to the metallic state. Atmospheric air is said to be rendered deleterious to life by the addition of $\frac{1}{250}$ of this gas.

At the temperature of 50 F., and under a pressure of 17 atmospheres, sulphydric acid becomes a colourless liquid more fluid even than sulphuric ether. It is alleged that a single cubic inch of the gas liberated in a large chamber, will in every part, be productive of its characteristic unpleasant odour. A current of the gas directed upon the tongue causes an astringent, acid and bitter taste. The specific gravity of sulphydric acid is 1.1912, that of atmospheric air being 1. In other words it is nearly ⅕th heavier. It is slowly decomposed by nitric oxide, and by sulphurous acid when moist. Nitric acid reacts with it explosively. If mixed with an equal volume of nitric oxide, by a reciprocal decomposition, sulphur, and sulphydrate of ammonia are precipitated, while nitrous oxide remains. With sulphurous acid when dry, it does not react; but water being present, condensation ensues with a deposition of sulphur, and according to Thomson, the production of a peculiar acid. At the temperature of 50° F., water takes up three times its bulk of sulphydric acid, which may be entirely expelled by a boiling heat. The aqueous solution reddens litmus, and becomes turbid after some time by exposure to the air, with the oxygen of which the hydrogen of the gas combines, while the sulphur precipitates. It has already been stated that water impregnated with sulphydric acid exists in many natural springs, which are much frequented by invalids.

The celebrated White Sulphur, Salt Sulphur, and Red Sulphur Springs of Virginia, are of this nature. They appear particularly efficacious as remedies for bilious disorders, and in cutaneous diseases.

Red sulphur springs are thought to be peculiarly useful in some pulmonary complaints, and to have a surprising and unaccountable influence in lowering the pulse. I shall advert to the red deposition in the salt sulphur, and red sulphur springs, again in treating of selenhydric acid.

136. EXPERIMENTAL ILLUSTRATIONS.

Method of extricating sulphydric acid gas, by means of a self-regulating reservoir, exhibited; also, the impregnation of water with it. Effects of its aqueous solution on litmus, and on various metallic solutions. Characters written, with dissolved acetate of lead, are blackened by exposure to the gas, or its aqueous solution. Its inflammation by nitric acid.

137. SYMPATHETIC PICTURE.

The original of this figure was drawn of a gigantic size, in acetate of lead, and was invisible at a little distance, until a jet of sulphuretted hydrogen was directed upon it. The image then appeared by the waving of the pipe, from which the gas flowed, as if it were the wand of a magician.

If the acetate has had time to become dry, the experiment will not succeed without restoring a due degree of moisture. This object is best accomplished, by passing a wet sponge over the back of the sheet on which the figure has been drawn.

RATIONALE.

The acetate of lead consists of acetic acid, and oxide of lead. The oxygen, of the oxide, unites with the hydrogen of the gas, while the sulphur and lead form a sulphuret, to which the blackness of the picture is due.

OF THE POLYSULPHIDE OF HYDROGEN, DISTINGUISHED BY THENARD AS A POLYSULPHURET.

There are various compounds formed by sulphur with metals, some of which are soluble; as for instance, the compound formed by boiling it with lime. This compound has been called a persulphuret of calcium. I would call it a persulphide. Scheele ascertained that on pouring into a diluted acid a persulphuret, such as that to which I have alluded, an oily looking liquid was precipitated, which subsequently received the name of bisulphuretted hydrogen. Thenard designates this compound as the polysulphuret of hydrogen, on account of the great and variable number of atoms of sulphur, which enter into its composition. Moreover he alleges that it constitutes a compound analogous in its properties to the deutoxide of hydrogen; being like that mysterious combination decomposable by many substances for which it has no affinity. Even the presence of the persulphide employed in its production is incompatible with its existence, and hence the impossibility of forming it, by pouring the acid into the solution. In that case an excess of the persulphide must inevitably be present.

He alleges that the polysulphuret (polysulphide) is always liquid at ordinary temperatures. Its colour is yellow, sometimes approaching a greenish brown. It whitens the tongue when applied to it, as is the case upon making a similar application of deutoxide of hydrogen. The same effect is produced upon the skin. Litmus paper is bleached by it, more especially when it is diffused in muriatic acid. Sometimes it has the consistency of an essential oil, sometimes of a fat oil, according to the proportion of its constituents, which has already been stated to be variable. Its odour is peculiar and disagreeable, especially at the period when having been recently formed the supernatant liquid is decanted from it. Then also it affects the eyes painfully. Sooner or later it is dissolved into its elements spontaneously. Charcoal, platinum, gold, iridium, and many other metals in the pulverulent form, cause the evolution of the hydrogen. Many metallic oxides have the same effect, some so actively as to cause a brisk effervescence. These results also ensue from contact with the deutoxide or ("bioxide") of manganese,—from magnesia,—from silex—and above all from pulverized barytes, strontites, lime, potash, and soda. From some of the facts mentioned by Thenard, I infer that this substance may be of great service in bleaching.

OF SELENHYDRIC ACID,

Commonly called Selenuretted Hydrogen, and designated in the Berzelian Nomenclature, as Hydric selenide.

Selenhydric acid is supposed to consist of one atom of sulphur, and one atom of hydrogen. It may be obtained from the selenide of potassium, or of iron, by the action of chlorohydric acid. It is a colourless gas, absorbable without change of colour by water, which has been boiled. Water thus impregnated, has an hepatic taste, reddens litmus paper, and if applied to the skin, stains it a brownish red. The solution exposed to the air, by the oxidation of the hydrogen, becomes gradually turbid from the surface downwards, acquiring a reddish hue, and depositing selenium in light flocks. All metallic salts, even those of iron and zinc, when they are neutral, are precipitated by selenhydric acid. The precipitates are generally of a deep black colour, yet those of zinc, manganese, and cerium, are flesh coloured. By the oxydizement of the hydrogen in selenhydric acid, selenium is precipitated of a cinnabar red colour on any moist body. This acid exercises upon the respiratory organs a violent action, which might easily become dangerous. It produces at first the odour of sulphydric acid, but soon after a prickling sensation in the membranes of the nostrils, which resembles that created by fluosilicic acid gas, but is more stimulating. Subsequently the eyes become red, and the sense of smell is paralyzed. A single bubble of the gas received into the nose, caused such a paralysis of the olfactory nerves, as to create insensibility even to the fumes of the strongest ammonia. The power of detecting odours was not recovered before the expiration of five or six hours.

Thenard mentions that Berzelius, in consequence of inhaling selenhydric acid gas, was attacked by a cough so severe, that a blister was deemed necessary. The quantity inhaled was so minute as to give the impression, that in its effects upon the human system, this gas is pre-eminently pernicious.

So far as my knowledge goes, judging from the description given by Berzelius, the precipitate from selenhydric acid, on exposure to air and moisture, agrees in appearance with the deposition which entitles the Red Sulphur Springs to their distinguishing epithet. I know of no other mineral in nature, which could preserve a red colour in the presence of sulphuretted hydrogen.

But my friend, Professor Wm. B. Rogers, of William and Mary College, informs me that he has ascertained the substance in question to be a vegetable growth, probably peculiar to sulphuretted waters: and that it abounds in several other springs in Virginia, Tennessee, and Alabama.

OF TELLUHYDRIC ACID,

Commonly called Telluretted Hydrogen, and designated in the Berzelian Nomenclature, as Hydric telluride.

When an alloy of tellurium with zinc or tin, is exposed to the action of chlorohydric acid, tellulydric acid is evolved. It is a colourless gas which strongly resembles sulphydric acid in smell, and in its chemical and mechanical properties. It reddens litmus paper, is soluble in water, producing a colourless solution, which by exposure to the air becomes brown, in consequence of the oxidation of the hydrogen and precipitation of the tellurium. It is probably composed of one atom of hydrogen, and one of tellurium.

OF NITROGEN OR AZOTE.

In the gaseous state, it forms nearly four-fifths of the atmosphere, in bulk. Its ponderable base is a principal element, in animal substances. In vegetables, it is only occasionally found. It was called azote, from the Greek ζωη, life, and α, privative of. It was subsequently named nitrogen, azote being equally applicable to other gases which are destructive of life.

I regret that Thenard, instead of abandoning the use of this bad word, has lately endeavoured to give it a further hold on nomenclature, by using the words azotous and azotic, in lieu of nitrous and nitric.

Nitrogen is derived from the same Greek verb as oxygen, combined with the word nitre or nitric. Hence nitrogen signifies a capacity to produce nitre, or nitric acid, as oxygen conveys the idea of a capacity to produce acids.

Means of obtaining Nitrogen Gas.

It may be procured by the aid of any substance which will, in a close vessel, abstract oxygen from the included portion of the atmosphere; as, for instance, by the combustion of phosphorus, or by iron filings and sulphur moistened. This gas may also be obtained by heating muscular flesh, (fibrin,) in a retort, with nitric acid very much diluted.

When obtained by means of phosphorus, a minute quality of this substance remains in solution in the nitrogen; when extricated by the action of nitric acid, it contains a small portion of carbonic acid. In either case it may be purified by washing it with an alkaline solution, or lime-water.

Another method of obtaining nitrogen gas, is to pass chlorine through liquid ammonia. The chlorine unites with the hydrogen of the ammonia, while the nitrogen is liberated. Care must be taken to have the ammonia in excess, otherwise a chloride of nitrogen may be formed, which is capable of producing the most deleterious explosions.

When the chlorite of lime is mingled with muriate of ammonia, and moistened, nitrogen is evolved.

138. *Apparatus for obtaining the Nitrogen from Atmospheric Air.*

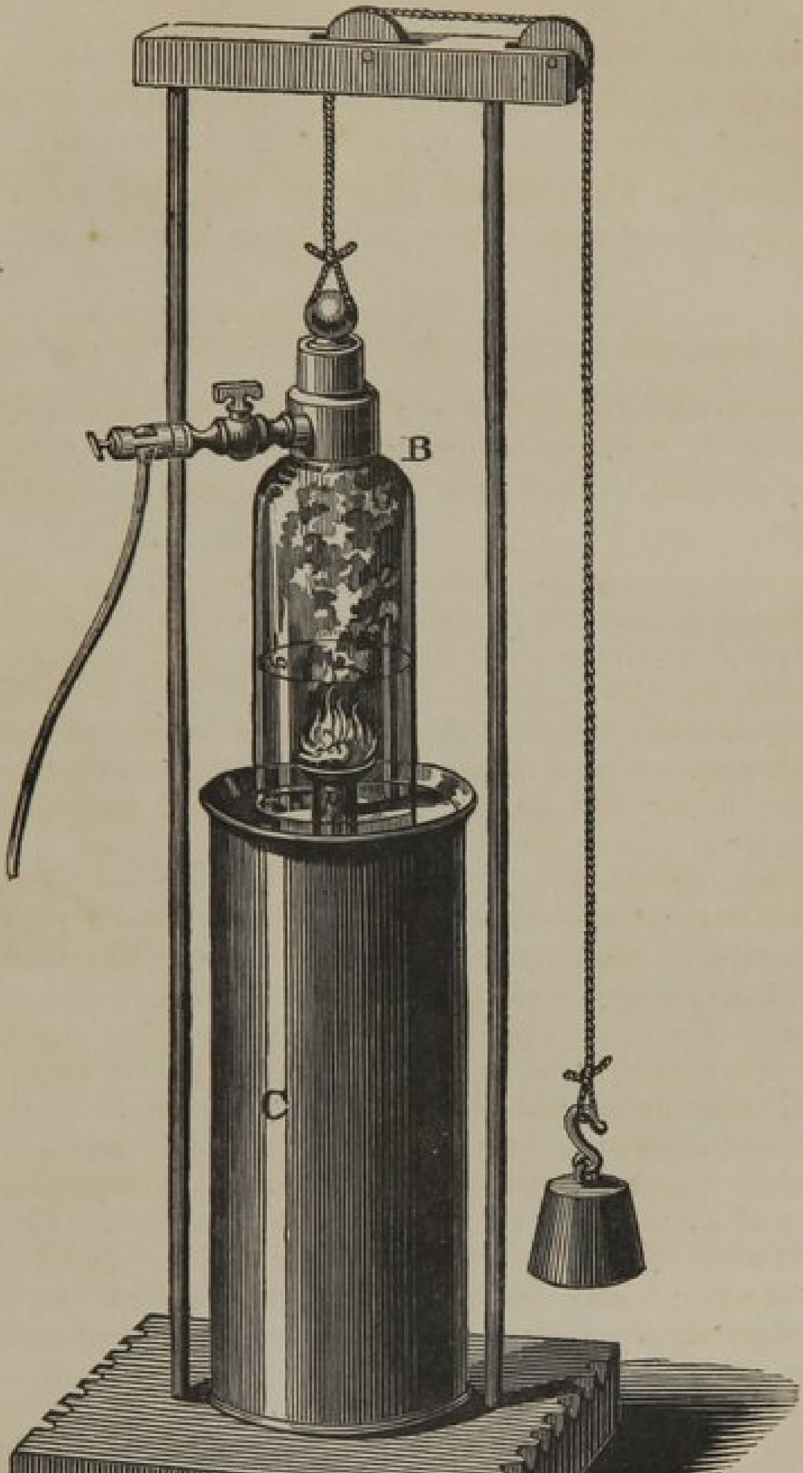
Apparatus for abstracting the Oxygen from Atmospheric Air, and leaving the Nitrogen so situated, as to be drawn easily from the containing vessel, in such quantities, and at such times, as may be desirable.

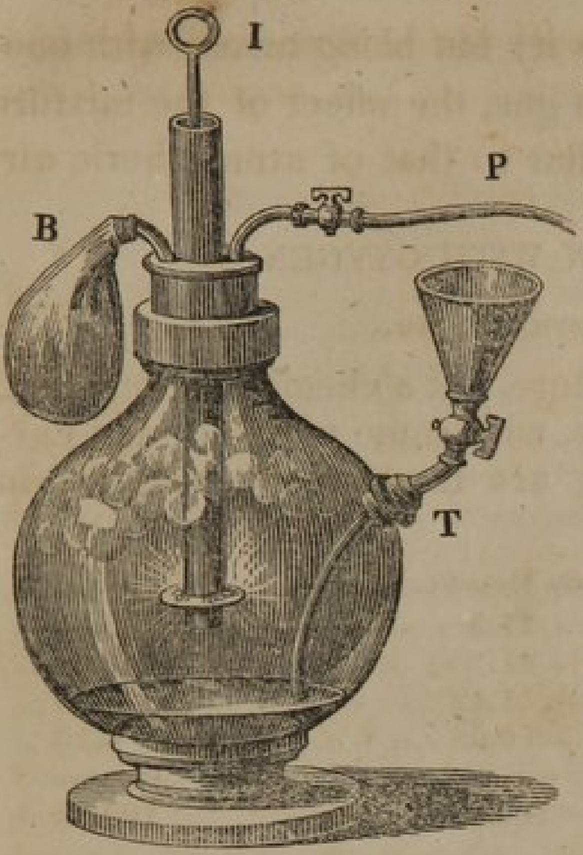
This apparatus, in its principal parts, differs not from the gasometer for oxygen, see article (105.) It is provided with a pipe, P, concentric with the axis of the lower vessel, surmounted by a small copper cup. The pipe in question descends perpendicularly from the level of the brim of the vessel to the bottom; being soldered into a hole in the latter, so that the bore being accessible from without, the copper cup at the upper end may, when necessary, be touched by the end of an iron rod introduced through the pipe, as already described in article (103.)

The inner vessel of the gasometer consists of a bell glass, B, suspended by a cord passing over a wooden gallows, with suitable pulleys. The bell has a perforated neck cemented into a brass cap furnished with a female screw for receiving a cock. To this cock a flexible lead pipe is attached by a gallows screw. Upon the copper cup, a sufficient quantity of phosphorus being placed, and the lower vessel adequately supplied with water, the bell glass is suspended within the lower vessel, as usual with gasometers, and allowed to descend about a third of its depth. Meanwhile the cock of the tube being open, the air is allowed to escape, so that the liquid within and without the bell glass may be on a level. The cock being in the next place closed, and the temperature of the phosphorus sufficiently raised to make it take fire by touching the cup with the extremity of an iron rod previously reddened in the fire, a brilliant combustion ensues. As soon as it declines, the iron meanwhile kept in the fire should be again introduced in order to sustain the combustion till all the oxygen is absorbed.

When the air in the bell glass is completely deoxygenated, which may be known by the yellow colour of the fumes; the residual nitrogen may be expelled into any recipient at pleasure, through the flexible pipe attached to the cock for that purpose, by depressing the bell in the water.

Abstraction of Oxygen from Atmospheric Air by Phosphorus.
(C. p. 166.)





139. *Additional means of obtaining Nitrogen.*

The apparatus, of which the figure subjoined is a representation, may be used for the purpose of abstracting the oxygen from the air, by means of phosphorus.

The process is quite analogous to that already explained, for the combustion of phosphorus in oxygen; excepting that the gun barrel is suspended from the cap, instead of entering from below, the situation of the cup for holding the phosphorus being varied so as to accord with the change. The bladder, B, affords room for the requisite expansion. The funnel and cork at T, facilitates the introduction of water to expel the nitrogen as wanted; and the pipe P, and the cock associated with it, serve to control and direct the transfer of the nitrogen to the vessels in which its presence may be required.

Of the Properties or Characteristics of Nitrogen Gas.

As a gas, it is distinguished by a comparative want of properties. It is lighter than oxygen gas, or atmospheric air. It supports neither life nor combustion, but is, obviously, a harmless ingredient in the air.

The affinity of nitrogen for caloric, compared with that which it displays for other substances, appears to be peculiarly great. Hence, it is not liable, like hydrogen or oxygen, to enter into combination with other matter, so as to part with the caloric to which it owes its existence as a gas; and when under any circumstances it does enter into combination, it seems more than almost any other substance, to carry caloric into combination with it; being, consequently, an ingredient in a majority of the most powerful, fulminating compounds.

Nitrogen has been suspected, by some chemists, of being a compound, but is generally considered as an element. At the temperature of 60° F., 100 cubic inches, weigh 29.73 grains. Its specific gravity, comparatively with air, is .97522.

140. EXPERIMENTAL ILLUSTRATIONS OF THE PROPERTIES OF NITROGEN GAS.

A portion of the nitrogen, obtained as above described, being introduced into a bottle, extinguishes a candle flame when introduced into it; but being mixed with one-fourth of its bulk of oxygen gas, the effect of the mixture in supporting flame, is similar to that of atmospheric air.

OF NITROGEN WITH OXYGEN.

OF ATMOSPHERIC AIR.

Atmospheric air is a mixture, not a chemical compound, of oxygen and nitrogen gas, with some moisture and carbonic acid. The following are the proportions given in Henry's Chemistry.

	By Measure.	By Weight.
Nitrogen gas	77.5	75.55
Oxygen gas	21.	23.32
Aqueous vapour	1.42	1.03
Carbonic acid	0.08	0.10
	100.00	100.00

The average of a great number of experiments made with my eudiometers, makes the proportion of oxygen 20.66 in 100 of air.

In addition to these constituents, it is alleged that there is a little chlorohydric acid in the atmosphere, in situations in the neighbourhood of the sea; and hence it arises, probably, that animals far inland, are much more fond of common salt, another compound of chlorine, than those in regions bordering on the ocean.

It has been made a question whether the nitrogen and oxygen of the air, are not in a state of chemical combination. I am of opinion, that no other cause of union between them exists, than that which is known to cause the equable diffusion of heterogeneous gaseous particles among each other, notwithstanding the difference of their specific gravities.

In its qualities, atmospheric air does not differ from a mixture. Oxygen mingled with hydrogen in the same proportion, as it is mingled with nitrogen in the air, has been found to support animal life, nearly as well.

The mechanical influence of the atmosphere, so far as it appertains to chemistry, has been sufficiently illustrated. See pages 31 to 42. I have also treated of its capacity to hold moisture, and to promote, and produce cold by evaporation. Some of the most accurate and easy methods of analysing it, will be mentioned under the heads of nitric oxide, hydrogen, and phosphorus.

EUDIOMETRICAL ANALYSIS OF THE ATMOSPHERE.

While on the subject of atmospheric air, the eudiometrical analysis of it becomes necessarily an object of attention. I have already given an engraving and description of a large eudiometer which I have designated as a volumescope. By means of that instrument it was demonstrated, that when the elements of water are mixed in the gaseous state and ignited, they will always combine in the proportion of two volumes of hydrogen, to one volume of oxygen. It follows that if any gaseous mixture containing oxygen, and no other gas capable of combining with hydrogen or oxygen, be ignited with an excess of hydrogen, all the oxygen will be condensed into water, and may be estimated as equal to one-third of the resulting deficit. It follows also that if to a gaseous mixture containing hydrogen, and no other gas with which hydrogen or oxygen can combine, an excess of oxygen be added and the mixture ignited, all the hydrogen will be condensed, and will in quantity equal two-thirds of the deficit. Thus if five volumes of atmospheric air, and three of hydrogen be introduced into the volumescope and ignited, the eight volumes will be reduced to rather less than five; of course a little more than three volumes will have been condensed; of which one-third is oxygen. In five volumes of atmospheric air, there is therefore somewhat more than one volume of oxygen. By the volumescope the excess cannot be accurately measured, but by other instruments which I have contrived, great accuracy is attainable. Before describing those, I will give engravings and descriptions of some implements for measuring gas, which much facilitate eudiometrical experiments; and which are also very useful in other pneumato-chemical operations. I am the more particular in describing my apparatus in the compendium, in order that I may not be under the necessity of taking up time during my lectures with such descriptions.

135. PISTON VALVE VOLUMETER.

I have contrived some instruments for measuring gas with great accuracy. I call them volumeters, to avoid circumlocution. They are of two kinds, one is filled by introducing it into any vessel containing the gas with which it is to be filled, over water, or mercury; the gas is introduced into the other through an orifice, as is usual in the case of filling a common bottle over the pneumatic cistern. The following figure will convey a correct idea of one of them, which having a piston and a valve, I call the piston valve volumeter.

The lever, L, is attached, by a hinge, to a piston, *p*, which works inside of a chamber, C. The rod of this piston extends beyond the packing through the axis of the bulb, B, to the orifice, O, in its apex, where it supports a valve, by which this orifice is kept close, so long as the pressure of the spring, acting on the lever, at L, is not counteracted by the hand of the operator.

Suppose that, while the bulb of this instrument, filled with water or mercury, is within a bell glass, containing a gas, the lever be pressed towards the handle, the valve consequently is drawn back so as to open the orifice in the apex of the bulb, and at the same time the piston descends below an aperture, A, in the

chamber. The liquid in the bulb will now of course escape, and be replaced by gas, which is securely included, as soon as the pressure of the spring is allowed to push the piston beyond the lateral aperture in the chamber, and the valve into the orifice, O, in the apex of the bulb.

The gas, thus included, may be transferred to any vessel, inverted over mercury or water, by depressing the orifice of the bulb below that of the vessel, and moving the lever, L, so as to open the aperture, A, in the chamber, and the orifice of the bulb simultaneously.

The bulk of gas, included by this volumeter, will always be the same; but the quantity will be as the density of the gas into which it may be introduced when filled. Hence in order to measure a gas accurately, the liquid, whether water, or mercury, over which it may be confined, should be of the same height within, as without. This is especially important, in the case of mercury, which, being in weight, to water, as 13.6 to 1, affects the density of a gas materially, even when its surface within the containing vessel, does not deviate sensibly from the level of its surface without.

To remove this source of inaccuracy, I employ a small gage which communicates, through a cock in the neck of the bell, with the gas within. In this gage, any light liquid will answer, which is not absorbent of the gas. In the case of ammonia, liquid ammonia may be used; in the case of muriatic acid gas, the liquid acid. One of the gages which I have used will be described, in the appendix, as attached to the mercurial sliding rod eudiometers. The other is simply an inverted glass syphon.

136. SIMPLE VALVE VOLUMETER.

Besides the lower orifice, O, by which it is filled with gas, the volumeter which this figure represents, has an orifice at its apex, A, closed by a valve attached to a lever. This lever is subjected to a spring, so as to receive the pressure requisite to keep the upper orifice shut, when no effort is made to open it.

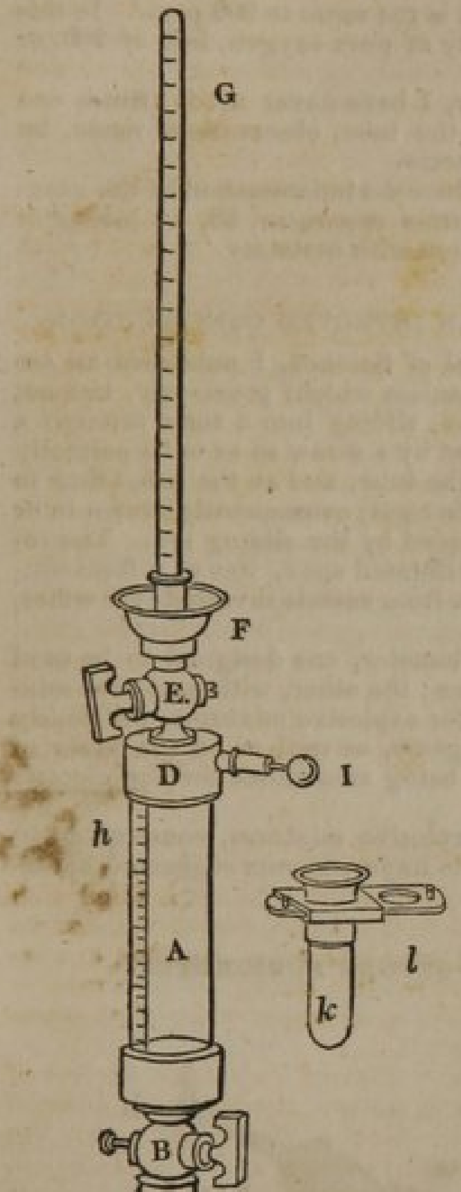
When this volumeter is plunged below the surface of the water of a pneumatic cistern, the air being allowed to escape, and the valve then to shut itself under the water, on lifting the vessel it comes up full of the liquid, and will remain so, if the lower orifice be ever so little below the surface of the water in the cistern. Thus situated, it may be filled with hydrogen, proceeding, by a tube, from a self-regulating reservoir. If the apex, A, be then placed under any vessel filled with water and inverted in the usual way, the gas will pass into it, as soon as the valve is lifted.

Volumes of atmospheric air are taken, by the same instrument, simply by lowering it into the water of the cistern, placing the apex under the vessel into which it is to be transferred, and lifting the valve: or preferably by filling it with water, and emptying it in some place, out of doors, where the atmosphere may be supposed sufficiently pure, and afterwards transferring the air, thus obtained as above described, by opening the valve while the apex is within the vessel, in which its presence is required. In this case, while carrying the volumeter forth and back, the lower orifice must be closed. This object is best effected by a piece of sheet metal, or a pane of glass.

It is necessary that the water, the atmosphere, and the gases should be at the same temperature during this process.

137. VOLTA'S EUDIOMETER.

The eudiometer, represented in this figure, was contrived by Volta, for the analysis of gaseous mixtures, and compounds containing oxygen, or hydrogen.



The body of this instrument, A, is a cylinder of glass, which is cemented below into a brass socket, united by a screw with the cock, B. This cock screws into a hollow brass pedestal, C, with the cavity in which, the bore of the cock communicates. The glass cylinder is also cemented into a cap, D, which is surmounted by a cock, E, supporting the basin, F. The cavity of the basin communicates, through the bore of the cock when open, with that of the cylinder. Into the perforation in the bottom of the basin, the sealed tube G, graduated into 200 parts, fastens by a screw, cut upon a socket, into which the tube is cemented. On one side of the cylinder, there is a metallic scale, *h*, each division of which indicates a section of the bore of the cylinder equivalent to ten degrees on the tube. I, is an insulated wire for passing the electric spark through any explosive mixture which may be introduced into the cylinder. *k*, is a measure which holds as much gas as, when admitted into the cylinder, would be equal to ten divisions of the metallic scale, or as would fill the upper tube to 100 degrees, if allowed to rise into it. This measure is furnished with a slide, in which a hole is represented at *l*. The measure is open when this hole is within it; it is closed when the hole is outside as it appears in the engraving. By this mechanism it is rendered certain that, with care, the volume of air, taken at one time, will be equal to that taken at another time.

In order to put this eudiometer into operation, open both the cocks, and depress it in the water of the cistern, until the water rises into the cylinder just above the lower cock. This cock is then to be closed, and the pedestal placed on the shelf of the cistern. Water is to be poured into the basin, until both the basin and cylinder are full. The glass tube, G, is then to be filled with water, and inverted, and the orifice, meanwhile, closed with the finger, is to be depressed below the surface of the water, in the basin, without admitting air. The tube is then screwed into its place, so as to occupy the position, in which it appears in the figure.

The upper cock being closed, let the measure, *k*, be plunged in the water of the cistern, the orifice open for the air to escape. Then invert it, the orifice being kept under the surface of the water. Next fill it with the mixture to be analyzed, as for instance, a mixture of equal volumes of hydrogen and atmospheric air. Shut the orifice by moving the slide, allow any excess of air to escape, and then placing the orifice of the measure under the pedestal of the eudiometer, open the orifice; the gaseous mixture will mount into the cavity of the cylinder. Shut the lower cock, and pass an electric spark through the included mixture. An explosion will ensue, and consequently a portion of the mixture will be condensed into water. By opening the cock, B, the deficit, thus produced, will be compensated by the entrance of an equivalent bulk of water. Open the upper cock, and allow the residual gas to mount into the graduated tube. Detach this tube from the eudiometer, and closing the orifice with the finger, under water, before lifting it from the basin, sink it in water, until this liquid be as high without, as within the tube. It may now be seen, how far the residual air falls short of the 100 measures introduced.

It must be evident that we might operate on double the quantity of gas, by taking the measure full of it twice instead of once; and that a mixture of two volumes air, and one volume hydrogen, might be analyzed, by taking three measures equivalent to 300 parts. The loss by the explosion would be the number of degrees that the residue should fall short of 300, when in the graduated tube.

A mixture of three volumes of hydrogen, with one of impure oxygen, might be analyzed by taking the measure twice full, which is the same as 200 parts. In this case, one-third of the deficit would be the quantity of pure oxygen, in ¼ of 200, or 50 parts, of the impure gas.

The metallic scale accompanying the cylinder, I have never used. Since one of its divisions, is equivalent to ten of those on the tube, observations made, by means of the latter, must be ten times more accurate.

Instead of resorting to an electric spark to produce the inflammation of the gases I have added to this eudiometer a *galvano ignition apparatus*, 58, by means of which a gaseous mixture may at any time be ignited with certainty.

AN ACCOUNT OF SOME EUDIOMETERS, OF AN IMPROVED CONSTRUCTION.

In the second volume of the American Journal of Science, I published an account of some eudiometers, operating by a mechanism which, previously, had not been employed in eudiometry. A graduated rod, sliding into a tube through a collar of leathers, soaked in lard, and compressed by a screw so as to be perfectly air-tight, was employed to vary the capacity of the tube, and at the same time to be a measure of the quantity of air, or of any other gas, consequently drawn in or expelled. About one-third of the tube was occupied by the sliding rod. The remainder, being recurved, and converging to a perforated apex, was of a form convenient for withdrawing measured portions of gas from vessels inverted over water, or mercury.

There were two forms of the sliding rod eudiometer, one designed to be used with nitric oxide, or with liquids absorbing oxygen; the other, with explosive mixtures. The latter differed from the eudiometers for explosive mixtures, previously invented, in the contrivance for exploding the gases, as well as in the mode of measuring them; a wire, ignited by galvanism, being substituted for the electric spark, as the means of inflammation.

I shall proceed to describe a eudiometer, for explosive mixtures, constructed on the principle of those above alluded to, with some improvements suggested by experience.

138. AQUEOUS SLIDING ROD HYDRO-OXYGEN EUDIOMETER.

FIG. 1.

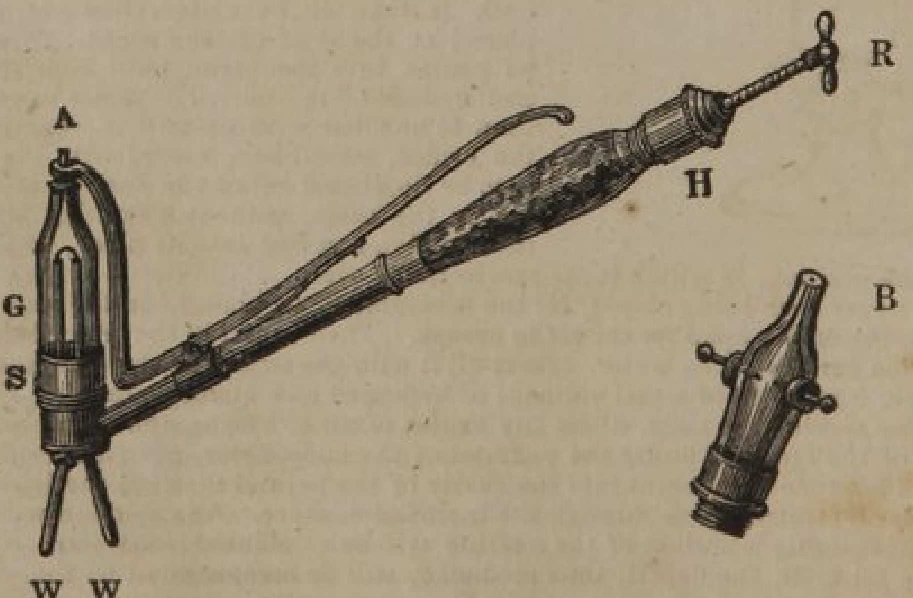
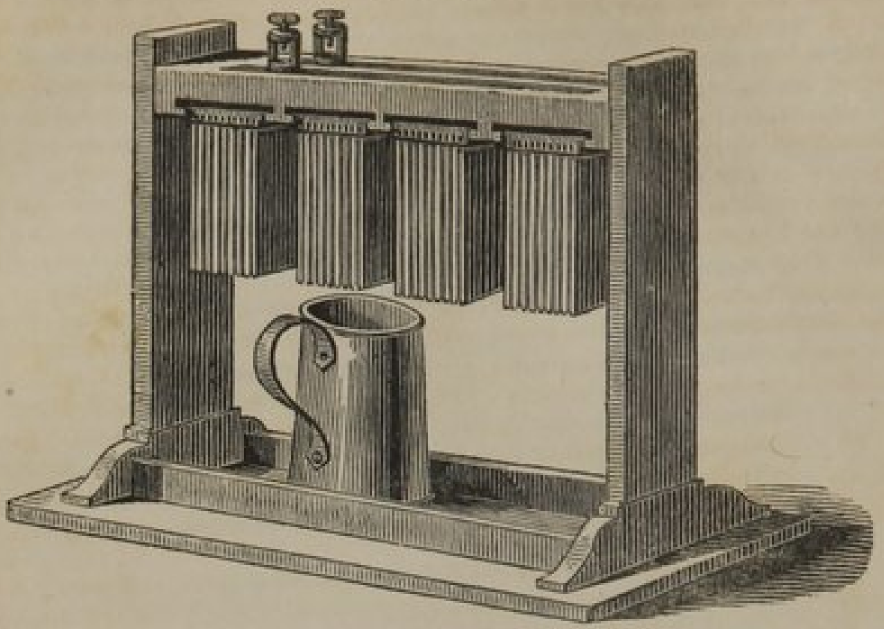
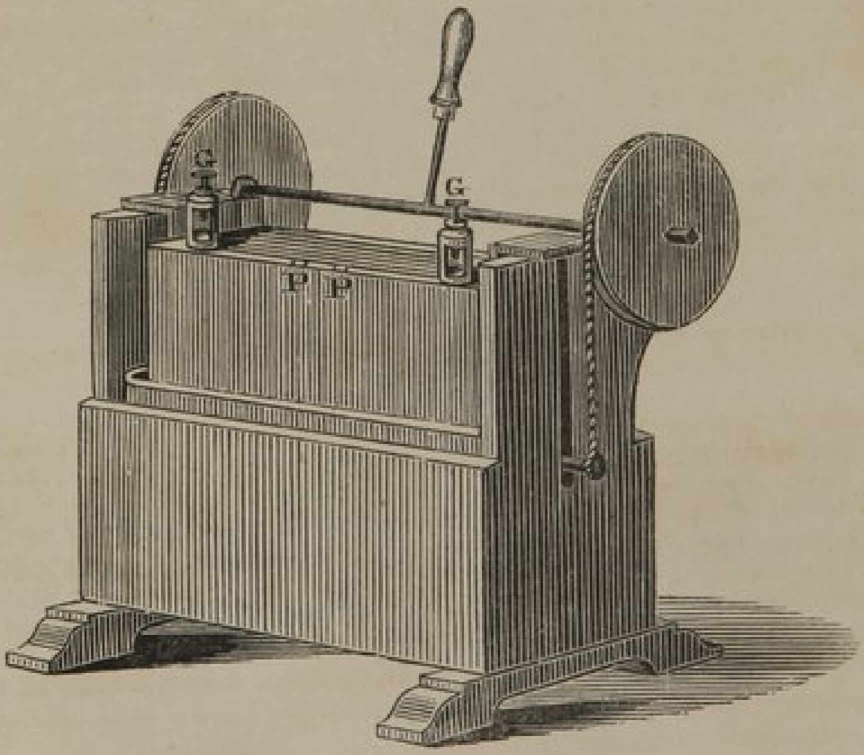


Fig. 1, represents a hydro-oxygen eudiometer, in which the measurements are made by a sliding rod, and the explosions are effected by the galvanic ignition of a platina wire.

FIG. 2.



Two furrows are made in the wood of the beam, one on each side. These are filled with melted solder, after having caused a metallic communication between one furrow and all the copper surfaces of the four calorimotors; also between all their zinc surfaces and the other furrow. The acid for exciting the plates, is contained in the jug below, which may be lifted so as to surround with acid either of the calorimotors. Hence while one is in operation, the others are by repose, recovering their igniting power.



Since the text on the opposite page was printed which refers to fig. 2, I have procured the preceding engraving of the apparatus which I have latterly employed to ignite the wire of my eudiometer. Accordingly I insert an impression of it, with a description. The apparatus which it represents is a calorimotor, containing two galvanic pairs, consisting each of two plates of zinc, and three of copper. The arrangement may be understood from the engraving and description in page 145. It differs from that apparatus only in size, and in the number of the pairs. The mechanism is similar. Into two cavities in two masses of soft solder, which constitute the poles of the instrument, the wires, W, W, of the eudiometer are forcibly pressed by one hand of the operator, while by the other the acid is made to act upon the plates through the instrumentality of the lever. Instantaneously on the ignition taking place, the circuit should be interrupted by lifting the eudiometer, as otherwise the wire may be fused.

In the instrument represented by the preceding cut, the igniting wire is soldered into the summits of the two brass wires, W W, which pass through the bottom of the socket S, parallel to the axis of the glass recipient, G, within which they are seen. One of the wires is soldered to the socket. The other is fastened by means of a collar of leathers, packed by a screw, so that it has no metallic communication with the other wire, unless through the filament of platinum, by which they are visibly connected above, and which I have already called the igniting wire. The glass has a capillary orifice at the apex, A, which by means of a lever and spring, (apparent in the drawing) is closed, excepting when the pressure of the spring is counteracted by the thumb of the operator. The sliding rod, R, is accurately graduated to about 100 degrees.

I have found it expedient to secure the valve which closes the aperture in the apex of the instrument, from the possibility of leakage during explosions, by means of an iron staple, with a screw, which is here represented. This fastens upon two pivots, one of which is inserted on each side of the brass socket, S, into which the glass recipient, G, is cemented. The staple hinges upon these pivots, and may be brought into a position, in which the screw, A, being immediately over the valve, may be made to tighten it; or the staple may be made to hang down, so as not to be in the way, when the instrument is to be charged.

In order to use the eudiometer, it must be full of water, free from air bubbles, and previously proved air tight,* the rod being introduced to its hilt, and the capillary orifice open, in consequence of a due degree of pressure on the lever, by which it is usually closed. Being thus prepared to ascertain the proportion of oxygen in the air, draw the rod out of the tube till 100 graduations are visible. A bulk of air, equivalent to the portion of the rod thus withdrawn, will of course enter at the capillary opening; after which the lever must be allowed to close it. Introduce the receiver into a bell glass of hydrogen, and opening the orifice, draw out the rod fifty additional graduations, or more; close the orifice, and withdraw the instrument from the water. Apply the projecting wires, W W, severally to the solder, (in the two furrows in the beam fig. 2, communicating with the poles of the four calorimotors,) then raise the jug so that it may receive one of them, and subject it to the acid. By the consequent ignition of the wire, the gas will explode. The instrument being plunged again into the water of the pneumatic cistern, so that the capillary orifice, duly opened, may be just below the surface; the water will enter and fill up the vacuity caused by the condensation of the gases. The residual air being excluded by the rod, the portion of the rod remaining without, will be in bulk equivalent to the deficit, which may consequently be ascertained by inspecting the graduation. I have performed this experiment in thirty seconds.

If oxygen is to be examined by hydrogen, or hydrogen by oxygen, we must of course have a portion of each, in vessels over the pneumatic cistern, and successively take the requisite quantities of them, and proceed as in the case of atmospheric air.

Another, and perhaps more accurate mode of operating with this instrument is, by means of one of the volumeters above described, to make a mixture of the different gases, in due proportion, in a bell glass. Thus, let two measures of atmospheric air, be added to one of the hydrogen; then on taking one hundred and fifty measures of the mixture into the eudiometer, there will be the same quantity of each gas, as if 50 measures of hydrogen, and 100 of air had been taken, as above described. In order to ascertain the quantity of pure oxygen in the gas from nitre or manganese, one measure of it might be added to three of hydrogen. Then of 200 measures of the mixture, which might be taken into the eudiometer, 50 would

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* To prepare the instrument and prove it to be in order, depress the glass receiver below the surface of the water in the pneumatic cistern, the capillary orifice being uppermost, and open; draw the rod out of its tube, and return it alternately, so that at each stroke, a portion of water may pass in, and a portion of air may pass out. During this operation, the instrument should be occasionally held in such a posture, as that all the air may rise into the glass recipient, without which its expulsion, by the action of the rod, is impracticable. Now close the orifice, (at the apex, A,) and draw out a few inches of the rod, in order to see whether any air can enter at the junctures, or pass between the collar of leathers and the sliding rod. If the instrument be quite air tight, the bubbles, extricated in consequence of the vacuum produced by withdrawing the rod, will disappear when it is restored to its place. This degree of tightness is easily sustained in a well made instrument.

consist of the gas to be assayed, and 150 of hydrogen; and one-third of the deficit caused by the explosion, would be the quantity of pure oxygen gas in the 50 measures.

If hydrogen were to be assayed, as for instance the gas evolved by the reaction of diluted sulphuric acid with zinc, as in experiment 116, it would be proper to take equal parts of the hydrogen and oxygen, as the gas which is not to be analyzed, must always be in excess. Taking then 200 measures into the eudiometer, two-thirds of the deficit caused by the explosion, would be the pure hydrogen, in 100 measures of the gas under analysis. The required mixtures may be made with great facility and accuracy, by either of the volumeters described page 169.

B, fig. 1, represents a glass with wires inserted through small tubulures, in the usual mode for passing the electric spark; should this method of producing ignition be deemed desirable for the sake of varying the experiment, or for the purpose of illustration. This glass, the other being removed, may be fastened into the same place. The wires, W, W, remain, but should be of such a height as not to interfere with the passage of the electric spark. The instrument is operated with as usual, excepting the employment of an electrical machine, or electrophorus, to ignite the gaseous mixture. For the travelling chemist, the last mentioned mode of ignition may be preferable, because an electrophorus is more portable than a galvanic apparatus.

In damp weather, or in a laboratory, where there is a pneumatic cistern, or amid the moisture arising from the respiration of a large class, it is often impossible to accomplish explosions by electricity.

139. SLIDING ROD GAS MEASURE.

The construction of this instrument differs from that of my sliding rod eudiometers, in having a valve which is opened and shut by a spring and lever, acting upon a rod passing through a collar of leathers. By means of this valve, any gas drawn into the receiver, is included so as to be free from the possibility of loss, during its transfer from one vessel to another. This instrument is much larger than the sliding rod eudiometers for explosive mixtures; being intended to make mixtures of gas, in those cases where one is to be to the other, in a proportion which cannot be conveniently obtained by taking more or less volumes of the one than the other, by means of the volumeters: for instance, suppose it were an object to analyze the air according to Dr. Thomson's plan of taking 42 per cent. of hydrogen. The only way of mixing the gases by a volumeter in such a ratio, would be to take the full of the volumeter 21 times of hydrogen, and 50 times of atmospheric air. By the large sliding rod instrument, this object is effected at once, by taking 42 measures of the one, and 100 measures of the other.

CHEMICAL COMPOUNDS OF NITROGEN WITH OXYGEN.

1 vol. or 1 atom of nitrogen = 14, forms, with	½ vol.	or 1 atom	oxygen,	1 vol. nitrous oxide.
	1 „	or 2 atoms	„	2 vols. nitric oxide.
	1½ „	or 3 „	„	hyponitrous acid.
	2½ „	or 5 „	„	nitric acid.
	2 „	or 4 „	„	1 vol. nitrous acid.

According to Berzelius, the last mentioned compound consists either of nitric acid and nitric oxide, or of the nitric and hyponitrous acids.

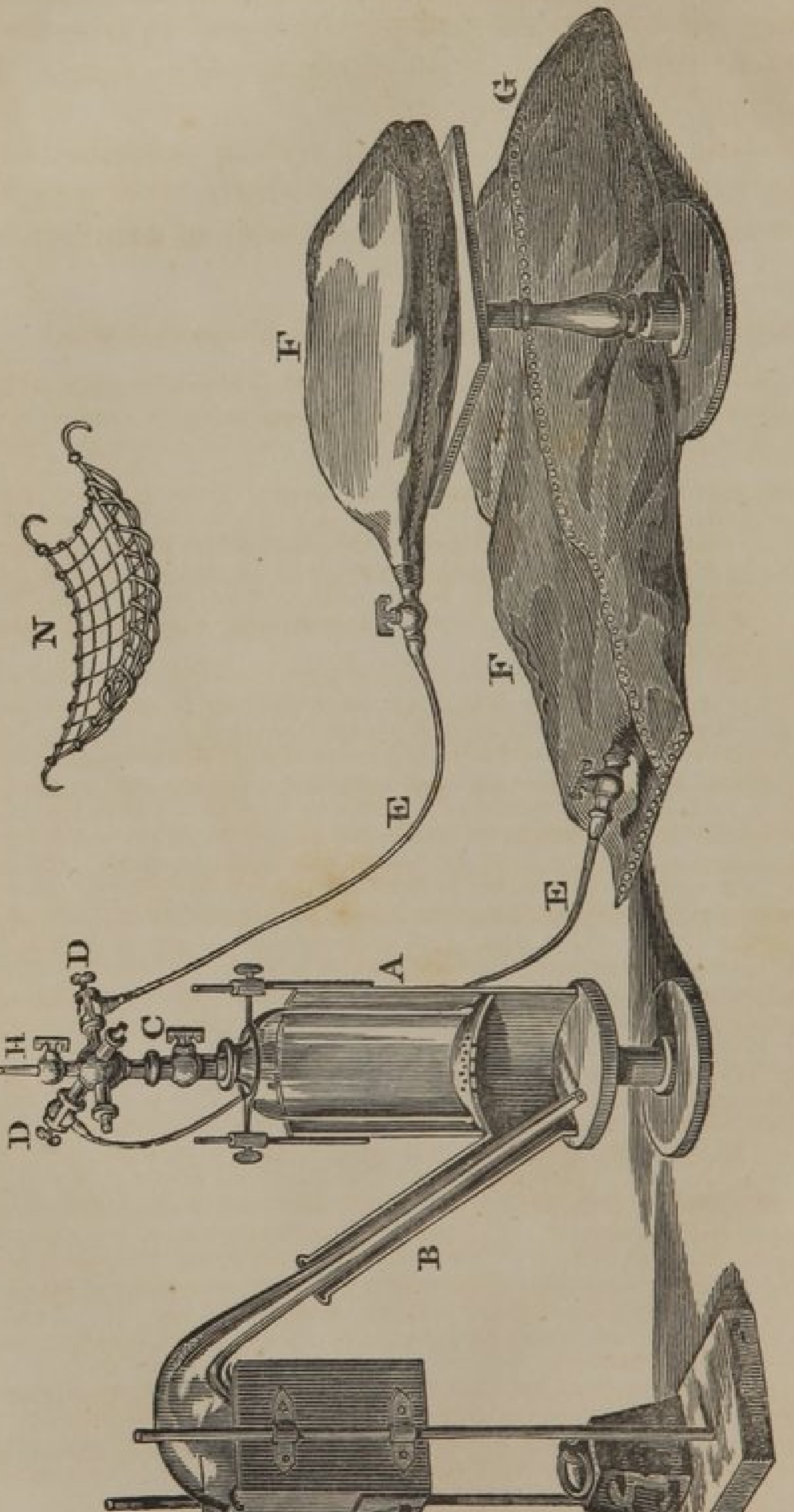
PROTOXIDE OF NITROGEN OR NITROUS OXIDE.

This substance does not exist in nature. When artificially obtained, it is gaseous; yet the experiments of Mr. Faraday have taught us that under great pressure, it may be converted into a liquid.

Sliding Rod Gas Measure.
(C. p. 174.)

Apparatus for Evolving and Collecting Nitric Oxide.

(C. p. 175.)



Means of obtaining Nitrous Oxide.

It may be obtained by the action of dilute nitric acid upon zinc: or by exposing nitric oxide gas to iron filings, sulphites, or other substances, attractive of oxygen. It is best procured by subjecting nitrate of ammonia to heat, and receiving the product in an apparatus described in the following article. As pure water absorbs this gas, Berzelius receives it over saturated solutions of common salt.

140. *Apparatus for evolving and preserving Nitrous Oxide Gas.*

A, represents a copper vessel of about eighteen inches in height, and nine inches in diameter, which is represented as being divided longitudinally, in order to show the inside. The pipe, B, proceeds from it obliquely, as nearly from the bottom as possible.

Above that part of the cylinder from which the pipe proceeds, there is a diaphragm of copper, perforated like a colander. A bell glass is surmounted by a brass cock, C, supporting a tube and hollow ball, from which proceed on opposite sides, two pipes, terminating in gallows screws, D D, for the attachment of perforated brass knobs, soldered to flexible leaden pipes communicating severally with leathern bags, F F. The larger bag is capable of holding about fifty gallons, the smaller one, about fifteen gallons.

The beak of the retort must be long enough to enter the cylinder, so that the gas in passing from the mouth of the beak, may rise under, and be caught by the diaphragm. This is so hollowed as to cause it to pass through the perforations already mentioned, which are all comprised within a circle, less in diameter, than the bell glass. The gas is, by these means, made to enter the bell glass, and is, previously to its entrance, sufficiently in contact with water, to be cleansed from the acid vapour which usually accompanies it. On account of this vapour, the employment of a small quantity of water to wash the gas, is absolutely necessary; and for the same reason, it is requisite to have the beak of the retort so long, as to convey the gas into the water, without touching the metal; otherwise, the acid vapour will soon corrode the copper of the pipe, B, so as to enable the gas to escape. But while a small quantity of water is necessary, a large quantity is productive of waste, as it absorbs its own bulk of the gas. On this account, I contrived this apparatus, in preference to using gasometers or air holders, which require larger quantities of water.

The seams of the bags are closed by means of rivets, agreeably to the plan of Messrs. Sellers and Pennock for fire hose. The furnace is so contrived, that the coals, being situated in a drawer, G, may be partially, or wholly removed, in an instant. Hence the operator is enabled, without difficulty, to regulate the duration or the degree of the heat. This control over the fire, is especially desirable in decomposing the nitrate of ammonia, as the action otherwise may suddenly become so violent, as to burst the retort. The iron netting, represented at N, is suspended within the furnace, so as to support the glass retort, for which purpose it is peculiarly adapted. The first portions of gas which pass over, consisting of the air previously in the retort, are to be allowed to escape through the cock, H. As soon as the nitrous oxide is evolved, it may be detected by allowing a jet from this cock, to act upon the flame of a taper.

To obtain good nitrous oxide gas, it is not necessary that the nitrate of ammonia should be crystallized; nor does the presence of a minute quantity of muriatic acid, interfere with the result. I have employed advantageously in the production of this gas, the concrete mass formed by saturating strong nitric acid, with carbonate of ammonia.

The saturation may be effected in a retort, and the decomposition accomplished by exposing the compound thus formed to heat, without further preparation.

RATIONALE

Of the Production of Nitrous Oxide, by the destructive Distillation of Nitrate of Ammonia.

Nitrate of ammonia consists of nitric acid and ammonia. Nitric acid consists of five atoms of oxygen, and one of nitrogen; ammonia, of one atom of nitrogen, with three atoms of hydrogen. In one atom of this salt, five atoms of oxygen, three of hydrogen, and two of nitrogen are present. It must be evident that if, in consequence of the heat, each atom of hydrogen takes one of oxygen, there will be but one atom of oxygen left for each atom of nitrogen. Hence, the whole of the salt is resolved into water, and protoxide of nitrogen, or nitrous oxide.

Properties and Composition of Nitrous Oxide.

It is a permanent gas.—100 cubic inches weigh about 50 grains. It supports the combustion of a candle flame vividly; though nitric oxide gas, containing twice as much oxygen, does not. Phosphorus is difficult to inflame in it, but burns with rapidity, when once on fire. The habitudes of sulphur, are in this respect, analogous to those of phosphorus. An iron wire burns in it nearly as well as in oxygen gas. Most of the combustible bodies burn in nitrous oxide. When ignited with hydrogen, an explosive reaction ensues, and water and nitrogen result. It has no attribute of acidity. It stimulates and then destroys life. Its effects on the human system are analogous to a transient, peculiar, various, and generally very vivacious ebriety. It is much more rapidly and extensively soluble in water, than oxygen.

Homburg's pyrophorus, or that which I have contrived to obtain from Prussian blue, takes fire on falling through the gas.

Mr. Faraday has shown that nitrous oxide may be liquefied under great pressure. When nitrate of ammonia was heated at one end of a sealed recurved tube, nitrous oxide was condensed into a liquid at the other end.

141. EXPERIMENTAL ILLUSTRATIONS.

The process and apparatus for producing, collecting, and breathing nitrous oxide gas, exhibited. The effect on a lighted candle, and on an iron wire, shown.

COMBUSTION OF PHOSPHORUS IN NITROUS OXIDE GAS.

There is a singular backwardness in the oxides of nitrogen to part with their oxygen to phosphorus, until it be intensely ignited, either by an incandescent iron, or by access of uncombined oxygen.

This characteristic in the case of nitrous oxide, may be illustrated by means of an apparatus like that employed for the combustion of phosphorus in oxygen, with a tall cylindrical receiver, and a tube descending through the neck, and along the axis of the receiver, terminating in a capillary orifice over the cup for holding the phosphorus. The upper end of the tube, outside the receiver, is furnished with a cock, to which a gum elastic bag inflated with oxygen is attached.

Under these circumstances, the receiver having been exhausted, and filled with nitrous oxide; phosphorus, previously placed within the cup, may be melted without taking fire. But as soon as the cock communicating with the bag of oxygen is opened, an intense combustion ensues; since the oxygen, emitted in a jet from the capillary orifice of the tube, reaches the melted phosphorus, and excites it into an active combustion, which the nitrous oxide afterwards sustains with great energy.

OF NITRIC OXIDE GAS,

FORMERLY CALLED NITROUS AIR.

This oxide is an artificial product, and is obtained only in the gaseous state. Its tendency to combine with oxygen, renders it impossible that it should exist where the atmosphere has access.

Means of obtaining Nitric Oxide.

It is evolved during the reaction between nitric acid, and copper, silver, and other metals.

142. SELF-REGULATING APPARATUS FOR GENERATING NITRIC OXIDE.

The command of a sufficient supply of nitric oxide is most conveniently attained, by means of a self-regulating apparatus made in the manner which I am about to describe, and which is illustrated by the adjoining figure. A glass vessel resembling a claret bottle, elevated upon a perforated foot, is placed within a glass jar, of which the rim rises to about the middle of the neck, which is furnished with a cock and gallows screw for the attachment of a flexible leaden tube. The cavity of the bottle being supplied with copper shreds or turnings, and the jar with diluted nitric acid; by the reaction of the metal with the acid, gas is copiously evolved, producing red fumes by generating nitrous acid with the oxygen of the air. The emission of the gas should be permitted until the red fumes disappear. The cock may then be closed unless it be desirable to allow the gas to be transferred to another vessel.

It should be understood that the acid passes into and out of the bottle, through the perforation in the stem; while by means of a fragment of glass the metallic shreds are prevented from escaping.

Properties and Composition of Nitric Oxide Gas.

It is colourless, permanently elastic, and rather heavier than air. By water, it is but slightly absorbed. It is not acid. It extinguishes a candle flame, but ignites Homberg's pyrophorus, and supports the combustion of phosphorus, if inflamed before immersion in it, or aided by access of a minute quantity of oxygen. It is fatal to animals—renders the flame of hydrogen green by mixture, does not explode with it, but does explode with ammonia. When platina sponge recently ignited, is introduced into a mixture of nitric oxide and hydrogen, water and ammonia are gradually evolved, in consequence of the elements of the oxide uniting severally with the hydrogen. It unites rapidly with oxygen gas, the oxygen of the air, or that of any other gaseous mixture: producing remarkable red acid fumes. It is absorbed by the green sulphate or protochloride of iron. The solution acquires the property of absorbing oxygen, and is, therefore, used in eudiometry. Nitric oxide is decomposed by moistened iron filings, also by ignited charcoal, arsenic, zinc, or potassium.

It is alleged by Berzelius that nitric oxide is capable of uniting with bases, in which case it plays the part of an electronegative or acid compound. Thus when the calcination of nitre is carried to a certain point, a compound of nitric oxide with potash is formed. He overlooks the fact, first noticed I believe, by Dr. Bridges, and first explained by me, that the potassium in nitre is converted by intense ignition into the state of peroxide, which evolves oxygen by the affusion of water.

143. EXPERIMENTAL ILLUSTRATIONS OF THE PROPERTIES OF NITRIC OXIDE.

Copper or silver being subjected to nitric acid, the nitric oxide gas is extricated, and collected in bell glasses, either over water, or mercury.

Absorption of nitric oxide gas, by protochloride, or green sulphate of iron, shown. Also, the method of ascertaining its purity, by the sliding rod eudiometer—and its application to eudiometry, in various ways, by means of that, and other eudiometrical instruments.

Self-regulating reservoir of nitrous gas, for eudiometrical experiments. Absorption of oxygen gas, by nitric oxide, and the consequent acidity, made evident by the effect on litmus. Homberg's pyrophorus in falling through the gas is ignited.

OF HYPONITROUS ACID.

This acid was isolated in the following manner by Dulong. Having subjected a mixture of four volumes of nitric oxide with one of oxygen, in a tube, to a freezing mixture; he obtained the acid in question, in the form of a deep green liquid, so volatile as to be converted into a red vapour, unless restrained by intense cold. The hyponitrous acid thus procured, is partially decomposed by water into nitric oxide, which escapes; while the oxygen combining with another portion of the hyponitrous acid forms nitric acid. This unites with the water, and protects the remainder of the hyponitrous acid from decomposition. It is alleged that a hyponitrite of lead is produced, when nitrate of lead is boiled with metallic lead. According to Berzelius, it is formed, in combination with bases, when nitrates are kept at a red heat for some time. Hyponitrous acid when isolated, does not combine directly with bases, but is resolved by contact with them into a nitrate and nitric oxide gas. Nevertheless it may be transferred from one base to another. It is alleged to form a crystalline compound with sulphuric acid, and to combine with nitric acid; but it is questionable whether in combining with nitric acid, it is not resolved into nitric oxide, and nitric acid.

OF NITROUS ACID.

This combination may be procured in the gaseous state, by mixing two volumes of deutoxide of nitrogen, and one of oxygen; or by subjecting fuming nitric acid to heat, and collecting the product in a receiver; also by distilling nitrate of lead. Moist nitrous acid is a gas of a deep red colour; when anhydrous, it is a liquid of an orange yellow which boils at 72°. In this form it may be obtained by passing deutoxide of nitrogen and oxygen, *both previously dried*, through a tube filled with fragments of porcelain; or by desiccating the nitrate of lead before employing it as above mentioned.

Berzelius affirms that there is no compound of nitrogen to which the name of hyponitrous acid should be given. The acid heretofore thus named, he calls nitrous acid, and he considers the combination above described, generally called nitrous acid, as a double acid, composed of his nitrous acid and nitric acid, or nitric acid and nitric oxide. As this compound cannot, as he alleges, combine with bases without decomposition, he objects to considering it as a distinct acid.

144. SYNTHESIS OF NITROUS ACID, BY NITRIC OXIDE AND OXYGEN GAS.

By means of a brass cap with a cock and gallows screw, let a tall cylindrical glass receiver, represented by the figure on the opposite page, be made to communicate with a pear-shaped glass vessel, as in the opposite engraving. Previously, however, to this communication being made, let both vessels be filled with water, by depressing them under the surface of that liquid in the well of the pneumatic cistern, the cocks being first opened to allow the escape of air, and afterwards closed. The apparatus is then to be placed on the shelf of the cistern, as represented.

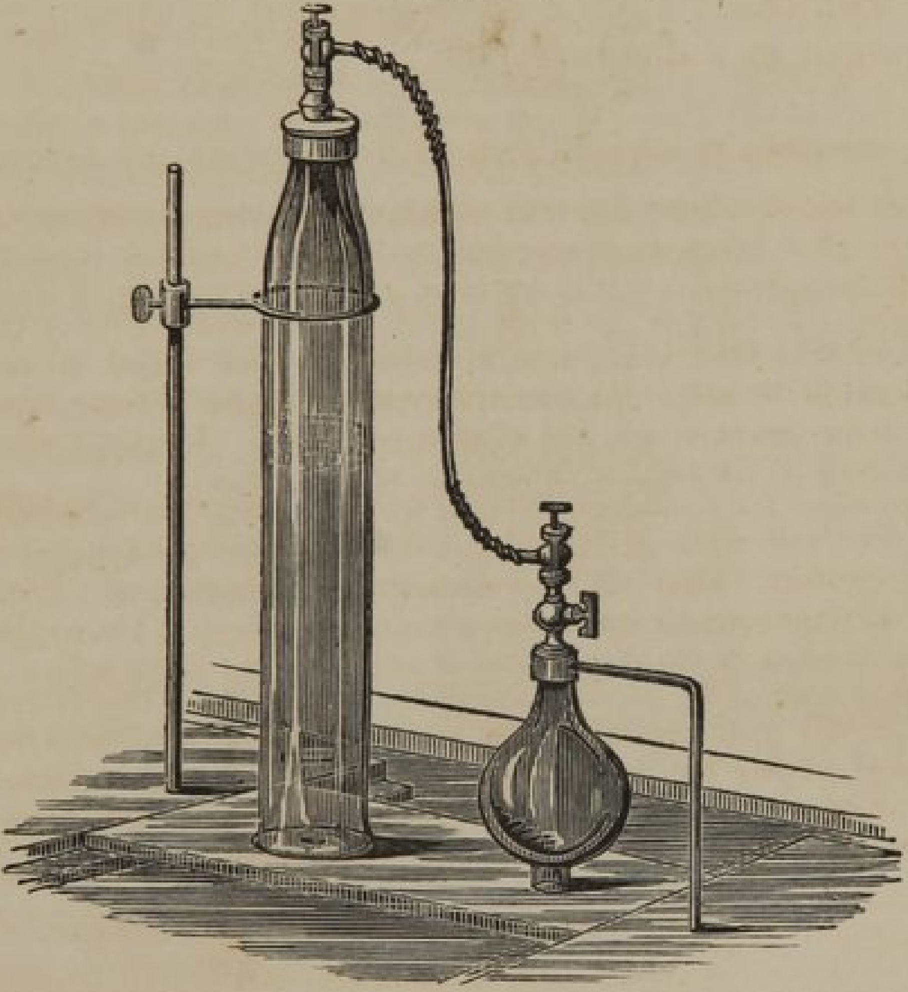
First allow the pear-shaped vessel, which I will call a volumeter, to be twice filled with nitric oxide, and as often allowed to yield up the contents to the receiver. Then fill the volumeter with oxygen gas. In the next place, open the communication again with the receiver. The oxygen passing into the nitrous oxide, produces dense fumes of nitrous acid. At first, in consequence of the rise of temperature which attends this combination, there appears some expansion; but a speedy absorption of the nitrous acid generated, causes the water to rise, and nearly fill the receiver. From some cause, I have never been enabled to attain a complete condensation by this process.

APPLICATION OF NITRIC OXIDE GAS IN EUDIOMETRY.

The property which this substance has of forming with oxygen, nitrous or hyponitrous acid, either of which is absorbed by water, has caused it to be used in eudiometrical operations; but owing to the variable proportions in which the above mentioned compounds are liable to be formed, the results thus obtained have been deemed uncertain, and the directions for using nitrous oxide, given by such eminent chemists as Dalton, Gay-Lussac, and Thomson, are at variance. Gay-Lussac gave an empirical formula, agreeably to which, one-fourth of the condensation produced by a mixture of equal parts of atmospheric air and nitric oxide, is to be assumed as the atmospheric oxygen present.

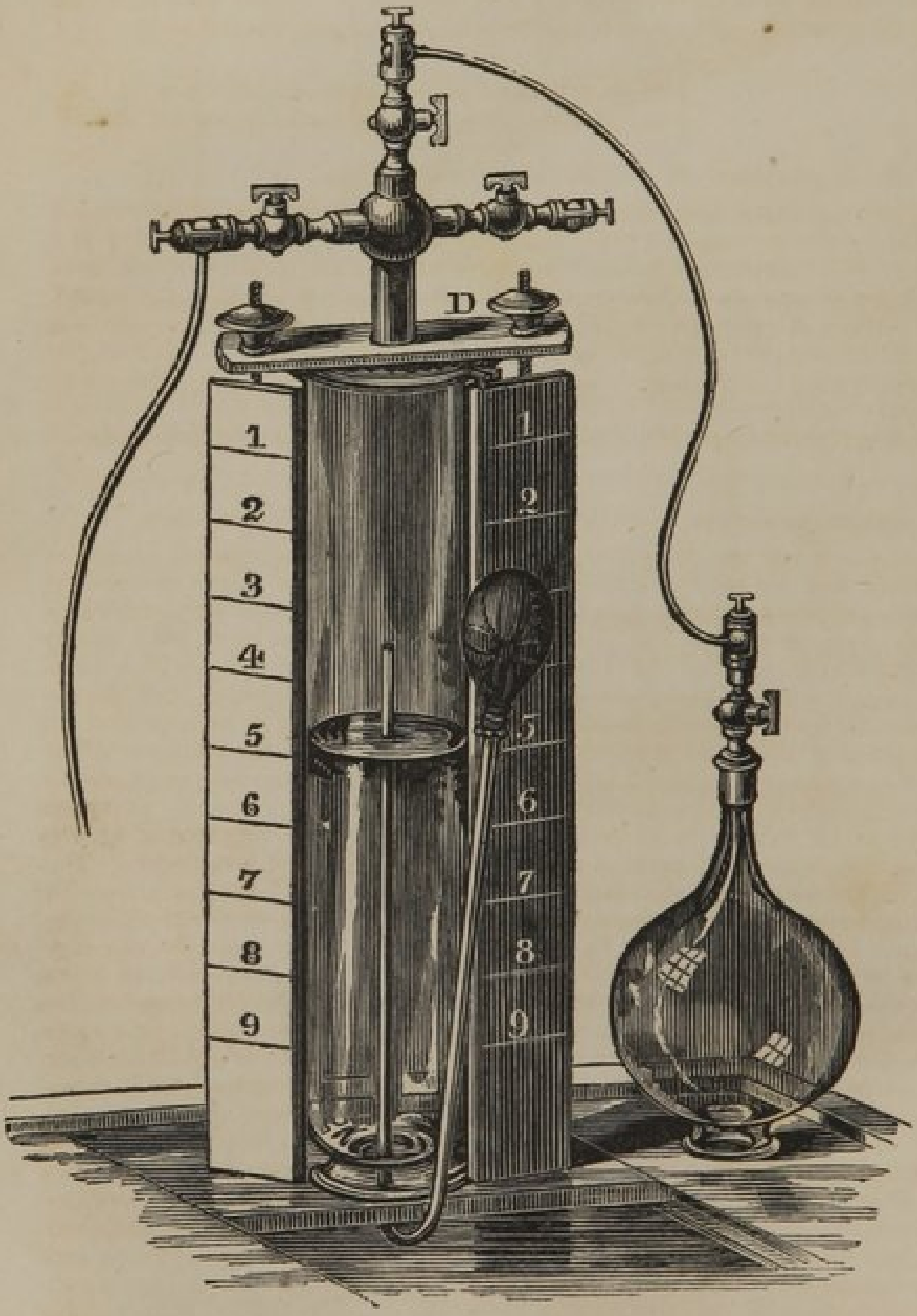
As in two volumes of nitric oxide, a volume of nitrogen is combined with one volume of oxygen occupying the same bulk as if merely mingled, to convert the nitric oxide into nitrous acid, which consists of the same quantity of nitrogen with two volumes of oxygen, one volume of oxygen must be requisite. Of course, if nitrous acid be the product, one-third of the deficit produced, would be the quantity of atmospheric oxygen present. This would be too much to correspond with the formula of Gay-Lussac.

Synthesis of Nitrous Acid.
(C. p. 180.)



Volumescope for the Analysis of Atmospheric Air, by means of Nitric Oxide.

(C. p. 181.)



Supposing hyponitrous acid produced, only one-half as much oxygen would be required, as is necessary to produce nitrous acid; so that instead of the two volumes of nitric oxide taking one volume, they would take only a half volume. The ratio of $\frac{1}{2}$ in 2.$\frac{1}{2}$, is the same as one in 5, or one-fifth, which is too little for Gay-Lussac's rule.

The formula recommended by Dr. Thomson, agreeably to which, one-third of the deficit is to be ascribed to oxygen gas, is perfectly consistent with the theory of volumes, and much more consonant to the results of my experiments, than that recommended by the celebrated author of that admirable theory.

The late Professor Dana ingeniously reconciled Gay-Lussac's statement, with the theory of volumes, by suggesting that a half volume of oxygen may take one volume of the nitric oxide, and another half volume of oxygen, two volumes.

	vol.		vol.	
	$\frac{1}{2}$ oxygen	takes	1	oxide and forms nitrous acid.
	$\frac{1}{2}$ oxygen		2	oxide and forms hyponitrous acid.
Deficit due to oxygen is as	1	to	3	

With the deference due to a chemist so distinguished as the author of the formula in question, I long strove unsuccessfully to verify his statements. Agreeably to a great number of experiments, annually repeated during many years with different instruments, it has been found, that when three volumes of nitric oxide are mixed, over water, with five of atmospheric air, nearly the same condensation is effected, as when like quantities of air and of hydrogen are ignited together. In order to demonstrate the truth of this allegation to my numerous class of pupils, I have employed the apparatus represented by the opposite figure. In this the volumes employed are so large as to make the results strikingly evident to the most remote observer.

145. *Volumescope for the Analysis of Atmospheric Air by Nitric Oxide.*

Secured in a screw rod and plate frame, there is a glass cylinder thirty inches in height, and about five inches in diameter. Into the brass plate which closes it at top, three cocks are inserted, each provided with a gallows screw. By means of a flexible leaden pipe, let one of the cocks be made to communicate with an air pump. Let the other cock, by like means, be made to communicate with a pear-shaped glass vessel, which acts as a volumeter, or volume measurer. Let the cylinder, by means of a scale placed on one side of it, be graduated so as to hold eight volumes, any three of which shall be equivalent, collectively, to the contents of the volumeter. The apparatus being thus prepared and secured, over one of the wells of the pneumatic cistern, (98,) exhaust the cylinder by means of the air pump, so as to cause the water to rise in it, until by the scale only five volumes of atmospheric air are left, and then open a communication with the volumeter. The air contained in this vessel will then pass into the cylinder, and if the graduation be consistent with the premises, the water will sink to the graduation designating the eighth volume. Now let the water by means of the air pump again be raised to the graduation marking the fifth volume, and introduce into the volumeter as much nitric oxide as it will hold. If under these circumstances, the communication between the pear-shaped vessel and the cylinder be re-established, the nitric oxide will pass into the cylinder, and combining with the oxygen of the contained air, will produce nitrous acid in red fumes, which the water will begin sensibly to absorb. This absorption is promoted and completed by jets of water, projected vertically through the mingled gases, by means of the gum elastic bag to which it is attached. It has been shown by the preceding part of the process, that the contents of the volumeter, added to five of air, would make eight volumes, were there no absorption; but the actual residue, when the experiment is well performed, is always a little less than five volumes, indicating that a little more than one volume of oxygen is contained in the five volumes of air employed, and that this is condensed by combining with twice its bulk of nitric oxide. The nitrous acid, usually thus called, consists of one atom or volume of nitrogen, with four atoms or two volumes of oxygen. Of course, to convert into this acid nitric oxide consisting of one atom, or one volume of nitrogen, and one volume or two atoms of oxygen uncondensed, one volume or two atoms of oxygen must be addded.

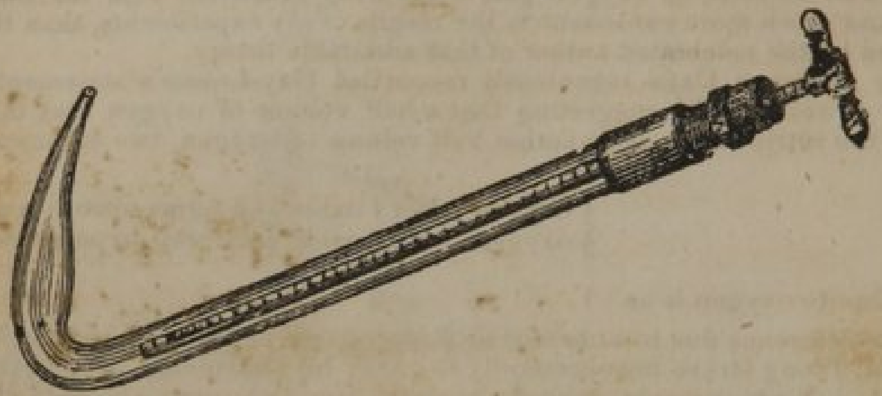
146. *Sliding Rod Eudiometer for Nitric Oxide.*

Fig. 1, represents the form of the sliding rod eudiometer, which I have found most serviceable for experiments with nitric oxide gas, or those in which green sulphate, or protochloride of iron, saturated with nitric oxide, is employed.

The rod for these experiments, is graduated into 150 large divisions, severally divided into five small ones, which, being each considered equal to two degrees, the whole number of degrees may be assumed either as 150 or as 1500.

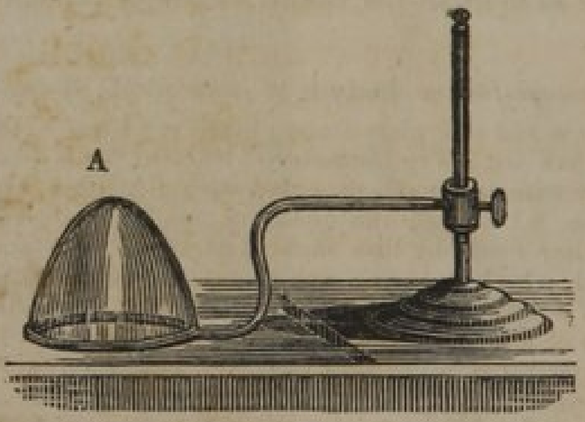
The mode in which the rod is made to measure gaseous fluids, has been explained, 138.

Fig. 1.



The receiver, fig. 2, shaped like the small end of an egg, is employed in these experiments, being mounted so as to slide up and down upon a wire.

Fig. 2.



This receiver being filled with water, and immersed in the pneumatic cistern, the apex, A, being just even with the surface of the water, by drawing out the rod of the eudiometer, take into the tube 100 measures of atmospheric air, and transfer it to the receiver. Next take 50 measures of nitric oxide from a bell as above described, and add it to the air in the receiver. Wash the mixture by a jet of water, which is easily produced from the apex of the instrument, and draw the whole of the residual gas into the tube, continuing to draw out the rod, until 150 graduations appear. In the next place, eject the residual gas from the instrument; the number of graduations of the rod which remain on the outside of the tube, shows the deficit produced by the absorption of the oxygen, and nitric oxide, in the state of nitrous acid.

In a great number of experiments, I have found the deficit to agree very nearly with that produced by the explosion of the same quantity of air with hydrogen in the aqueous sliding rod hydro-oxygen eudiometer.

147. METHOD OF ASCERTAINING THE PURITY OF NITRIC OXIDE, BY NITRIC OXIDE AND GREEN SULPHATE, OR PROTOCHLORIDE OF IRON.

The purity of nitric oxide is easily ascertained, by means of a solution of protochloride, or green sulphate of iron, and the sliding rod eudiometer above described. A small bottle being filled with a solution of the salt, and inverted upon the shelf of the hydro-pneumatic cistern, take into the eudiometer one hundred measures of the gas, and transfer them to the bottle, which must be agitated for two or three minutes. The receiver (fig. 2) being filled with water, and depressed into the water of the hydro-pneumatic cistern, till the apex, A, is on a level with the surface; throw up into it the residual gas. In the next place, draw it into the eudiometer. The distance which the rod is drawn out, shows the quantity, which may be again ascertained in ejecting it from the tube. A saturated solution of nitric oxide, in the above mentioned ferruginous solutions, has the power of absorbing oxygen, and was consequently recommended by Sir H. Davy, as the means of ascertaining the quantity of that gas in the air. The mode of using them would be the same as that just described, taking oxygen into the eudiometer, instead of nitric oxide, and filling the bottle with the ferruginous solution of nitric oxide, instead of the pure sulphate or protochloride of iron.

I have found this method of ascertaining the quantity of oxygen, in the air, much more tedious, and much less satisfactory, than those already described.

THEORY OF VOLUMES.

It is presumed that a reader, who has carefully studied this work thus far, may have his attention advantageously directed to the theory of volumes; otherwise, the language now usually employed, in treating of combinations, resulting from the union of gaseous substances, will not always be intelligible to him.

It has been advanced by Gay-Lussac, that substances, when aeriform, unite in volumes which are equal; or that when unequal, the larger volume is double, triple, or quadruple the other.

This hypothesis has been verified by experience, with respect to all substances which are capable, while gaseous, of being combined or decomposed. It is extended by inference to other substances, under the idea, that all are susceptible of the aeriform state. A volume is said to be the equivalent of another volume, when capable of forming with it a definite compound, or when just adequate to displace it from combination.

It must be evident, a priori, that if each atom, of whatever kind, occupies in the aeriform state an equal space, atoms may be as well represented by equal volumes as by their equivalent numbers, the former affording by measure, what the latter gives by weight. Now experience justifies the belief, that in general, atoms do assume an equality of volume, when rendered aeriform, and that when the bulks assumed are unequal, the inequality may be removed by multiplying or dividing, by a whole number, those volumes which are smaller or larger than the rest. This is all that the hypothesis of Gay-Lussac requires.

Berzelius infers that water, and the protoxides of chlorine and nitrogen, each consist of one atom of oxygen, and two atoms of the other ingredient. Admitting this to be a correct inference, equivalent weights of the four elementary gaseous substances above mentioned, actually occupy equal spaces; so that their atoms are as well represented by equal volumes, as by the numbers indicating their ratio to each other in weight. But if we suppose that in the compounds above mentioned, there is only one atom of each ingredient, the equivalent volumes of chlorine, hydrogen, and nitrogen, although still equal to each other in bulk, will each be twice as large as the equivalent volume of oxygen. The British chemists, in general preferring the last mentioned view of the atomic constitution of the compounds above mentioned, represent the atoms of chlorine, hydrogen, and nitrogen, each by one volume, the atom of oxygen by a half volume.

When gaseous substances enter into combination, preserving the aeriform state, in some cases there is a reduction of volume, in others none. When a reduction does ensue, the bulk, or resulting volume of the compound, is to the aggregate bulk of the constituent volumes, either as 1 to 2, 1 to 3, 1 to 4, or 2 to 3, 2 to 5, &c.

This will be rendered evident by the following table, in which the number of atoms, and the number of volumes which enter into some very important compounds, are represented by corresponding squares. Each square stands for a volume, and half a square for half a volume.

In the second column are the squares or half squares, representing the equivalent volumes or half volumes, of all substances which naturally exist in the gaseous state. Then follow the compounds formed by such elements, each represented by an association of the volumes of which it is constituted. In the third column the resulting volume of each aggregate, after combination, is represented.

Among the instances cited in the two next pages, it will be seen, that there is none in which the bulk of the constituent volumes is to that of the resulting volume in a ratio greater than that of 3 to 1. The only permanent gas in which the elements are alleged to exist in a state of greater condensation, is olefiant gas, consisting of two volumes of carbon, and two of hydrogen, condensed into one. There are some vapours consisting of the same elements in the same atomic proportion, in which 8 or 9, or even according to Thomson, 25 constituent volumes are contained in 1 resulting volume.

EQUIVALENT WEIGHTS AND VOLUMES OF GASES AND VAPOURS.

Gases and Vapours.	Component Volumes.	Resulting Volumes of Compounds.	Pressure of Liquefaction. Atmospheres.
Oxygen	O 8		
Chlorine	C 36		4 at 60°
Protoxide of Chlorine	C 36 O 8	44	
Chlorous Acid . .	C 36 O 8 O 8 O 8	60	
Hydrogen . . .	H 1		
Steam	H 1 O 8	9	
Chlorohydric Acid	C 36 H 1	37	40 at 50°
Nitrogen	N 14		
Atmospheric Air .	O 8 N 14 N 14	36	
Nitrous Oxide . .	N 14 O 8	22	50 at 45°
Nitric Oxide . .	N 14 O 16	30	

Gases and Vapours.	Component Volumes.	Resulting Volumes of Compounds.	Pressure of Liquefaction. Atmospheres.
Nitrous Acid . .	N 14 O 16 · O 16	46	
Ammonia . . .	N 14 H 1 · H 1 · H 1	17	6½ at 50°
Sulphurous Acid .	S 16 · O 16	32	2 at 45°
Sulphydric Acid .	S 16 · H 1	17	17 at 50°

OF NITRIC ACID.

Although under ordinary circumstances, nitrogen will not combine with oxygen; yet, when mixed with it, and exposed to a succession of electric sparks, nitric acid, one of the most important agents in chemistry, is generated. Berzelius alleges that traces of nitric acid, in combination with ammonia, may almost always be discovered in the rain water accompanying thunder storms. This chemical combination is probably produced by lightning. The same author states that when a jet, consisting of one volume of nitrogen and fourteen of hydrogen, is inflamed while flowing into a vessel containing oxygen, nitric acid is produced. There are probably some unknown means, by which chemical union is induced between nitrogen and oxygen; whence the great quantity of nitrate of potash spontaneously produced in various situations.

It has been supposed that this acid is formed during the eudiometrical analysis of atmospheric air by hydrogen, and that the deficit being thus increased, leads to an undue estimate of the oxygen. I consider this impression erroneous, as upon one occasion, by exploding successive portions of hydrogen with atmospheric air, I collected nearly half an ounce of water, and found it devoid of acidity.

Of the Means of obtaining Nitric Acid.

The production of nitric acid by electricity, is too laborious to be resorted to for the purpose of the chemist.

Agreeably to the usual process, nitre, which consists of nitric acid and potash, is subjected to heat with an equal weight of sulphuric acid, in a glass, porcelain, or iron retort, communicating with a glass receiver. The acid is displaced by the superior affinity of the sulphuric acid for the potash, and being vaporized by the heat, passes into the receiver, where it condenses into a liquid. Thus obtained, it is more or less contaminated with nitrous acid, or nitric oxide, and chlorohydric and sulphuric acids. By distilling from it about a third of the whole quantity, the nitrous and chlorohydric acids pass over into the receiver with the portion of the acid distilled, leaving the residue in the retort free from them. Sulphuric acid may be removed by distilling the nitric acid from one-eighth of its weight of pure nitre, or by the addition of barytes, which precipitates in the form of an insoluble compound with the sulphuric acid. Chlorohydric acid may in like manner be removed by a solution of silver; as this metal forms with the chlorine an insoluble compound, which precipitates.

Of the Properties of Nitric Acid.

Nitric acid emits pungent suffocating fumes, and has a peculiar odour. When pure it is colourless, but when exposed to the light, it is slowly decomposed into oxygen gas and nitrous acid, or nitric oxide, which is absorbed, giving an orange colour to the nitric acid. This decomposition takes place much more rapidly in the sun. Nitric acid cannot be obtained free from water. With almost all the metals it reacts powerfully, also with organic substances, causing them to be oxydized. It stains and destroys the skin. It may be considered as consisting of the ingredients of atmospheric air, in the liquid form, but containing ten times as much of the active principle, oxygen. It is the most energetic principle in gunpowder. In its highest state of concentration, at a specific gravity of 1.55, one atom of this acid contains one atom of water. This concentrated acid boils at 175° and freezes at — 40°. When it contains one atom of acid to four of water, it has a specific gravity of 1.42, and boils at 248°. Any acid, whether weaker or stronger than this, has the boiling point at a lower temperature. If weaker it is strengthened, if stronger it is weakened, by boiling; and acids of all degrees of strength become, by the continued application of a sufficient degree of heat, of the specific gravity of 1.42. The officinal specific gravity is 1.5, in which case it contains two atoms of water to one of acid.

Nitric acid is employed in giving a yellow colour, and for various other purposes in manufactures. It is used in medicine for fumigations, in cases in which chlorine is unsuitable.

148. EXPERIMENTAL ILLUSTRATIONS.

The extrication and distillation of nitric acid, shown by means of a glass retort and receiver, heated by a lamp or small sand bath. Its action on various substances exemplified.

Of the orange coloured fuming Nitric Acid, called Nitrosonitric Acid, in the Swedish Pharmacopœia.

In whatever proportion sulphuric acid may be employed in the process above described for procuring nitric acid, the liquid obtained is of an orange colour. This colour becomes deeper, when the quantity of sulphuric acid employed, is insufficient to produce a bisulphate with the potash. I am under the impression, that in some degree the same result follows when the acid exceeds this proportion. In either case the water, which in the absence of some other base is indispensable to the existence of nitric acid, is not furnished in sufficient quantity. Hence the latter is partially resolved into oxygen and nitrous acid, which, together with the nitric acid, passes into the receiver, constituting an orange coloured fuming liquid, mentioned by Berzelius under the name of nitrosonitric acid. This acid by exposure to heat, disengages nitrous acid gas, and becomes colourless nitric acid. Nitrosonitric acid ignites essential oils, carbon, and phosphorus; the latter explosively. It is much more energetic in its reaction with such substances, than pure nitric acid; which, probably, when nitric oxide is not present, requires for its existence a larger proportion of water. I deem it probable that it is with nitric oxide, not nitrous or hyponitrous acid, that nitric acid is combined in nitrosonitric acid. Berzelius conceives that either view of its composition may be correct.

149. EXPERIMENTAL ILLUSTRATION.

Reaction of nitrosonitric acid with carbon and oil of turpentine, exhibited.

OF THE AGENCY OF NITRIC OXIDE IN GENERATING SULPHURIC ACID.

When nitric oxide, atmospheric air, sulphurous acid, and aqueous vapour, are mingled, a crystalline compound is formed, which, if the operation be performed within a glass vessel, will appear upon the interior surface in a crystalline deposition, resembling hoar frost. When water is added to this compound, it is resolved into sulphuric acid and nitric oxide. The former combines with the water, while the latter escapes in the gaseous form, producing with oxygen, if present, the red fumes of nitrous, or hyponitrous acid. It may be inferred that hyponitrous acid, produced as above mentioned, yields one atom of oxygen to the sulphurous acid, converting it into sulphuric acid. The acid thus produced, unites with the nitric oxide and water; but on being subjected to a larger portion of water for which it has a greater affinity, the nitric oxide is allowed to escape. These habitudes of the agents in question, excite greater interest on account of their agency in the generation of sulphuric acid; one of the most valuable of the instruments which have been placed within the reach of the chemist.

150. EXPERIMENTAL ILLUSTRATION.

Into a glass globe with three tubulures, introduce on one side the beak of a half pint retort, containing about a pound of mercury, and as much sulphuric acid as will cover it to the depth of half an inch, applying to the retort a chauffer of coals. Into the other tubulure, fasten the termination of a pipe proceeding from a self-regulating reservoir of nitric oxide gas. The third tubulure should be closed by a glass stopple. The mercury takes one atom of oxygen from the sulphuric acid, converting it into sulphurous acid, which enters the globe. As soon as this appears to have taken place, a portion of the nitric oxide gas is allowed to enter from the opposite side. Meeting with atmospheric air within the vessel, the nitric oxide will produce red fumes, which encountering the sulphurous acid, will condense into a crystalline deposition. Occasionally, the stopple must be lifted to allow the access of fresh air, and the supply of this and the gases must be so regulated, that the red fumes shall be repeatedly produced and condensed. When a deposition of crystalline matter, sufficiently striking, has been produced, if water be poured into the globe, the deposition will be speedily decomposed with an evolution of nitric oxide. This gas, meeting with the oxygen of the air, produces red fumes, which, by the admission of sulphurous acid, are again condensed into crystals. These crystals, as before, by the addition of water, are decomposed into nitric oxide gas, and sulphuric acid. The water in the globe being decanted and tested, gives decided indications of the presence of sulphuric acid.

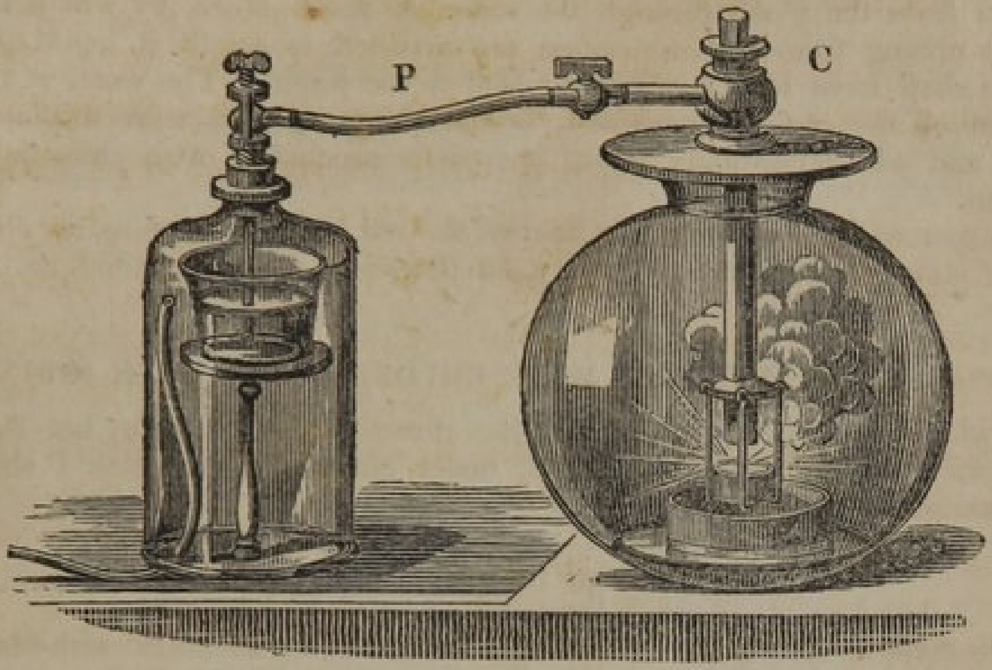
Of the process usually employed in the manufucture of Sulphuric Acid.

The means employed in the experiment above described, are convenient for the purpose of illustration, but could not be resorted to profitably for the manufacture of sulphuric acid. The combustion of one portion of sulphur, and the simultaneous deflagration with nitre, of another portion, the fumes created in both ways being received in a large chamber lined with lead, and covered at bottom with water, are the means usually employed by the manufacturing chemist. Each atom of nitre consists of an atom of potash and an atom of nitric acid. Three out of the five atoms of oxygen, in each atom of the acid, unite with an atom of sulphur, converting it into sulphuric acid, which combines with the potash. The two remaining atoms of oxygen, together with the nitrogen of the acid, are evolved as nitric oxide, which, with atmospheric oxygen, moisture and sulphurous acid, produced by the burning sulphur, generates the crystalline compound above described. Of late years, the presence of an adequate quantity of moisture has been insured by the introduction of steam at proper intervals. The crystalline compound subsiding into the water is decomposed into sulphuric acid, which remains in solution, and nitric oxide. This oxide meeting with further portions of oxygen and sulphurous acid, again contributes to the formation of the crystalline compound, to be again decomposed. This process continues, until the water in the chamber becomes sufficiently impregnated with sulphuric acid, when it is transferred to leaden boilers. In these it is concentrated by boiling, until it begins to act on the lead. It is then removed to a platina alembic, or glass retorts, and boiled down to a specific gravity of 1.850. After it has reached that density, no farther concentration can be obtained by heat. This, accordingly, is the standard specific gravity of the sulphuric acid of commerce.

In some manufactories, nitric oxide is supplied by the reaction of nitric acid with starch, sugar, or molasses, oxalic acid being produced at the same time, the proceeds of which reduce the cost of the process.

151. *Production of Sulphuric Acid illustrated.*

The apparatus which I am about to describe, serves to show in miniature, the process for generating sulphuric acid.



Into a globular glass vessel holding about eight gallons, represented in the preceding figure, introduce as much water as will cover the bottom to the depth of about two inches. The vessel has a wide mouth, which is ground to fit a circular metallic plate. Through a hole in the centre of this plate, a gun barrel, open at both extremities, is made to descend. From the lower extremity, a ring of about two inches in diameter is suspended by wires, hooked to a perforated circular piece of sheet metal, which encircles, and is soldered to the barrel. In the ring thus suspended, a conical frustum of iron, having an hemispherical cavity, is seated, so as to be a little above the water. Between the outside of the gun barrel, and the inside of the brass casting, C, which supports it, there is a passage from the pipe, P, into the cavity of the globe. This pipe communicates also with the water of a tumbler, supported within the bell glass, as in the preceding experiments. A tube leads from a suction pump into this vessel, which is placed on the shelf of the pneumatic cistern, covered by water as usual.

The apparatus being thus arranged, the leaden plate, with the gun barrel, ring, and frustum, appended to it, must be removed from the globe, the iron frustum lifted out of the ring, and some nitrate of potash (nitre) being introduced into the cavity in the frustum, it must be made moderately red hot. It is then to be restored to its seat in the ring, below the gun barrel, and the plate and gun barrel must be returned to their previous position, over the mouth of the globe, so that the whole may be situated as represented in the drawing. Lumps of brimstone, about the size of peas, are to be dropped through the gun barrel into the melted nitre. As each lump reaches the nitre, a combustion ensues, equally remarkable for beauty and brilliancy. The globe then becomes filled with sulphurous acid gas, accompanied by nitric oxide gas, and a crystalline deposition ensues. Meanwhile, to keep up a supply of oxygen within the globe, and to prevent the escape of fumes into the apartment, the suction pump is put into operation, in order to draw the fumes out of the globe, and cause them to be replaced by air, which enters through the gun barrel. The water rises from the cistern into the bell, until the resistance which it offers, to further elevation, is greater than that which the water, in the tumbler on the stand, opposes to the entrance of air from the pipe; and consequently, the air is drawn from the globe through the water in the tumbler, by which the fumes arising from the combustion are arrested, especially if liquid ammonia shall have been previously added to the water. The water at the bottom of the globe, meanwhile, becomes impregnated with sulphuric acid, and will accordingly afford a copious precipitate with chloride of barium.

To protect the globe from the heat of the red hot iron frustum, a cylinder of sheet lead is placed below it, in the water, as represented in the figure.

COMPOUNDS OF NITROGEN WITH CHLORINE AND WITH IODINE.

Neither chlorine nor iodine combines directly with nitrogen, but both unite with the nitrogen of ammonia, under circumstances which I shall mention presently.

CHLORIDE OF NITROGEN.

This compound may be obtained by placing a bell glass, filled with chlorine, over a solution of one part of nitrate of ammonia, in 12 of water, at the temperature of 70°.

The chloride appears in drops, which resemble olive oil, and which, being heavier than water, subside to the bottom of the basin containing the solution. It is remarkable that this substance does not explode with many combustibles which would appear more likely to decompose it, than those with which it does explode. Thus it explodes with either turpentine or caoutchouc, but not with camphor.

I have made the chloride of nitrogen several times. The force with which a minute portion explodes, on contact with oil of turpentine, would hardly be credited by those who have not witnessed this phenomenon. An open saucer of Canton china was fractured by a globule not larger than a grain of mustard seed. The glass tube employed to project the globule into the saucer, was violently dispersed in fragments.

IODIDE OF NITROGEN.

When iodine is kept in liquid ammonia, it is converted into a brownish black substance, which is an iodide of nitrogen, and which may be collected and dried on bibulous paper at a gentle heat. The iodide of nitrogen thus formed, evaporates spontaneously. It explodes by a slight pressure, or when heated, or much dried, being resolved into nitrogen gas and iodine.

ON THE THEORIES OF COMBUSTION, ACIDITY, AND ALKALINITY.

The student has now advanced so far in practical knowledge respecting the phenomena of combustion, and the properties of some acids, that I deem it expedient to present to him some general views of combustion, acidity, alkalinity, and additional instruction respecting nomenclature.

I am the more inclined to this course, as among the compounds of nitrogen, there are three acids and an alkali.

ON THE THEORIES OF COMBUSTION.

Stahl supposed the existence, in all combustibles, of a common principle of inflammability, which he called phlogiston, from φλογιζω, to burn. He inferred that all substances, in burning, give out phlogiston. The fallacy of this hypothesis is evident, since metals become heavier during combustion, obviously in consequence of the absorption of oxygen from the atmosphere. By the advocates of the phlogistic theory, nitrogen was confounded with carbonic acid, and carbon with hydrogen, because both carbon and hydrogen were conceived to consist of phlogiston, nearly pure; and oxygen, in combining with them, was supposed to become phlogisticated air; the name then given to nitrogen gas. It is now well known, that with carbon, oxygen forms carbonic acid; with hydrogen, water; and that nitrogen gas contains neither carbon nor hydrogen.

Sulphuric, and phosphoric acids, and metallic oxides, were severally supposed to be ingredients in the sulphur, the phosphorus, or the metals producing them. Thus of two bodies, that which was actually the lighter was assumed to contain the other.

The celebrated Lavoisier, to whom we are chiefly indebted for the exposure of these fallacies of the theory of phlogiston, having ascertained oxygen to be an indispensable agent in all ordinary cases of combustion, was erroneously led, to infer that it was in all cases necessary to that process. But it is now well known, that there are many instances of combustion, in which oxygen has no agency.

I would define combustion to be a state of intense corpuscular reaction, accompanied by an evolution of heat and light.

That increase or diminution of temperature consequent to chemical combination, which constitutes combustion when productive of heat and light, has been ascribed to a mysterious law by which bodies undergo a change in their capacity to hold caloric. It has been supposed that the capacity of the compound is in some instances greater, in others less, than the mean capacity of the constituents; and that in the former case union is followed by an absorption of caloric, and of course by cold; in the latter, by the expulsion of caloric, and consequently, by the production of heat.

Yet, when the capacities of compounds, are compared with those of their ingredients, the result does not justify the idea that the heat given out by the latter, in combining, is produced by a diminution of capacity. At best, this hypothesis only substitutes one enigma for another, since it does not account for the alleged change of capacity.

The diversity of power to hold caloric in a latent state, technically designated by the word capacity, is now generally ascribed to the intervening influence of electricity. It has been shown, that if neighbouring bodies be electrified by means either of glass, or resin, previously subjected to friction, they will repel each other; but that if one be thus excited by glass, and another by resin, attraction between them will ensue. Hence the excitements are considered of an opposite nature. It will be recollected, that, according to the Franklinian theory, the vitreous excitement results from a redundancy; the resinous, from a deficiency of the electrical fluid. Hence, Franklin designated the former as positive, the latter as negative electricity. By others, the different electric excitements are considered as the effects of two different fluids, attractive of each other, but self-repellent. The one has accordingly been called by them resinous, the other vitreous electricity. Yet, even by electricians who suppose the existence of two fluids, the terms positive, and negative, are employed.

It has been suggested that Voltaic phenomena, combustion, acidity, alkalinity, and chemical affinity, may owe their existence to the principle by which the different electric excitements are sustained in electrified bodies, modified in some inexplicable manner, so as to act between atoms instead of masses. This suggestion derives strength from the following facts, which have been fully illustrated in the lectures on electricity and galvanism.

The pole of a Voltaic series terminated by the more oxydizable metal, has been shown to display a feeble electrical excitement, of the same kind as that which is producible by friction in glass, while the other pole displays the opposite excitement, in like manner producible in resin. From reiterated experimental observation, it is now generally inferred, that of any two substances chemically combined and simultaneously exposed to wires proceeding from the Voltaic poles, one will go to the positive, the other to the negative pole. Atoms are supposed to have electrical states the opposite of the poles to which they may be attracted, and are said to be electronegative, when attracted by the positive pole, and electropositive when attracted by the negative pole.

Substances which have opposite relations to the Voltaic poles, have an affinity for each other, which is usually stronger in proportion as the diversity of their electric habitudes is the more marked. Thus, for instance, oxygen, which is pre-eminently electronegative, and potassium, which is pre-eminently electropositive, have under ordinary circumstances a predominant affinity for each other. The power of the Voltaic wires in severing such substances when combined, appears to be analogous to that exercised by atoms, which, by superior affinity, cause decomposition. But then there is this discrepancy, that the elements, after being attracted from each other by the wires, do not combine with *them*, as they do with atoms, which by superior affinity, are productive of a similar decomposition. It would seem as if particles, separated from each other by the Voltaic pile, undergo successive changes in their electric states, which first paralyze their ability to remain in combination, and afterwards their susceptibility to the attraction of the poles; so that instead of adhering to them, they escape. Yet even in this respect there is greater analogy between chemical affinity, and that transiently exercised by the Voltaic poles, than at first view might be supposed; since the former power is found to be created, destroyed, altered, or even reversed by extraneous causes. Potassium, which, under ordinary circumstances, takes oxygen from iron, or carbon, yields it to these substances at very high temperatures. Iron attracts oxygen from hydrogen, in one case, yet relinquishes it to the same principle in another. Obviously the coherence of vegetable and animal fibres, is due to a cohesive power induced in the constituent ponderable atoms by the powers of vitality. The hempen cable which holds a ship of the line at anchor, is, by ignition, resolvable into water and charcoal. The deutoxide of hydrogen, and oxide of silver, by mere contact, and without any resulting union of their ponderable atoms, are converted explosively into water and silver.

By some philosophers, who ascribe the opposite electrical excitements to the influence of distinct fluids, it is conjectured that these fluids, when separated, become surcharged with heat and light, which they abandon on uniting. Hence when sufficiently accumulated, and subsequently combined, ignition or explosion ensues, in consequence of the copious evolution of those imponderable principles. When these consequences result from the chemical reaction of ponderable particles, they are ascribed to the escape of heat and light arising from the union of electric matter, previously forming a mean of their combination with ponderable matter. That electricity, in some mysterious mode, varies the power of ponderable substances, to combine with each other, and to retain heat and light in a latent state, seems to me highly probable; yet I cannot consider any effort hitherto made, as successful in explaining how, consistently with its known habitudes, it can operate to produce such wonderful results.

In reply to the hypothesis above stated, admitting the existence of two electric fluids, to which there are great objections, it may be demanded, why is not cold produced when the electricities are severed, if, under these circumstances, they abstract from the surrounding medium that surcharge of caloric which they relinquish on being reunited.

On all sides it must be admitted that between chemical reaction, galvanism, and electro-magnetism, there is an intimate association, which must be explained, before the phenomena of combustion can be well understood.

It has been mentioned, that of known bodies, oxygen has proved the most electronegative. It is questionable whether the next place to oxygen is to be ascribed to chlorine or fluorine. After these, bromine, iodine, sulphur, selenium, and tellurium, may follow.

Among the metals, we have a series of substances, varying from those in which the electropositive power is pre-eminently great, as in potassium, sodium, lithium, barium, calcium, magnesium, &c., to such metals as belong rather to the electronegative class. Hence, setting out from the extreme above mentioned, we may proceed through a long range of metals less and less electropositive, till we arrive at such as produce electronegative combinations with either oxygen or chlorine, or both. More or less within this predicament, I think we find tin, mercury, gold, platina, palladium, antimony, arsenic, molybdenum, and lastly tellurium. Thus at an intermediate point between the extremes, at which oxygen and the alkaligen metals are placed, there are substances, whose electrical relation to the pile is equivocal or wavering; and it should be understood that this relation is always comparative. Chlorine is electropositive with oxygen, and perhaps fluorine, and electronegative with every other body. Iodine is electropositive, with oxygen, chlorine, bromine, and probably with fluorine; while with other substances it is electronegative.

Substances of the two opposite classes, in combining with each other, constitute compounds which are either electropositive or electronegative, accordingly as the different energies of their ingredients preponderate. Thus in alkalies consisting of oxygen, united with the alkaligen metals, the electropositive influence predominates; while the reverse is true of acids consisting of the same electronegative principle, oxygen, in combination either with sulphur, nitrogen, phosphorus, carbon, boron, silicon, selenium, or other substances, which, in their electrical habitudes, lie between oxygen and those metals.

In some cases we see an electronegative, or an electropositive power, attached to compounds, which is not equally displayed by either of their constituent elements separately. Cyanogen, consisting of carbon and nitrogen, is a striking instance of an electronegative principle thus constituted; and in ammonia, and the vegetable alkalies lately discovered, we have instances of electropositive compounds produced from principles comparatively electronegative.

OF THE INFLUENCE OF THE HABITUDES OF CHEMICAL AGENTS WITH THE VOLTAIC SERIES, ON NOMENCLATURE, AND CLASSIFICATION.

It would follow from the statements above made, that there should be a resemblance between the properties of substances which have a proximity to each other in the electric series. Accordingly we find, as I have already had occasion to state, that those which approach each other in the higher part of the electronegative scale, have, by distinguished writers, especially in Great Britain, been classed as supporters; while those which are electropositive, or feebly electronegative, have been, by the same authors, classed as combustibles. Also certain electronegative compounds, formed of the pre-eminently electronegative principles, have been associated as acids, while other compounds, of oxygen at least, which have the opposite polarity, have been associated as bases, under some of the subordinate divisions of alkalies, alkaline earths, earths proper, or simply as oxides. Pursuant to the views upon which the basacigen class has been founded, the list of electropositive compounds should comprise other bodies besides oxides. Originally, acids owed their name and classification to the usual characteristic of sourness, of which, for a long time, no known acid had been found deficient. Agreeably to the definitions which I have given in page 126, this can no longer be treated as an indispensable characteristic of acidity.

The idea of a class of supporters of combustion, and of combustibles, has no better foundation than that certain substances are more frequently agents in combustion, and therefore called supporters. Thus hydrogen will produce fire only with oxygen and chlorine; sulphur with oxygen, chlorine, and the metals; and carbon with oxygen; but as either oxygen or chlorine will burn with a great variety of substances, they have been called supporters of combustion, and the substances with which they combine during combustion, combustibles. Iodine, and latterly bromine, have been classed among the supporters, because they combine with almost all the bodies with which the other elements classed under that name unite, and in some cases with an evolution of heat and light. Yet they are not gaseous like oxygen and chlorine, and are as analogous to sulphur as to oxygen. There appears to me to have been an error in taking either of these substances into the class of supporters while excluding sulphur, which, next to oxygen and chlorine, has the property of burning with the greatest number of substances. In other respects, sulphur seems, in its properties, to be intermediate between iodine and phosphorus. The habitudes of selenium appear to range between tellurium and sulphur.

Hydrogen, phosphorus, carbon, boron, and silicon, are no more entitled to be called combustibles, than oxygen, chlorine, bromine and iodine to be called supporters; and it should be observed that these appellations are evidently commutable according to circumstances; since a jet of oxygen, fired in hydrogen, is productive of a flame similar to the inflamed jet of hydrogen in oxygen. If we breathed in an atmosphere of hydrogen gas, oxygen gas would be considered as inflammable, and of course a combustible. The arrangement which I have adopted of classifying as basacigen bodies those which have heretofore been treated as supporters, with the addition of some others, renders it unnecessary to resort to that incorrect mean of distinction.

ON THE NOMENCLATURE OF OXIDES, ACIDS, AND SALTS.

It may be proper, before proceeding further in the study of the acids and oxides, to make the student acquainted with the meaning of certain terms and terminations, employed by chemists in designating these substances.

Where, in consequence of different degrees of oxidizement, substances form two oxides, or two acids, one containing a larger, the other a lesser proportion of oxygen, the acid, or oxide, having the lesser proportion, is distinguished by the name of the substance oxygenated, and a termination in *ous;* that containing the larger proportion of oxygen is designated in the same way, substituting *ic* for *ous*, as sulphur*ous* acid and sulphur*ic* acid, nitr*ous* and nitr*ic* oxide or acid. As respects oxides, however, these terminations have only been used in the cases adduced, and in that of carbon*ic* oxide. That ingredient in an acid, or in a base, which is least electronegative, is called the radical. When an acid is discovered having less oxygen than one with the same radical, of which the name ends with *ous*, the word *hypo* is prefixed. Hence the appellations *hypo*nitrous, *hypo*sulphurous. The same mean of distinction is employed to designate a degree of oxygenation exceeding that designated by *ous;* but less than that designated by *ic*. Hence the name *hypo*sulphuric. If there be a third acid having still more oxygen, the letters *oxy* are prefixed.

Acids, of which the names terminate in *ous*, have their salts distinguished by a termination in *ite*. Acids, of which the names end in *ic*, have their salts distinguished by a termination in *ate*. Thus we have nitr*ites* and nitr*ates*, sulph*ites* and sulph*ates*. If the alkali be in excess, the word *sub* is prefixed, as *sub*sulphate. If the acid be in excess, *super* is prefixed, as *super*-sulphate. The letters *bi* are placed before the name of salts, having a double proportion of acid; hence carbonate and *bi*-carbonate.

The oxide in which the oxidizement is supposed to be at a maximum, is called the *per*oxide. This monosyllable, *per*, is also used in the case of acids, to signify the highest state of oxygenation, and has been improperly, as I conceive, substituted for *oxy*, in the case of *per*chloric acid, as already suggested. Most chemists apply the monosyllable in question to distinguish a salt formed with a peroxide. Thus the red sulphate of iron has been called the *per*-sulphate of iron. The nitrate of the red oxide of mercury, the *per*-nitrate of mercury. Agreeably to a similar rule, salts formed with *prot*oxides, have the word *proto* prefixed, as in the instances of *proto*-nitrate, *proto*-sulphate.

It has already been stated that by the British chemists the binary compounds of oxygen, chlorine, bromine, iodine, fluorine, and cyanogen, when not acid, are designated by the termination in *ide*. I have distinguished the binary compounds of all the basacigen bodies by appellations ending in *ide* excepting those which are acid. I should deem it preferable if this termination were considered as applicable to all compounds of the basacigen bodies, whether acids, bases or neutral, and that the terms acid and base, should be considered as severally indicating the subordinate electronegative, and electropositive compounds. In that case oxybase, chloribase, fluobase, bromibase, iodobase, cyanobase, sulphobase, telluribase, selenibase, would stand in opposition to oxacid, chloracid, bromacid, iodacid, cyanacid, sulphacid, selenacid, telluracid. Yet for convenience, the generic termination *ide* might be used without any misunderstanding; and so far the prevailing practice might remain unchanged. Resort to either appellation would not, agreeably to custom, be necessary in speaking of salts or other compounds analogous to them; since it is deemed sufficient to mention the radical, as if the salt consisted of an acid combined with a metal, not an oxide. Ordinarily we say, sulphate of lead, not sulphate of the oxide of lead. This last mentioned expression is resorted to, only where great precision is desirable. In such cases, it might be better to say sulphate of the oxybase of lead.

ON THE ORIGIN OF THE IDEA OF AN ACIDIFYING PRINCIPLE.

At the period when the French nomenclature was adopted, oxygen was considered as the sole acidifying principle. Of course every acid being supposed to consist of oxygen, in part, it was enough to call it an acid to convey a correct idea of its composition in that respect. But when, at a subsequent period, it was shown that many acids were destitute of oxygen; and that other substances were nearly as efficient as oxygen in generating acids by a union with acidifiable bodies, it became necessary to prefix syllables in order to distinguish the acid compounds produced by one acidifying principle, from those produced by others. The term acidifying principle originated with the error through which that character was exclusively assigned to oxygen. From convenience, more than any conviction of the propriety, it was afterwards used occasionally in reference to chlorine, hydrogen, and other elements which are found to produce acids in combining with a variety of substances.

It will be seen that there is no adequate reason for considering any element as an acidifying principle. The term radical originated at the same time, being the name given to the substances which oxygen was supposed to acidify. It has since been extended to all substances which form acids, or bases, with the basacigen bodies. After this explanation, the student will understand my meaning when I say that oxacids, or acids formed with oxygen, require no other designation than such as may indicate their radicals; whereas all other acids, in addition to the term formed from the radical, must have others prefixed, showing which of the basacigen substances constitutes their electronegative principle. Thus already in describing the acids formed by oxygen and chlorine, we have used the terms iodic and chloriodic; the first being equivalent in its import to an oxacid or one in which oxygen is the electronegative ingredient, the other indicating an acid in which the radical iodine remaining the same, chlorine is the electronegative ingredient.

OF ACIDITY AND ALKALINITY.

I have already, page 126, given definitions of acids and bases, founded principally on their habitudes with the Voltaic poles; and in the second place, upon the established characteristics of sourness and reddening litmus. Acidity was originally synonymous with sourness, as it continues to be in colloquial language; but many substances are now called acids by chemists, which do not produce those effects. They are never, in fact, produced by such acids as the silicic, uric and margaric acids, &c. which are insoluble in water. Solubility, however, notwithstanding these exceptions, is in general an attribute of the acids, and the great majority of them redden vegetable blues, yet sulphurous acid whitens litmus, and indigo is not reddened by any acid. Acids neutralize alkalies, and restore colours destroyed by them. Acids do not usually combine with acids, nor alkalies with alkalies, but acids and alkalies unite energetically with each other. I infer that alkalinity, acidity, and galvanic polarities, have a common cause, perhaps in some appropriate combinations of the imponderable, but material, causes of heat, light, and electricity. To other combinations of these imponderable principles, the sweetness of sugar, the pungency of mustard, or of pepper, and the activity of certain vegetable poisons, may be due. It is known that in morphia and strychnia, and in certain vegetable acids, the acid and alkaline properties are attached to ponderable elements, which exist in other compounds, without inducing acidity or alkalinity.

OF THE COMPOUND OF HYDROGEN WITH NITROGEN,

Called Ammonia or the Volatile Alkali.

As substances which are analogous in their most important properties, are often utterly different in their composition, it is impossible to adopt any arrangement in treating of them, which may be in both respects satisfactory. The compound, which is the subject of this article, was naturally associated with the other alkalies, when their composition was unknown; although now generally ranged with the other compounds of nitrogen, whilst its former associates are placed among the metallic oxides.

Formerly, only three alkalies were known—potash, soda, and ammonia. The two former being difficult to vaporize, have been called fixed alkalies: the latter, being naturally aeriform, has been called the volatile alkali. A new mineral fixed alkali was discovered in 1817, and named lithia. It was procured from a stone called Petalite. Hence its name from the Greek λιθειος, stony.

All the alkalies abovementioned have a peculiar taste, called alkaline. They all produce, in certain vegetable colours, characteristic changes, which differ according to the matter subjected to them, but are not varied by changing the alkali.

They restore colours changed by acids, and are capable of neutralizing acidity.

By their reaction with oils, soaps are generated, which are soluble in water.

There are certain metallic oxides which have been called earths, because they enter into the congeries ordinarily known by the name of earth, and which, in different degrees of intensity, have all the alkaline properties abovementioned, excepting the last.

There are also some vegetable compounds which possess, to a sufficient extent, the attributes of alkalies, to be classed among them.

According to Bonsdorf, the halogen elements of Berzelius produce bases which in some cases display alkalinity. He has noticed a change of colour, indicating an alkaline reaction on litmus paper reddened previously by an acid, and dipped into solutions of the chlorides of calcium, magnesium, and zinc.

It is my present intention, as introductory to the subject of ammonia, only to adduce a few experiments which illustrate the properties of alkalies in general.

157. EXPERIMENTAL ILLUSTRATIONS.

Of the Characteristic Effects of the Alkalies on certain Vegetable Colours.

Into infusions of turmeric, alkanet, Brazil wood, and rhubarb, a few drops of solutions of either of the alkalies, being introduced, turmeric, from a bright yellow, becomes brown; rhubarb, from nearly the same yellow, becomes red. Brazil wood, from a light red, becomes violet red; and alkanet, from red, becomes blue. Acids being added, the colours are restored; but by a sufficient quantity of alkali are changed, as in the first instance, and may be again restored by the acids; so that the experiment may be repeated several times with the same infusions.

A blue infusion obtained from red cabbage, is rendered green by any alkali. By adding some acid, the blue colour is restored; by a further addition of the acid, the infusion becomes red. An alkali being next introduced, it becomes blue, and by a further addition of alkali, the green colour reappears. By alternately using acids and alkalies, these changes may be repeated several times.

The power of various acids in reddening infusions of litmus, shown; and subsequently, the restoration of the blue colour by either alkali.

Means of obtaining Ammonia.

Ammonia is obtained from sal ammoniac, the salt from which it received its name.

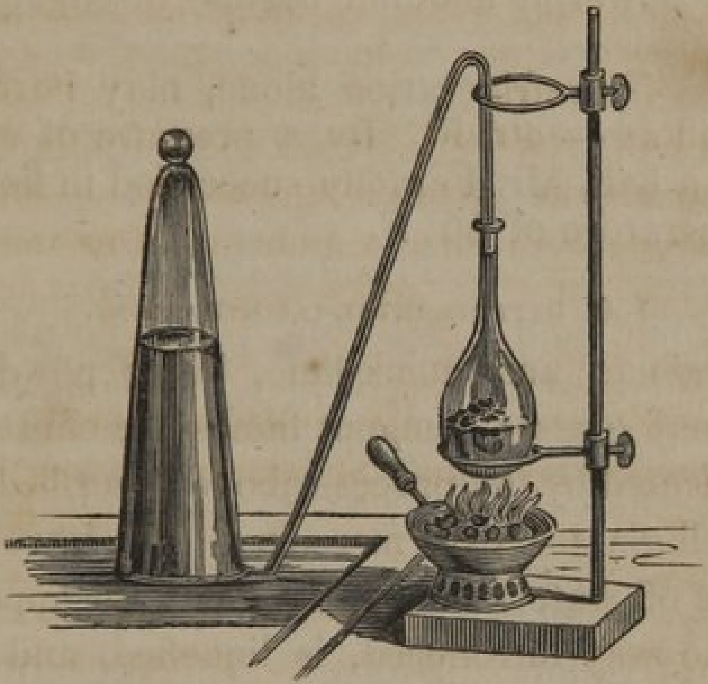
To evolve this alkali in the gaseous state, one part of sal ammoniac (chloride of ammonium) and two parts of quick-lime, both as finely pulverized as possible, are to be heated gradually in a glass matrass. The ammonia is partially extricated by the mere mixture of the materials; but heat is necessary to complete the operation.

Sal ammoniac is, according to the opinion generally entertained, a compound of chlorohydric or muriatic acid and ammonia. The lime having a greater affinity for the acid than the ammonia, by simple elective affinity, combines with it, and liberates the alkali in that gaseous state which it naturally assumes when isolated.

A different view of this subject is taken by Berzelius, which will be mentioned in treating of ammonium.

When it is an object to have the gas perfectly free from humidity, it is necessary to arrest the process as soon as moisture begins to condense in the neck of the receiver; or to interpose between the neck and the recipient used to receive the gas over the mercury, a tube containing dry hydrate of potash in small fragments.

158. EXPERIMENTAL ILLUSTRATION OF THE PROCESS FOR OBTAINING GASEOUS AMMONIA.



A flask, containing two parts of slaked lime, and one of sal ammoniac, both well pulverized, and thoroughly intermingled, is exposed to as much heat as the glass will bear.

A bell glass is so placed over the mercurial cistern, as to receive any gas which may pass from the orifice of a tube luted at one end into the flask charged with the materials, and the other entering the mercury so as to be under the bell.

Properties of Ammonia.

Ammonia acts like an alkali upon the organs of taste, upon vegetable colours, and in neutralizing acidity. When very much diluted with air, it is agreeably stimulating to the smell. In any considerable proportion, it is intolerable to the eyes and organs of respiration. It is not inflammable in the air; yet inflames with chlorine, spontaneously, and with oxygen, by the aid of an electric spark, or galvanic ignition. A candle flame is at first enlarged; afterwards extinguished by immersion in this gas. Water absorbs it with surprising velocity, and will hold from 450 to 670 times its bulk.

Ice melts in it more speedily than in a fire.

Heat either decomposes, or volatilizes, all ammoniacal compounds; and either of the fixed alkalies, or of the three more powerful alkaline earths, disengage it from any of the acids.

Ammonia, by refrigeration alone, may be condensed into a liquid at — 40° F. By a pressure of six atmospheres and a half, Mr. Faraday succeeded in liquefying it at the temperature of 50° F.

159. EXPERIMENTAL ILLUSTRATIONS.

Sal ammoniac and quick-lime, being powdered and mixed in small glasses, pungent fumes are emitted. Ammonia extricated by the process above described, and collected in bell glasses, over mercury. The introduction of a few drops of water, causes the gas to disappear. Ice, in the same way introduced, is liquefied, and causes a like result. Characteristic changes effected in the colour of water, tinctured by turmeric, alkanet, Brazil wood, and rhubarb.

Evolution of gas shown, by means of potash and an ammoniacal salt introduced into a glass vessel over mercury.

A mixture of ammonia, with oxygen gas, exploded.

OF THE COMPOSITION OF AMMONIA.

According to Berzelius, ammonia was first ascertained to be a compound of nitrogen and hydrogen, by his celebrated countryman, Scheele.

At a later period, Bertollet ascertained the ratio in which these substances exist in it, which is by volume that of three of hydrogen to one of nitrogen, condensed into two volumes, and by weight, three of hydrogen to fourteen of nitrogen. See Table, page 186.

The partial decomposition of ammonia may be effected by subjecting it to a succession of electrical sparks. Each spark causes the decomposition of a portion of the gas, but as the process proceeds, it becomes more difficult; so that a complete decomposition is impracticable. That portion which is decomposed, is doubled in volume; since the three volumes of hydrogen and one of nitrogen while combined, occupy but half of the space which they would fill if uncombined.

Ammonia, by being made to pass through tubes at a red heat, is resolved into its constituents. This result is promoted by the presence of metallic wire. Any metal will have more or less effect, but iron is most efficacious. It appears from recent experiments of Despretz, that this metal, by continued exposure, may be made to take up nearly twelve per cent. of its weight, becoming a nitruret, by the absorption of the nitrogen of the ammonia. It is supposed that other metals, which, after a like exposure, exhibit no increase of weight, receive and abandon nitrogen alternately; an operation which appears to be singular and mysterious. The metals become brittle during this process. Probably their influence is, in its nature, electrochemical. In its effects it appears to be the inverse of that by which the union of the elements of water is promoted by the presence of some metals in a state of minute division.

The decomposition and analysis of ammonia has been attempted by ignition with oxygen gas. I have often caused them to inflame by means of a wire ignited by galvanism. I believe it to be almost impracticable to ascertain the result accurately by measurement, on account of the liability of ammonia to be absorbed by the moisture of the apparatus, the water produced by the combustion, and the mercury employed to confine the gases.

A spontaneous and explosive combustion ensues between chlorine and the hydrogen of gaseous ammonia. When chlorine is passed in bubbles through concentrated liquid ammonia a reaction takes place, with so much noise as apparently to endanger the containing vessel.

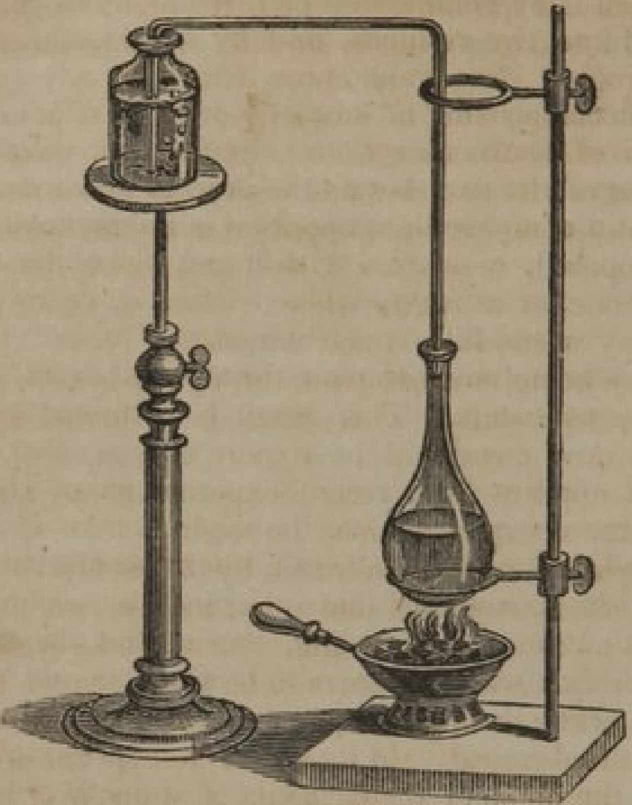
This process has already been mentioned among the means of obtaining nitrogen.

In its reaction with ammonia iodine differs from chlorine. When iodine is brought in contact with dry ammoniacal gas, it forms a thick black fluid, which, when saturated with ammonia, becomes more liquid. This compound is decomposed by water forming the iodide of nitrogen. See page 192.

With various metallic oxides, ammonia forms explosive compounds; especially those known as fulminating gold, and the most dangerous species of fulminating silver. By these appellations however, other compounds of those metals are designated. By some mysterious influence, probably electrochemical, the affinities between the oxygen and hydrogen are suspended, without being destroyed. Yet by slight causes, whether mechanical or chemical, the equilibrium is subverted with explosive violence.

The specific gravity of ammoniacal gas is 0.5902; 100 cubic inches weigh about 18 grains.

160. PROCESS FOR OBTAINING WATER OF AMMONIA.



If instead of being conveyed into a bell glass, the gas be received in water contained by a phial, the water may be saturated, constituting aqua ammoniæ, or water of ammonia.

The absorption of ammoniacal gas by water, causes so much heat, that to produce a saturated solution, refrigeration by ice water is necessary.

Water, saturated with ammonia, when gradually cooled to the temperature of — 40° F., crystallizes in long needles, having a silky gloss. No doubt these crystals owe their existence to the presence of water, which exists in them as water of crystallization. Water of ammonia is lighter than water. In combining with the gas this last mentioned liquid loses weight in proportion to the degree of the impregnation. At a maximum, at ordinary temperatures, the alkali constitutes about one-third of its weight.

OF AMMONIUM.

It is well known that Davy resolved potash and soda severally into metals and oxygen, by exposing those alkalies to the divellent influence of the Voltaic poles. Subsequently, Berzelius not having at command an apparatus sufficiently powerful, when unassisted, to effect this decomposition, ascertained that by placing mercury in contact with a fixed alkali properly moistened, and also in communication with the negative pole, while the alkali communicated with the positive pole, an amalgam would result, either of potassium or sodium, according to the alkali employed.

The results, when ammonia is subjected to the galvanic circuit in contact with mercury at the negative pole, having a perfect analogy, as respects the production of an amalgam, with those obtained by a similar exposure of the other alkalies, as above described, led naturally to the inference that the causes were analogous; and that in the case in question, no less than in the others, a metallic radical had been deoxydized and united with the mercury. This inference was rendered more plausible by the evolution of oxygen at the positive pole, during the formation of the amalgam. Yet ammonia was known to consist of hydrogen and nitrogen; and to consider either or both of these as oxides, was inconsistent with all the knowledge otherwise obtained respecting them. By some chemists, however, nitrogen was conjectured to be the oxide of a metal, with which this amalgam was supposed to be formed. For this supposed metal, the name of nitricum was suggested. Hence the contact of the amalgam with water was conceived to cause the absorption of oxygen by the nitricum, and consequently the extrication of hydrogen.

Gay Lussac and Thenard explained the formation of the amalgam, by supposing the absorption of ammonia by the mercury, together with a portion of hydrogen derived from a simultaneous decomposition of water.

Berzelius admits the fact of the union of the elements of ammonia and hydrogen with the mercury, in the proportions alleged by the distinguished philosophers above named; but conceives that by the addition of an atom of hydrogen to the ammonia, this alkali is converted into a metal which he calls ammonium. To the union of this metal with mercury, he ascribes the production of an amalgam; and to a resolution of the metal into its elements, the evolution of the ammonia and hydrogen. When an atom of ammonia is presented to an atom of water, he infers that the hydrogen converts it into ammonium, which is simultaneously oxydized by the oxygen. Hence an atom of ammonia, when combined with an atom of water, may be considered as acting as an oxybase of ammonium. When gaseous ammonia is presented to chlorine, one portion of it is decomposed, of which the nitrogen is liberated, while the hydrogen converts another portion into ammonium. This forms with the chlorine a chloride of ammonium, and accordingly, by this appellation, sal ammoniac, or muriate of ammonia, must be designated, agreeably to the hypothesis under consideration.

When in the process abovementioned for obtaining ammonia, chloride of ammonium (sal ammoniac) is mingled with the oxide of calcium (lime); by double elective affinity the chlorine combines with the calcium, and the oxygen with one atom of the hydrogen in the ammonium, so that water and ammonia are evolved. The latter assumes the gaseous form, while the water unites with the chloride and remains in union with it, if the heat be not raised unnecessarily, and continued too long.

If we attempt to decompose ammonia, without the assistance of mercury, it yields nothing but hydrogen and nitrogen; yet to produce the amalgam, it is sufficient that the wire employed be coated with mercury. The globule of mercury which is left after the spontaneous decomposition which the mass sustains, is in volume often not more than the two hundredth of that of the amalgam.

The most elegant mode, says Berzelius, of obtaining the ammoniacal amalgam, is to place a globule of the amalgam of mercury and potassium in a cavity of a piece of chloride of ammonium slightly moistened. The globule soon enlarges to many times its previous dimensions, by the absorption of the ammonium which relinquishes its chlorine to the potassium.

The ammoniacal amalgam agitated in dry atmospheric air, yields hydrogen and ammoniacal gas. The same gaseous substances are extricated from it when plunged into ether or naphtha. The ammoniacal amalgam may be preserved for some time if surrounded by hydrogen.

Berzelius does not consider ammonia as capable of becoming a base without first being converted into ammonium by the acquisition of hydrogen. In this state without further change it can, like other metals, form salts by combining with any of the halogen principles. But to combine with oxacids, the ammonium must, like other metals, be oxydized. The presence of water at once metallizes and oxydizes ammonia. The hydrogen converts the ammonia into a metal, the oxygen converts that metal into an oxide.

When gaseous ammonia precipitates from an aqueous solution of an haloid salt a metal in the state of an oxide, water is decomposed, the hydrogen converting the ammonia into the metal ammonium, while the oxygen converts the metal into an oxide. Meanwhile the ammonium combining with the halogen principle of the haloid salt, takes the place previously occupied by the oxydized metal.

161. EXPERIMENTAL ILLUSTRATIONS.

In a cavity, made in a bit of muriate of ammonia, a moistened globule of mercury is supported, in communication with one of the poles of a Voltaic pile. The mercury is made to communicate with the other pole. The metal swells rapidly, and assumes all the characteristics of an amalgam.

An amalgam of potassium being introduced into a cavity in a piece of sal ammoniac, is rapidly converted into the ammoniacal amalgam, with a prodigious enlargement in bulk.

OF PHOSPHORUS.

MEANS OF OBTAINING PHOSPHORUS.

It is obtained from the phosphate of soda in urine, or the phosphate of lime in bones. Impure phosphoric acid may be extricated from the earth of bones, by the stronger affinity of sulphuric acid. As, at a high temperature, charcoal takes oxygen from phosphorus, the phosphoric acid is decomposed by ignition with it in a retort, the beak of which is so introduced into water as to have the orifice a little below the surface. Phosphorus distils into the water, and condenses in tears.

Agreeably to another process, the phosphate of soda, which may be procured at the shops, is decomposed by nitrate of lead, by complex affinity. The phosphorus is separated from the resulting phosphate of lead, by distillation with charcoal, as in the process above mentioned.

Of the Properties of Phosphorus.

It is often of a light flesh colour, but when pure, colourless and translucent. It is rather harder than wax, but is more easily divided by the knife.

Phosphorus is insipid, and probably inodorous; but in consequence of its oxydizement it emits a feeble alliaceous odour of phosphorous, or hypophosphoric acid. When pure it is flexible, but the presence of $\frac{1}{600}$ of sulphur renders it brittle. Subjected to the rays of the sun, it acquires a red colour. If heated to 155° and suddenly cooled, it becomes black.* Thenard, however, states that this change cannot be effected in phosphorus which has not been repeatedly distilled. He suggests it as possible, that the colour of phosphorus when pure, is black, and that the colour which it usually assumes, may be due to the presence of hydrogen, which has been long known to be evolved, when phosphorus in the usual state, is fused and subjected to the Voltaic poles.

Exposed to the air, at ordinary temperatures, phosphorus combines slowly with oxygen, appearing luminous in the dark; but without any sensible evolution of heat. Less heat is requisite to cause the inflammation of phosphorus in atmospheric air, than in oxygen; and less also is necessary in this last mentioned gas, in proportion as the pressure is reduced. Phosphorus melts at 108°, and inflames at 148°. At 550° it boils, and may be purified by distillation from a retort filled with hydrogen gas, receiving the product under water.

When sprinkled either with powdered sulphur, carbon, fluoride of calcium, carbonate of lime, or various other bodies, and placed in a receiver, from which the air is subsequently exhausted, phosphorus inflames. Professor A. D. Bache, who has much enlarged the list of substances capable of producing this result, has succeeded in inflaming phosphorus in an exhausted receiver by enveloping it

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* Thenard Traite de Chymie. See Vol. 1st, page 90, 6th edition.

previously in muslin, or paper pierced with small holes. He conceives that with the exception of bodies exercising a chemical affinity, as in the instance of sulphur, the substances associated with the phosphorus act mechanically, and have upon it no other effect besides that of promoting its union with the oxygen remaining in the receiver. This opinion is corroborated by the fact, that the removal of the air may be too rapid, or too complete, to produce the inflammation.

Phosphorus may be crystallized by solution in boiling naphtha, and gradual refrigeration. Like sulphur, phosphorus, in volatilizing, produces a feeble light, without entering into any chemical combination. Water, in which phosphorus has been kept, oxygen being excluded, acquires the power of shining, when agitated. The admission of air destroys this phosphorescent property. The specific gravity of phosphorus is 1.77. Phosphorus is oxydized by the action of nitric, or nitrosonitric acid, and converted into phosphoric acid.

162. EXPERIMENTAL ILLUSTRATIONS OF THE PROPERTIES OF PHOSPHORUS.

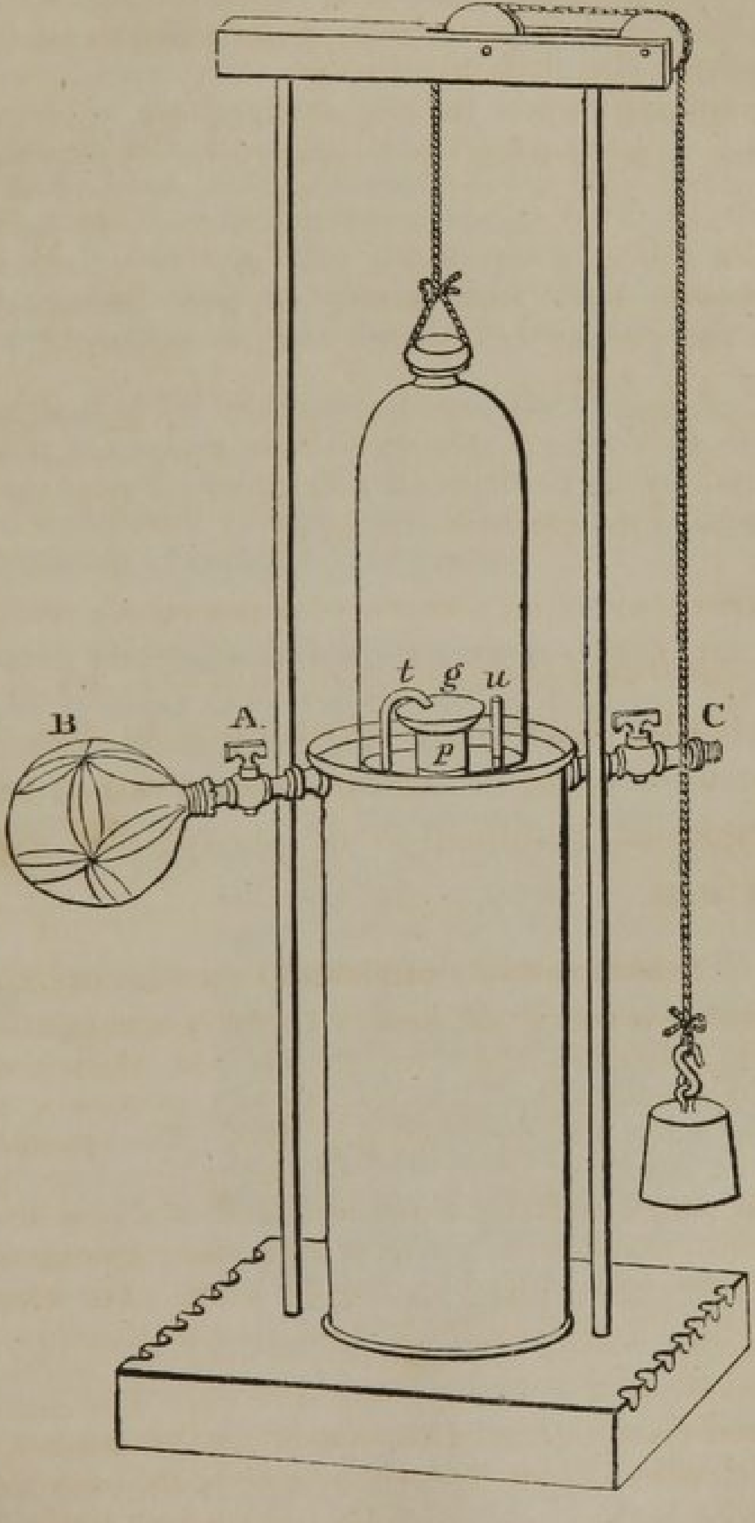
Phosphorus exhibited, and inflamed by friction, or a gentle heat. Luminous appearance in the dark. Combustion in oxygen, in nitrous, and in nitric, oxide.

Anomalous combustion of phosphorus consequent to rarefaction.

COMBUSTION OF PHOSPHORUS IN NITRIC OXIDE GAS.

The backwardness of the gaseous oxides of nitrogen to part with their oxygen to substances under circumstances in which it would be readily yielded by atmospheric air, has been already mentioned, and a method of illustrating it has been described, page 176. The opposite engraving represents an apparatus, which may be used to extend the illustration to nitric oxide, which producing a corrosive fume of nitrous acid by admixture with oxygen, cannot be employed in apparatus requiring the aid of an air pump, without some risk of injuring the latter. The apparatus in question is nearly the same as that used for the separation of nitrogen from atmospheric air. There are, however, in this, two additional tubes; and the bell employed is without any cap or cock. The cock at A, to which a gum elastic bag, supplied with oxygen gas, is attached, communicates with a pipe inside, which descends close along the inner side of the cylindrical copper vessel till it reaches the bottom, then bends at right angles, and proceeds along the bottom of the vessel till it reaches the copper pipe in the axis of the vessel. Next it bends at right angles upwards, and ascends vertically in close contact with the pipe, till it reaches the copper cup, *g*, by which the pipe is surmounted. It is there so recurved as to

Combustion of Phosphorus in Nitric Oxide.
(P. 212.)



overhang and direct its orifice, *t*, downwards into the cavity of the copper cap.

Another tube, *u*, proceeds from its junction, with a screw and cock, C, on the other side of the vessel, and descends to the bottom, rising again, like the tube above mentioned, along the central pipe, till it reaches the brim of the cup, where it terminates without a curvature. After the proper quantity of phosphorus is placed in the cup, the atmospheric air may be allowed to escape from the bell glass through the cock, C, by sinking it into the water with which the vessel must have been filled nearly to the brim. The air being expelled, and a communication made with a self-regulating reservoir of nitric oxide, by means of the flexible leaden tube attached to the cock for that purpose, the bell may be supplied with a quantity of this gas, sufficient to occupy about two-thirds of its capacity. The cocks being then closed, and the communication with the reservoir interrupted, a red hot iron must be introduced through the bore of the central pipe, *p*, till it touches the cup. For this purpose, it is of course necessary that the apparatus should be upon a table, with a suitable aperture, and of a height sufficient to allow the iron to enter the orifice of the pipe, *p*.

Although by the heat of the incandescent iron, the phosphorus will be fused, no combustion will ensue, until, by opening a communication with the gum elastic bag, a small quantity of oxygen gas is allowed to enter. But no sooner is this permitted to take place, than a most brilliant, and almost explosive evolution of heat and light ensues.

163. REACTION OF PHOSPHORUS WITH NITROSONITRIC ACID.

If into a tall tube of about an inch and a half in diameter, and fifteen inches in height, some strong nitric acid be introduced, and about five grains of phosphorus, a reaction will ensue, which is invariably energetic, and sometimes explosive. The phosphorus, abstracting oxygen, the acid is converted into nitric oxide gas, and nitrous acid vapour, which are copiously evolved, so as to fill the upper part of the tube, and overflow it in a beautiful red fume. Meanwhile, vivid flashes arise from the oxygenation of the phosphorus, and pieces of it are occasionally thrown up into the gas in the tube, where a vivid combustion ensues between the phosphorus and the oxygen of the nitric oxide gas or nitrous acid.

The residual nitric acid will be found intermingled with phosphoric acid.

Latterly, in performing this experiment, I have surrounded the tube with a very stout glass cylinder, and another of wire gauze; as upon one occasion a violent explosion took place, which did much damage among my apparatus. If the phosphorus be reduced into small fragments, the risk of an explosion is increased.

APPLICATION OF PHOSPHORUS IN EUDIOMETRY.

One of the most simple modes of ascertaining the quantity of oxygen in the air, is to introduce into a graduated tube, containing 100 measures of air, a stick of phosphorus, supported by a wire. The phosphorus slowly dissolves in the nitrogen, and combining with the oxygen, causes its absorption by the water. When, by these means, the oxygen is all absorbed, the quantity of nitrogen remaining will be known by inspecting the graduation. The difference between this quantity and 100, the number of measures taken, is the quantity of oxygen absorbed.

164. A SIMPLE ATMOSPHERIC EUDIOMETER, BY PHOSPHORUS.

If a cylinder of phosphorus be supported upon a wire (as here represented) within a glass matrass, inverted in a jar of water, the oxygen of the included air is gradually absorbed. In order to determine the quantity of oxygen in the air, we have only to ascertain the ratio of the quantity of gas absorbed, to the whole quantity of air included in the matrass at the commencement of the process.

This object may be attained by weighing the matrass, when full of water, and when containing that portion only which rises into it in consequence of the absorption. As the weight in the first case is to the weight in the last, deducting the weight of the glass in both cases, so will 100 be to the number of parts, in 100 of atmospheric air, which consist of oxygen gas.

Again, the contents of the vessel may be discovered by the sliding rod gas measure, p. 174, and the absorption measured by introducing from the same instrument as much air as will compensate it. As the whole content, to the quantity which compensates the absorption, so is 100 to the quantity of oxygen, in 100 parts of the atmosphere.

If the neck of a vessel of this kind hold about one-fourth as much as the bulb, by graduating the neck, so that each division will represent a hundredth part of the whole capacity, the result may be known by inspection.

Eudiometrical processes by the slow combustion of phosphorus, are tedious, requiring many days to complete them, and consequently the aid of barometrical observations to ascertain, and allow for any intervening changes in atmospheric pressure.

It is alleged that nitrogen is enlarged one-fortieth of its bulk, by the phosphorus which it dissolves. This is to be deducted in estimating the residual gas.

The action of the phosphorus may be accelerated by heat: but in that case the operation must be performed over mercury; and the manipulation will be found troublesome and precarious.

165. VOLUMETER FOR THE ANALYSIS OF ATMOSPHERIC AIR BY PHOSPHORUS.

Page 181, article 145, a volumescope is described for showing the diminution of bulk in five volumes of atmospheric air, consequent to the admixture of nitric oxide.

The same apparatus may, with some modification, be employed to show the diminution of volume resulting from the combustion of phosphorus. This object is effected by associating with the volumescope the apparatus employed for the combustion of phosphorus in oxygen, page 104, article 103. For this purpose the volumescope, instead of being situated over the pneumatic cistern, should be placed in a small tub, into the bottom of which is inserted a tube, supporting, at the upper extremity, the cup for the phosphorus. The phosphorus being placed in the cup, and water in the tub, this liquid is raised by an air pump until no more than five volumes of air remain in the cylinder.

The phosphorus is then ignited, by means of a red hot iron, and the process conducted as already described, page 166, article 138.

As soon as the expansion resulting from the heat of the combustion ceases, it will be seen that a little more than one volume out of the five has been condensed.

COMPOUNDS OF PHOSPHORUS WITH OXYGEN.

Three atoms of phosphorus, with two atoms of oxygen, form one atom of the oxide of phosphorus.

One atom of phosphorus equivalent 16,
- With one and a half atoms of oxygen, equivalent 12, forms phosphorous acid, equivalent 28.
- With two and a half atoms of oxygen, equivalent 20, forms phosphoric acid, equivalent 36.

Two other oxacids of phosphorus are alleged to exist, one called hypophosphoric acid, containing a proportion of oxygen intermediate between those in phosphoric and phosphorous acid, the other called hypophosphorous acid, and containing less oxygen than either of the others. The existence and composition of these acids are involved in doubt.

OF THE OXIDE OF PHOSPHORUS.

When phosphorus, melted under hot water, is subjected to a jet of oxygen from a tube with a capillary orifice, oxide of phosphorus and phosphoric acid are produced. The acid dissolves, and the oxide being at first suspended in the water, subsides subsequently in red flakes. This oxide is insipid and inodorous. It is not luminous in the dark, even when rubbed. At a heat a little below redness, in close vessels, it is decomposed into phosphoric acid and phosphorus. If the air be admitted, phosphoric acid is the sole product. The oxide of phosphorus takes fire spontaneously in chlorine, producing the perchloride of phosphorus and phosphoric acid. It is inflamed by the action of nitric acid. With chlorate of potash it explodes violently: also with nitrate of potash previously warmed. The white matter with which phosphorus becomes coated when kept in water, and which is generally supposed to be a hydrate of an oxide, is stated by Thenard to be a hydrate of phosphorus.

166. EXPERIMENTAL ILLUSTRATION.

Reaction of oxygen with phosphorus melted under water.

OF PHOSPHOROUS ACID.

This acid has been generally considered as the product of the slow combustion of phosphorus with atmospheric oxygen; but Thenard alleges, that hypophosphoric acid is the product of this combustion. Phosphorous acid may be procured by passing vaporized phosphorus over corrosive sublimate heated in a tube. Chloride of phosphorus results; which, by reaction with water, produces chlorohydric and phosphorous acids. The chlorohydric acid being more volatile, may be expelled by heat.

Phosphorous acid is a colourless, inodorous, crystalline body, possessing a pungent taste, and reddening litmus paper. Phosphorous, in common with hypophosphorous acid, possesses powerful deoxydizing properties.

OF PHOSPHORIC ACID.

Phosphoric acid may be obtained by adding sulphuric acid to phosphate of barytes. The sulphuric acid unites with the barytes, forming an insoluble salt, which precipitates, while the phosphoric acid remains in solution. When phosphorus is gradually added to nitric acid, phosphoric acid is generated, and remains mingled with the residual nitric acid. If the mixture thus obtained be heated to redness, to expel the nitric acid, the phosphoric acid is converted into paraphosphoric acid.

Properties of Phosphoric Acid.

Phosphoric acid is an inodorous, colourless, viscid liquid, possessing in a high degree the property of reddening litmus. It cannot be obtained free from water. When exposed to a red heat, and afterwards cooled, it forms a transparent brittle glass. This fusion should be effected in a platina crucible, since phosphoric acid, when heated to redness, attacks either glass or porcelain. The acid, if examined after this exposure to heat, is found, although its composition remains the same, to have acquired new properties. On this account, the name of paraphosphoric has been given it, while the term phosphoric, is applied to designate the acid in the state first described. Nitrate of silver yields, with phosphoric acid, a yellow precipitate; with paraphosphoric acid a white precipitate. Albumen is coagulated by the latter, but not by the former.

Solid paraphosphoric acid, when exposed to the air, deliquesces, and is in a few days converted into phosphoric acid. The same change is produced in a short time, by boiling water. The solid white flakes which are obtained by the quick combustion of phosphorus with oxygen, consist of paraphosphoric acid. It may likewise be produced by fusing the biphosphate of soda, which by these means is converted into a paraphosphate. Mr. Graham, who has made a number of interesting experiments on this subject, states, that the acid which is contained in fused phosphate of soda, is a third species of phosphoric acid, which coincides in composition with the others, but not in properties.

To bodies which possess different properties while containing the same number of atoms of the same elements, and having the same atomic weight, the term isomeric has been applied. Thus, phosphoric and paraphosphoric acids, are isomeric bodies.

OF THE CHLORIDES OF PHOSPHORUS.

It has been shown, article 109, that phosphorus burns spontaneously in chlorine. If the chlorine be in excess, the deutochloride is formed; if the phosphorus be in excess, the protochloride is obtained. The latter is a transparent, colourless, fuming, inflammable liquid, heavier than water, and having a disagreeable smell. When brought into contact with water, a reciprocal decomposition takes place, and chlorohydric and phosphorous acid are produced. The deutochloride is a white, crystalline, inflammable body, which is converted into vapour at a temperature much below 212°. It forms a neutral compound with ammonia, and its vapour is alleged to redden dry litmus paper. Hence, by some chemists, it is considered as an acid. I doubt if litmus paper is ever reddened by an acid, unaided by water. The deutochloride and water decompose each other, forming phosphoric and chlorohydric acid. The chlorine bears the same ratio to the phosphorus in these chlorides, as the oxygen bears to the phosphorus in phosphorous and phosphoric acid.

OF THE BROMIDES AND IODIDES OF PHOSPHORUS.

The protobromide is a yellow fuming liquid; the deutobromide, a crystalline, volatile solid. In their reaction with water and composition, they agree with the chlorides of phosphorus. Iodine appears to combine with phosphorus in almost every proportion. There are, however, at least two definite combinations, which correspond in composition with the chlorides and bromides.

OF THE SULPHIDES AND SELENIDES OF PHOSPHORUS,

Commonly called Sulphurets, and Selenurets.

When phosphorus is melted with sulphur, or when sprinkled with it, and placed in a receiver from which the air is subsequently withdrawn, (see page 211,) a sulphide of phosphorus is formed. This sulphide may consist of various proportions of its ingredients, according to the circumstances under which it is produced. Sometimes it is liquid, sometimes solid.

Selenium, like sulphur, combines with phosphorus in almost every proportion. The sulphides and selenides of phosphorus, are decomposed by water.

The incorporation of sulphur with phosphorus, when effected by heat, is sometimes productive of explosion; and the resulting mass is spontaneously inflammable in the air.

OF PROTOPHOSPHURETTED HYDROGEN.

Protophosphuretted hydrogen may be obtained by heating a concentrated solution of phosphorous acid, or by adding phosphorus to the materials for generating hydrogen.

Of the Properties of Protophosphuretted Hydrogen.

It is a colourless, inflammable gas, with an odour similar to that produced by the combustion of arsenic. Under the ordinary pressure of the atmosphere, protosulphuretted hydrogen does not inflame spontaneously with oxygen; but, if the pressure be reduced about one-third, combustion ensues.

On meeting with oxygen, this gas becomes luminous in the dark, in consequence of the slow combustion of the phosphorus, though the heat evolved be inadequate to inflame the hydrogen. If the process for producing the philosophical candle, described in article (119,) be repeated, with the addition of comminuted phosphorus to the materials, protophosphuretted hydrogen will be generated, and escaping into the air, will produce a jet luminous in the dark.

167. OF PERPHOSPHURETTED HYDROGEN.

Perphosphuretted hydrogen may be produced by the reaction of chlorohydric acid with the phosphuret of calcium, which is obtained by subjecting lime to the vapour of phosphorus at a bright red heat in a porcelain or coated glass tube. The gas may also be evolved by heating in a retort, 75 grains of phosphorus, 1500 of slaked lime, with 4 ounces water; or by 50 grains of caustic potash, and 40 of phosphorus, moistened by 60 drops of water. The phosphorus should be added first, and the potash last; as the heat which it evolves, contributes to the heat required for the operation. The body of the retort should be filled with hydrogen, or a few drops of ether should be added, to prevent the first portions of the gas from inflaming with the atmospheric oxygen of the retort. By its affinity for the phosphorus, and the metal of the phosphuret, the oxygen of the water is separated from the hydrogen; which, while nascent, unites with a portion of the phosphorus, and forms perphosphuretted hydrogen.

The beak of the retort being depressed below the surface of mercury, each bubble, as it escapes into the atmosphere, explodes. It produces at the same time a dazzling flash, which is transformed into a beautiful wreath of smoke, consisting of aqueous vapour and phosphoric acid, created by the oxygenation of hydrogen and phosphorus. Each wreath as it rises, expands in diameter, and when the bubbles succeed each other quickly, a series of them may be seen in the air simultaneously.

Of the Properties of Perphosphuretted Hydrogen.

Perphosphuretted hydrogen is a colourless gas, possessing an alliaceous smell, and a bitter taste. Water dissolves it in small quantity, forming a yellow solution, which has a bitter taste, and a smell resembling that of the gas. When this gas is brought in contact with oxygen, or atmospheric air, it explodes with a loud noise and a vivid flash; being converted into phosphoric acid and water. The same mixture, in narrow tubes, undergoes a similar change, slowly and without the evolution of heat and light.

Perphosphuretted hydrogen may be decomposed either by heat, by the electric spark, or by the rays of the sun. Professor Rose considers protophosphuretted and perphosphuretted hydrogen as isomeric, and of course similar in composition, though different in properties. If the opinions of Rose are correct, one of the compounds, abovementioned, should be called phosphuretted hydrogen, the other, paraphosphuretted hydrogen. See article on phosphoric acid, page 217.

Chemists do not agree in their statements respecting the composition of gaseous compounds of hydrogen with phosphorus.

168. METHOD OF EXHIBITING THE INFLAMMATION OF SMALL PORTIONS OF GAS.

This figure illustrates an advantageous employment of the sliding rod eudiometer, in exhibiting the spontaneous combustion of phosphuretted hydrogen, the splendid colour of the flame of cyanogen, and other experiments, where the combustible character of a small quantity of gas is to be shown.

For the experiments in question, the instrument is charged agreeably to the mode already described in the case of the eudiometers, by introducing the apex into any bell glass or other vessel holding the gas, and drawing out the rod, by which a portion of the gas, equivalent in bulk to the part of the rod withdrawn, enters the receiver of the eudiometer through the hole in the apex.

The receiver being then removed from the bell glass, and held up in a position favourable for observation, the rod is slowly returned into its tube, so as to expel the gas in a jet suitable for inflammation.

In the case of phosphuretted hydrogen, the gas burns spontaneously as soon as it escapes from the apex. In the case of other inflammable gases, inflammation is produced by the flame of a taper.

OF CARBON.

Nature presents us with the most beautiful and purest specimens of this substance. The diamond is pure carbon. When equal weights of charcoal and diamond are severally exposed to the focus of a powerful lens, in oxygen gas, included in different bell glasses, they are both converted into carbonic acid. In like manner, when diamond powder is heated with nitre, or iron, the effects are analogous to those which would arise from charcoal.

Carbon is very abundant in nature, in the various kinds of fossil coal, from anthracite or plumbago, in which it is nearly pure, to the variety called candle, or cannel coal, which is replete with bitumen. In bituminous coal there is much hydrogen. Carbon pervades vegetable and animal matter, as an essential element. It is, especially, a constituent of the fibres of wood.

Until of late, plumbago was considered as a chemical compound of iron with carbon. Berzelius alleges it to be carbon mingled, but not combined, with iron and other impurities.

I ascertained that anthracite, when completely burned in oxygen gas, produced no diminution of volume, the products being water and carbonic acid. I infer, therefore, that the combustible portion of this coal consists, almost solely, of carbon, united with hydrogen and oxygen, in the proportion for forming water.

Plumbago is sometimes found in the form of hexagonal crystals.

Of the Methods of obtaining Charcoal.

In the laboratory, charcoal is obtained, sufficiently pure, by heating wood intensely in close vessels. In the large way, it is procured by igniting large quantities of wood, so covered with earth, that the access of air may be at first controlled, and afterwards prevented.

Coke is obtained from bituminous coal, by a process analogous to that employed to obtain vegetable charcoal, which it resembles in chemical, though not in mechanical properties.

Of the Properties of Carbon.

It is inodorous and insipid, usually black. Charcoal of wood is one of the best radiators, and worst conductors of heat. There is reason for believing this peculiarity to result from its excessive porosity; as in the form of anthracite, carbon conducts heat better, and probably radiates it worse. Charcoal is highly susceptible of galvanic ignition.

Next to the metals, charcoal is the best conductor of electricity. It appears, from the experiments of Professor Silliman, that charcoal, when exposed to the influence of a powerful Voltaic series, undergoes fusion and volatilization, so as to be transferred from the positive to the negative pole, on which it forms a projection.

Charcoal, when intensely ignited, without access of air, becomes denser, harder, and a good conductor of heat. Substituting animal products for those of vegetation, in the usual process of carbonization, animal charcoal is obtained. It does not, like the coal of vegetable substances, retain the form of the bodies from which it may be procured, and is replete with cavities, created by the escape of the gaseous elements associated with it in the organic state.

It has a grayish black colour, and a brilliancy resembling that of plumbago. Carbon is precipitated in various forms, from coal gas; among others, in that of long brittle filaments, associated in tufts resembling locks of hair. The specific gravity of carbon, in the state of diamond, or in that of common charcoal, when examined in the pulverulent form, so that the result shall not be affected by the numerous cavities existing in it when in mass, is about 3.5. The apparent lightness of charcoal is caused by its porosity. The specific gravity of anthracite does not exceed 1.6; that of plumbago, 2.32; yet they are both much more compact than charcoal, and in proportion to the space occupied by them in mass, obviously much heavier.

Carbon, under some circumstances, appears to have a transcendent affinity for oxygen. In its ordinary state, it requires a temperature above redness, in order to exhibit this affinity; in other words, to burn. In proportion as it becomes denser and more pure, we find it more difficult to ignite.

Thus the susceptibility of ignition increases from the diamond to tinder, in the following gradation. Diamond, plumbago, anthracite, coke, charcoal of hard wood, charcoal of soft wood, tinder.

In some forms, and when mixed with certain metals, iron or antimony, for instance, as when obtained by carbonizing prussian blue, or tartrate of ammonia, and antimony, it takes fire at ordinary temperatures, spontaneously.

According to Despretz, during its combustion, carbon evolves caloric sufficient to melt one hundred and five times its weight of ice. It is not to be inferred, that this is true of carbon in all its forms.

Berzelius alleges that the same degree of heating power, is not possessed by every kind of charcoal; some of its forms, according to him, producing much more heat in burning than others. This I should not believe, without conclusive evidence.

Of the Decolouring and Disinfecting Power of Charcoal.

Carbon, as procured from organic products, especially animal matter, displays a great power to combine with, and precipitate colouring matters. Hence it is extensively used in the refining of sugar; and generally in chemical processes, in which the objects of research are entangled with colouring matter. This power is not inherent in elementary carbon, but appears to be due to its previous associations, or to some peculiarity of arrangement, derived from the process of carbonization.

Animal charcoal is much more efficacious than that derived from vegetables. The carbonaceous mass, obtained by igniting blood with carbonate of potash, appears to have the greatest efficacy. That the presence of an alkali, during the ignition, contributes to the effect, seems to justify the conjecture, that cyanogen, the generation of which, in combination with the alkali, is a necessary concomitant, has some agency in the process. Charcoal is a powerful antiseptic, operating efficiently in preserving water or meat from putridity. Moreover, water, rendered extremely foul, as that from the public sewers, may be purified by filtration through pulverized charcoal. In fact, filters are now extensively manufactured, in which charcoal is the most efficient, and only chemical agent employed. The gravel, sand, and sponge, usually associated with it, act mechanically.

Of the Power of Charcoal, and other Substances, to absorb Aëriform Fluids.

Charcoal, which has in a state of ignition been submerged in mercury, on being introduced into gaseous substances, condenses into its pores a large quantity of the surrounding aëriform matter, whatever it may be. The quantity condensed, varies with the gas, from 90 times the bulk of the charcoal, as in the case of ammonia, to 1.75 times as in the case of hydrogen. During their absorption, the gases give out heat, and the more in proportion to the rapidity with which the condensation is effected; and if, on the other hand, by exposure within an exhausted receiver, the gas be evolved, cold is produced. Charcoal thus deprived of gas, reabsorbs any gas exposed to it, as greedily as if recently ignited.

This faculty of absorbing gaseous substances, is impaired by humidity; which charcoal is prone to absorb in the form of vapour, afterwards condensing it into the state of water. Water partially displaces the gases previously absorbed.

The aëriform fluids absorbed by charcoal, are expelled by heat, unchanged, with the exception of sulphuretted hydrogen and oxygen. The former deposits sulphur, and the latter is gradually converted into carbonic acid. The absorption of this last mentioned principle continues for some time, but in quantity, has not been found to exceed 14 times the volume of the carbon. In a rarefied medium, charcoal absorbs less in weight, but more in volume; so that the increased resistance of the gas arising from a diminution of pressure, counteracts, to a certain extent, the power of the coal to condense into its pores a certain weight. The power of absorption varies in a degree with the number and minuteness of the pores existing in the charcoal; of course, it varies with the wood by which it is yielded. Charcoal of box-wood, is pre-eminent in absorbing power; that furnished by woods of a lighter kind, is very inferior in this power. Plumbago and anthracite, have no capacity, even after ignition, to absorb gases.

In the property of absorbing aëriform fluids, charcoal is not singular. De Saussure ascertained that different porous minerals, and many kinds of wood, also silken and woollen stuffs, absorb many times their volume of gas.

When porous bodies are placed in a mixed atmosphere of various gases, they are absorbed in proportion to their reciprocal attractions, and that exercised by the pores of the substances employed.

A mixture of oxygen, with hydrogen or carbonic acid, is more copiously absorbed than either when alone; yet by heat or exhaustion, they are liberated without diminution. Nevertheless, sulphuretted hydrogen and oxygen, when acted upon by charcoal, produce water, sulphur being deposited.

The absorption of moisture by charcoal and other porous bodies, has long been noticed. On this account, it is difficult to weigh a body previously made red hot, before an increase of weight ensues, from this cause.

Those aëriform fluids are most liable to absorption, which are capable of assuming the liquid state.

These facts, explain the augmentation in weight received by charcoal exposed to the air, which amounts to between ten and twenty per cent.

I have devoted more space to this subject, because it illustrates a property which otherwise might not be sufficiently considered. It forms a peculiar instance of mechanico-chemical agency, if I may be allowed to use a new word to express the idea. Without the porous or cellular structure which it possesses in the form of charcoal, carbon is not endowed either with disinfecting, absorbing, or colour-removing powers; and yet it is evident, that the carbon acts in charcoal by a species of chemical affinity, unaided by which the cellular structure would be inefficient in the processes under consideration. As respects the transmission of contagious or infectious effluvia, the absorbing power of porous bodies merits attention.

I believe that the carbonaceous matter evolved during the burning of sugar, actually neutralizes those fetid emanations which it is employed to correct in the chambers of the sick.

COMPOUNDS OF CARBON WITH OXYGEN.

One atom or one volume of carbon equivalent 6,	With one atom or half volume of oxygen, equivalent 8, forms 1 atom or 1 volume carbonic oxide, equivalent 14.
	With two atoms or one volume of oxygen, equivalent 16, forms 1 atom or 1 volume carbonic acid, equivalent 22.

Two atoms or volumes of carbon equivalent 12, with three atoms or one and a half volumes of oxygen, equivalent 24, form 1 atom oxalic acid, equivalent 36.

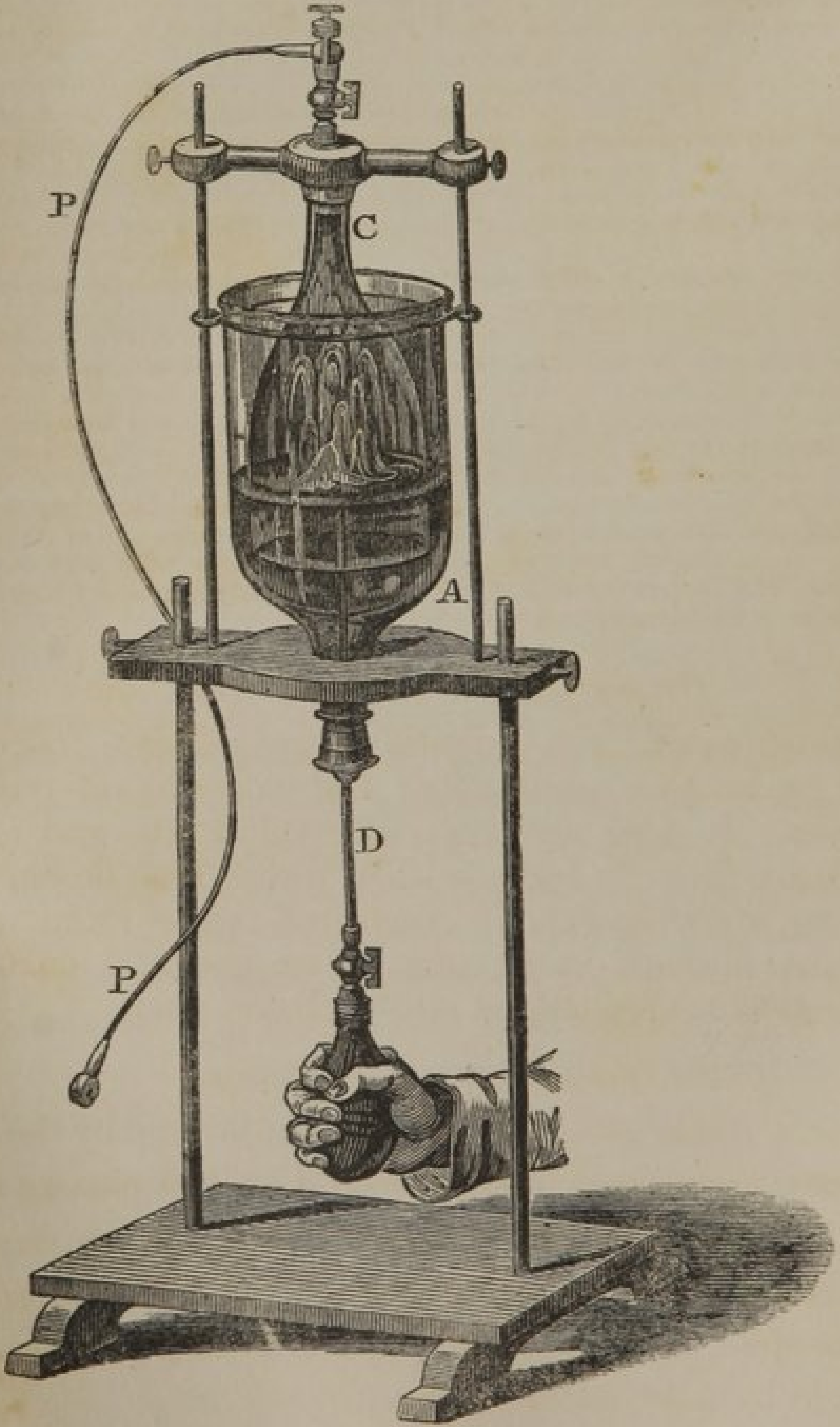
Two other compounds of carbon with oxygen, are alleged to exist; one called croconic, the other mellitic acid. The latter contains four atoms of carbon to three of oxygen; the former five of carbon to four of oxygen.

OF CARBONIC OXIDE.

This compound is produced by the combustion of carbon with an inadequate supply of oxygen, or when bodies containing carbonic acid are heated with certain substances having an affinity for oxygen. Thus it may be procured, by heating carbonate of lime with iron filings. The best process, however, for obtaining carbonic oxide in a state of purity, is to heat five parts of concentrated sulphuric acid with one of oxalic acid; which, being deprived by the sulphuric acid of the water which is essential to its existence, is resolved into carbonic oxide and carbonic acid. The latter gas may be removed by lime water, leaving the carbonic oxide in a state of purity.

Apparatus for separating Carbonic Acid from Carbonic Oxide, by means of Lime Water.

(P. 225.)



169. *Apparatus for separating Carbonic Oxide from Carbonic Acid, by means of Lime-Water.*

Lime-water being introduced in sufficient quantity into the inverted bell glass, another smaller bell glass C, is supported within it as represented in this figure. Both of the bells have perforated necks. The inverted bell is furnished with a brass cap having a stuffing box attached to it, through which the tube D, of copper, slides air-tight. About the lower end of this tube, the neck of the gum elastic bag is tied, so that the cavity of the bag may communicate with that of the tube. The neck of the other bell is furnished with a cap and cock, surmounted by a gallows screw, by means of which a leaden pipe, P P, with a brass knob at the end suitably perforated, may be fastened to it, or removed at any moment. Suppose this pipe, by aid of another brass knob at the other extremity, to be attached to the perforated neck of a very tall bell glass filled with water upon a shelf of the pneumatic cistern: on opening a communication between the bells, the water will subside in the tall bell glass over the cistern, and the air of the bell glass C, being drawn into it, the lime-water will rise into and occupy the whole of the space within the latter. As soon as this is effected, the cocks must be closed, and the tall bell glass replaced by a small one filled with water, and furnished with a gallows screw and cock. This bell being attached to the knob of the lead pipe, to which the tall bell had been fastened before, the apparatus is ready for use. I have employed it in the new process for obtaining carbonic oxide from oxalic acid, by distillation with sulphuric acid in a glass retort. The gaseous product consists of equal volumes of carbonic oxide and carbonic acid, which, being received in a bell glass communicating as above described, by a pipe with the bell glass, C, may be transferred into the latter, through the pipe, by opening the cocks. As the gaseous mixture enters the bell, C, the lime water subsides. As soon as a sufficient quantity of the gas has entered, the gaseous mixture may, by means of the gum elastic bag and the hand, be subjected to repeated jets of lime-water, and thus depurated of all the carbonic acid. By raising the water in the outer bell, A, the purified carbonic oxide may be propelled, through the cock and lead pipe, into any vessel to which it may be desirable to have it transferred.

Properties of Carbonic Oxide.

Carbonic oxide is a colourless insipid gas, indecomposable by heat or electricity; and incapable of reddening litmus. It does not support combustion, and is destructive to life. It burns with a feeble blue flame, and combining with oxygen, is converted into carbonic acid. By platina sponge, a mixture of oxygen and carbonic oxide is gradually changed into carbonic acid.

170. EXPERIMENTAL ILLUSTRATIONS.

Carbonic oxide gas evolved from oxalic acid by the process above mentioned, and collected in bell glasses over water. Combustion and detonation of it with oxygen gas, effected by means of a sliding rod eudiometer, or volumescope. Subsequent absorption of the resulting carbonic acid by lime water shown.

OF CARBONIC ACID.

The proportion of this gas, existing in the atmosphere, is much less than was formerly supposed, being, according to some experiments of Thenard, not more than a thousandth part. It is this portion, however, that produces the pellicle on lime water, during its exposure to the air; and which, under like circumstances, by combining with the alkalies, enables them to effervesce with acids. Carbonic acid is incessantly a product of combustion, and of the respiration of animals. It is a principal ingredient in marble and limestone.

Means of procuring Carbonic Acid.

It may be evolved from any carbonate, by heat or by acids. It is usually procured for the impregnation of water, by the superior affinity of sulphuric acid for the lime, in marble. Excepting that it is more costly, chlorohydric acid is preferable, for this purpose, as the chloride of calcium, being very soluble, does not, like the sulphate, clog the vessels.

Carbonic acid is evolved copiously during the vinous fermentation.

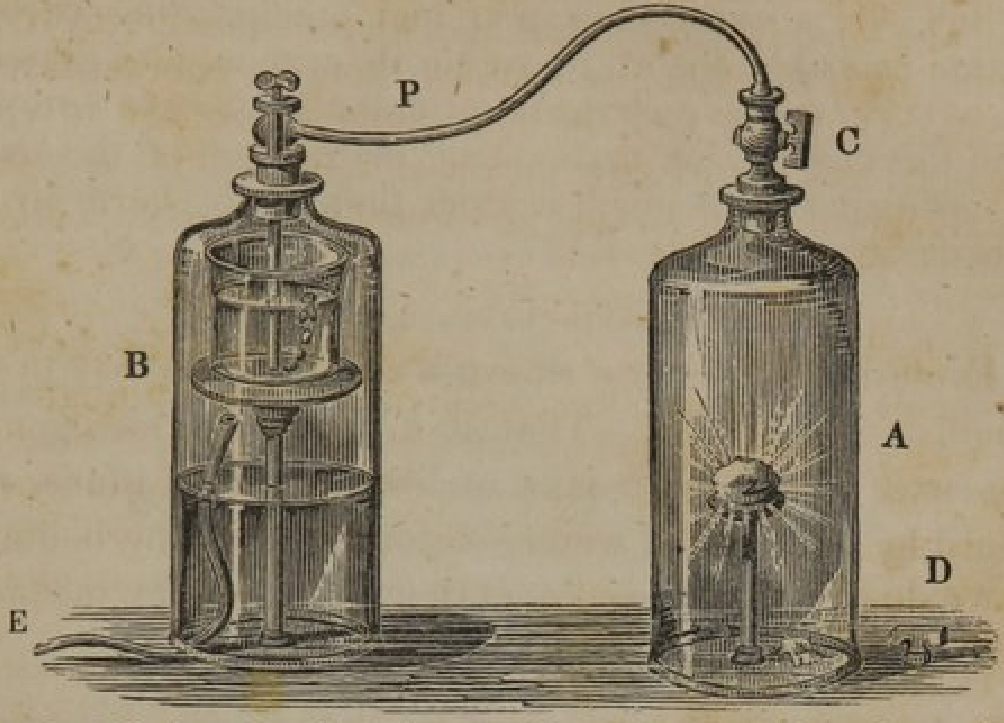
The process and the self-regulating reservoirs described articles 116 and 117, may be resorted to for carbonic acid, substituting lumps of marble for zinc. The best materials for the evolution of this gas, are, agreeably to my experience, muriatic acid and calcareous stalactites.

Carbonic acid might be procured at a trifling cost, by drawing, by the aid of a suction pump, the effluvium of burning charcoal through water, to deprive it of dust, and then forcing it into the cavities in which its pressure may be desirable.

This process, for the production and employment of carbonic acid, generated by the combustion of charcoal, is illustrated in the small way by the following engraving and description.

171. COMBUSTION OF CHARCOAL OR OTHER COMBUSTIBLES IN OXYGEN GAS.

The figure represents an apparatus which I have contrived for exhibiting the combustion of charcoal, or other combustibles, in oxygen gas. Two large glass bells, A, B, each furnished with a tubulure at the apex, are associated by means of the pipe, P, which in one of the bells, B, communicates with a tube, extending about five inches within the bell, below its neck, so as to reach into some lime-water, or an infusion of litmus, contained in a glass vessel, on a stand, as represented in the figure. The wooden stand, which holds the glass vessel, and the iron stand which supports the coal in the bell, A, must be previously fixed on the shelf of the pneumatic cistern, as observed in the drawing; so that A, when including the coal, may be over the mouth of the cock, D, which communicates with one of the gas holders, situated under the shelves of the pneumatic cistern; which, for this experiment, should be filled with oxygen.



Into the bell glass, in which the glass is placed, a pipe from the suction pump of the hydrostatic blowpipe is made to enter and reach nearly to the stand. The apparatus having been prepared thus far, the bells must be lifted so as to permit a live coal to be put upon the iron stand, as represented in the drawing. As soon as they are restored to their previous situations, the suction pump must be put into operation, and the cock, D, of the gas holder, containing the oxygen, opened, so as to allow a current of the gas to have access to the coal, by replacing the air, which is withdrawn, by the pump through the pipes, P and E. The coal burns splendidly, and as the oxygen becomes saturated, it is drawn off, by the suction pump, being made in its way from A to B, to pass through the liquid in the vessel, into which descends the tube proceeding from A. If the liquid be water tinged with litmus, it will become red by the action of the carbonic acid: if it be lime-water, a copious milky precipitate will appear.

On the Properties of Carbonic Acid.

It is a colourless gas, with a pungent smell, and an acid taste.

At the temperature of 32°, and under a pressure of forty atmospheres, it condenses into a colourless liquid.

Water takes up its own bulk of this gas, whatever may be its density. It combines with earths, alkalies, and metallic oxides, forming with lime, barytes, strontites, magnesia, and oxide of lead, compounds which are insoluble. Hence, it precipitates either lime-water, barytic-water, or a solution of acetate of lead. Litmus is reddened by this acid. It destroys life, and extinguishes flame, but is not insalubrious to breathe, when much diluted with air.

Carbonic acid is very antiseptic. When concentrated in water, it is grateful to the stomach. Potassium burns in this gas, absorbing oxygen and precipitating carbon. Plants probably absorb it, retain its carbon, and give out its oxygen. The respiration of animals tends to compensate this change, by carbonizing the oxygen of the air.

Carbonic acid is much heavier than atmospheric air, its specific gravity being 1.5277.

172. EXPERIMENTAL ILLUSTRATIONS.

Evolution of the gas shown—also its property of extinguishing a candle.—That it differs from nitrogen, is rendered evident by means of lime-water. Litmus, reddened by carbonated water—colour restored by boiling.

Analysis of mixtures, containing the gas, by means of the sliding rod eudiometer, with lime-water.

173. *Apparatus for showing some of the Distinguishing Properties of Carbonic Acid Gas.*

Having introduced into the three necked bottle, represented in this figure, one or two ounces of carbonate of ammonia, add about half as much nitrosonitric acid. An active effervescence will ensue, arising from the expulsion of the carbonic acid from the ammonia, by the stronger affinity of the nitric acid. At the same time, sufficient fume will be generated to make it evident, how far the vessels are occupied by the gas, to the exclusion of atmospheric air. By these means the movements of the carbonic acid gas will be recognised, as ascending to the upper vessel, it will fill, and finally overflow this vessel, through the crevice, between the brim and cover.

The cover being removed, a lighted candle will cease to burn, when lowered into the fume, indicating the space occupied by the gas. This space will comprise the whole cavity of the vessel, so long as the aperture, A, is closed; but, on removing the cork from this aperture, the gas will flow out, and the stream marked by the accompanying fume, will be seen descending towards the table, and will extinguish the flame of a candle if made to encounter it; or, it may be received into a mug, so as to arrest the combustion of a taper introduced into it, or upon which the contents of the mug may be poured.

Under these circumstances, a taper will burn any where within the vessel, V, if it be not below the aperture, A, above which the gas is not now seen to extend itself. But if one of the orifices of the bottle be opened, the carbonic acid will be found entirely to desert the upper vessel.

It will thus be made evident, that this gas, from its greater specific gravity, has, in the atmosphere, some of the habitudes of liquids; while its incapacity to support combustion, will be demonstrated.

The specific gravity of carbonic acid, being rather more than one-half greater than that of atmospheric air, it does not speedily leave any cavity in which it may be introduced. It is on this account that persons often perish on entering wells. This gas may be displaced from such situations, by mechanical agitation, by means of any bulky body alternately raised and depressed quickly. Any very inflammable matter, lowered while in a state of inflammation, as a cloth dipped in alcohol or oil of turpentine, would dislodge the gas if not let down into it so precipitately as to be extinguished. The firing of guns into the well, might be useful. Moistened gunpowder, in the same state as in the squibs made by boys, might be worthy of trial. An ounce of gunpowder might be spread over the bottom of a bucket, lowered into the well, and ignited by letting a squib, burning coal, or red hot iron, fall into it.

174. IMPREGNATION OF WATER WITH CARBONIC ACID.

The process by which water is impregnated with carbonic acid, may be easily understood from this engraving.

A condenser, A, is fastened at bottom, into a block of brass, which is furnished with a conical brass screw, by means of which it is easily attached firmly to the floor. In this brass block are cavities for the two valves, one opening inwards from the pipe, B, the other outwards, towards the pipe, C. The pipe, B, communicates with the self-regulating reservoir.

The gas which the condenser draws in from the reservoir, is forced through the other pipe into a strong copper vessel, in which the water is situated, and which is represented, in the figure, as if the front part were removed in order to expose the inside to inspection.

If due care be taken to expel all the air in the vessel before the impregnation is commenced, the water will take up as many times its bulk of gas, as the pressure employed exceeds that of the atmosphere.

When duly saturated, the water may be withdrawn at pleasure, by means of the syphon, D, of which one leg descends from the vertex of of the vessel, to the bottom, while the other is conveniently situated for filling a goblet.

OF OXALIC ACID.

Latterly oxalic acid, long known as a product of vegetation, has been found to belong to the compounds of carbon with oxygen; and still more lately croconic and mellitic acid have been added to this class. Yet when the necessity of water to the existence of these acids is taken into view, it appears to me questionable if they may not be considered as acids, with a double radical consisting of hydrogen as well as carbon.

Oxalic acid may be obtained from the common sorrel, *Rumex acetosa*, or from the wood sorrel, *Oxalis acetosella*, from which it derives its name. In these plants it exists in the state of binoxalate of potash. It may also be procured by the reaction of one part of sugar, with six of nitric acid. The weight of the acid obtained is equal to three-eighths of the materials. Wood, glue, silk, or hair, may be substituted for sugar in this process; but when these substances are used, the product is impure. Next to sugar, starch and molasses are probably the best materials. Dr. Thomson states that oxalic acid may be procured by digesting shavings of wood in a solution of caustic potash, at a heat considerably above that of boiling water.

Of the Properties of Oxalic Acid.

Oxalic acid is extremely sour, and one grain in a half pint of water is sufficient to redden litmus distinctly. It cannot exist uncombined with water or some other base. The atomic composition of this acid would authorize us to consider it as a binary compound of carbonic acid and carbonic oxide. In every atom of oxalic acid in its appropriate crystalline form, there are three atoms of water. When these crystals are exposed to an unusually dry atmosphere, or to a temperature of 80°, a partial efflorescence ensues; and if the heat be raised to 212°, they part with two atoms of water, which they recover on exposure to the air after cooling. When heated to 300°, oxalic acid is decomposed.

Oxalic acid is an energetic poison. The best antidotes for it are magnesia, or the calcareous carbonates in the pulverulent form; especially chalk. When oxalic acid meets with either of these bodies, an insoluble and comparatively inert oxalate is formed.

With chlorohydric acid oxalic acid forms a crystalline compound called chloroxalic acid, which may be obtained by exposing acetic acid to the rays of the sun in a vessel filled with chlorine. Oxalic acid is soluble in water and alcohol.

OF MELLITIC ACID.

Mellitic acid is obtained in crystals from a very rare mineral called the honey stone, which is a mellitate of alumine. This acid is soluble in water and in alcohol, and has a sour taste.

OF CROCONIC ACID.

Croconic acid may be procured in yellow crystals, from the croconate of potash, which is generated in the process for procuring potassium by means of carbon. It is inodorous, has an acid and astringent taste, and reddens litmus.

The oxalic, mellitic, and croconic acids, resemble vegetable acids so much, that they are usually classed with them, although, excepting oxalic acid, they are not vegetable products.

OF THE COMPOUNDS OF CHLORINE WITH CARBON AND OXYGEN.

There are two compounds consisting of chlorine, oxygen, and carbon. To one of these which has been recently discovered, the name of chloral has been given, to the other, that of chlorocarbonic or chloroxycarbonic acid. The latter name is preferable, as the other would convey the idea of an acid made solely by the union of chlorine with carbon.

OF CHLORAL.

When chlorine is passed through alcohol, which consists of hydrogen, oxygen, and carbon, one portion combines with hydrogen, forming chlorohydric acid, while another combines with oxygen and carbon, forming a chloral.

Chloral is described as a colourless transparent liquid with a pungent odour. Its specific gravity is 1.502. It boils at 201° and may be distilled unchanged. With water it forms a white crystalline mass, apparently a hydrate.

Chloral consists of nine atoms of carbon, six of chlorine, and four of oxygen.

OF CHLOROXYCARBONIC ACID.

When equal volumes of dry chlorine and carbonic oxide gas are mingled, and exposed to the solar rays, they combine and condense into one volume of a colourless acid gas, to which the name of chloroxycarbonic acid has been given, as above mentioned. It is exceedingly offensive to the eyes and to the organs of respiration. It reddens litmus paper, and with ammonia forms a white salt. By contact with water, a reciprocal decomposition ensues, and chlorohydric and carbonic acids are produced. It consists of one atom of chlorine, and one atom of carbonic oxide.

OF THE COMPOUNDS OF CHLORINE WITH CARBON.

Chlorine forms four compounds with carbon. The dichloride is a white crystalline inflammable solid endowed with a peculiar odour, resembling that of spermaceti. At 250° it sublimes in crystals. It is fusible by heat, and boils at a temperature between 350° and 450°. The dichloride consists of one atom of chlorine and two of carbon.

The protochloride is obtained by passing the perchloride in vapour through a red hot porcelain tube. The perchloride is decomposed into the protochloride and chlorine. The protochloride is a transparent colourless liquid, with a specific gravity of 1.4875. It is composed of one atom of chlorine and one of carbon.

When the liquid produced by the union of chlorine and olefiant gas, usually called chloric ether,* is exposed to the sun, in contact with a sufficient quantity of chlorine, the perchloride of carbon is produced. It is a friable, colourless, transparent, crystalline body, nearly tasteless, and resembling camphor in smell. While exposed to the flame of a spirit lamp, it burns with a red flame, but the combustion ceases as soon as the lamp is removed. It melts at 320°, and at 360°, is converted into vapour which may be condensed without decomposition. It is nearly twice as heavy as water. The perchloride of carbon consists of three atoms of chlorine and two atoms of carbon.

All the above described chlorides are insoluble in water, acids, or alkalies, but are soluble in oils, alcohol, and ether. When chloral is boiled in a solution of potash, a decomposition ensues, and a chloride of carbon is evolved in vapour, and may be condensed in a receiver. This chloride is a colourless transparent liquid, with an odour similar to that of chloric ether. Its specific gravity is 1.48. This chloride consists of five atoms of chlorine and four of carbon.

OF THE BROMIDE OF CARBON.

When bromine is brought in contact with half its weight of periodide of carbon, heat is evolved, a decomposition ensues, and bromides of iodine and carbon are formed. The bromide of carbon is a volatile, colourless liquid, of a sweet taste, and an etherial odour.

OF THE IODIDES OF CARBON.

The protiodide of carbon, is a liquid in properties strongly resembling the bromide of carbon. The periodide appears under the form of yellow crystalline scales, which have a sweet taste, a strong aromatic smell resembling that of saffron, and are heavier than water.

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* See page 239.

OF THE BISULPHIDE OF CARBON, GENERALLY CALLED BISULPHURET OF CARBON.

The bisulphide of carbon is obtained by passing the vapour of sulphur over charcoal heated to incandescence in a porcelain tube. It is a transparent, colourless, volatile liquid, possessing an acrid taste, and a peculiar nauseous smell. Its specific gravity is 1.272. It boils at 105°, and does not freeze at — 60°. At a temperature a little above the boiling point of mercury, it inflames. When the bulb of a spirit thermometer, wrapped in lint imbued with this liquid, was placed within a receiver, and the air withdrawn, the temperature fell to — 82°.

Dr. Thompson supposes, that the solid mass obtained by washing the nitre out from gunpowder, is probably a solid sulphide of carbon.

OF XANTHOHYDRIC ACID AND XANTHOGEN.

Mr. Zeise discovered, that when the bisulphide of carbon is agitated with a solution of pure potash in alcohol, cooled to 32°, acicular crystals are deposited. These crystals are composed of potash united to an acid, to which Mr. Zeise has given the name of hydroxanthic. According to the nomenclature which I have adopted, it should be called xanthohydric acid. In order to procure this acid, the xanthohydrate of potash, obtained by the process above described, is to be exposed to the action of sulphuric acid, which, from its superior affinity, unites with the potash, and liberates xanthohydric acid. This acid is an oleaginous, colourless, inflammable liquid, heavier than water, of which the taste is at first sour, subsequently astringent and bitter; and the odour strong and peculiar. Litmus is reddened when exposed to its action. Mr. Zeise supposes this acid to consist of hydrogen, and a compound of carbon and sulphur, which he calls xanthogen, and which in this acid plays the same part as cyanogen in prussic or cyanhydric acid. He supposes that this acid, when presented to certain metallic oxides, is resolved into water, and a xanthide of the metal employed.

OF THE COMPOUNDS OF CARBON WITH HYDROGEN.

Carbon and hydrogen are in opposite extremes, as respects their susceptibility of the aeriform state. Per se, carbon is probably more difficult of volatilization by heat, than any other substance in nature. Hydrogen, on the other hand, as far as our experience goes, is not susceptible of condensation, even into the non-elastic state of fluidity. There is, however, a powerful affinity between these substances; and hence, when a compound which contains them, is subjected to heat, they are made to combine in various proportions, according to the intensity of the ignition, and the influence exercised by the nitrogen, or oxygen, which may have been associated with them.

Properties of the Compounds of Carbon with Hydrogen.

In general, these substances are distinguished by inflammability.

In the gaseous state they constitute, when ignited, the flame of candles, lamps, gas lights, and culinary fires. They are incapable of supporting life, but are not actively noxious to the organs of respiration, when diluted with the air.

Means of obtaining the Gaseous Compounds of Carbon with Hydrogen.

They are obtained by the destructive distillation of bituminous coal, wood, oil, tar, and other inflammable substances.

The illuminating power of these various forms of gas, seems to be in proportion to the quantity of carbon condensed into a volume, provided there be oxygen enough to consume it; but, otherwise, the excess of carbon renders the flame smoky. Hence the greater brilliancy of small flames, or those excited by a current of air, as in the Argand lamp.

The same flame which in common air is unpleasantly fuliginous, transferred to oxygen gas, displays a perfect brilliancy.

The known compounds of carbon with hydrogen, are numerous and complicated; and yet it is probable that many exist in nature, or may be produced by art, with which we are at present unacquainted. We have had occasion to state, page 217, that where bodies have, in the same volume, the same number of atoms of each of their ingredients, and yet differ in their properties, they are said to be isomeric, from ίσος equal, μερος part. Compounds in which the constituents are in the same ratio, but in which the resulting volumes exist in different degrees of condensation, are said to be polymeric with respect to each other, from πολυς many, μερος part. The last term is applied to a class of the compounds of carbon with hydrogen, in all of which these elements exist in the same ratio of atom for atom; yet from some difference in the mode of aggregation, or, as I believe, in the extent and modes of their association with heat, light, and electricity, their degree of condensation when in the aëriform state, and their properties in other respects, are quite different.

We have then two groups of the carburets of hydrogen, in one of which diversity of properties is attended by a corresponding diversity in the ratio of the carbon to the hydrogen, while in the other this ratio is uniform, although the properties and resulting volumes in the aëriform state, differ.

In the first group, there are four compounds.

1. Fire damp, also called carburetted hydrogen, or light carburetted hydrogen, consisting of two volumes or atoms of hydrogen, with one volume or atom of carbon.

2. The compound above alluded to, in all the varieties of which there are as many atoms of one element as of the other, and for which Dr. Thomson proposes the appellation of carbohydrogen as a generic appellation.

3. Bicarburet of hydrogen, in which two atoms of carbon are united with one of hydrogen.

4. The tritocarburet of hydrogen, or naphthaline, in which three atoms of carbon are combined with one atom of hydrogen.

The second group, which is subordinate to the first, being formed in fact by the ramifications of carbohydrogen, one of its branches, according to Dr. Thomson, comprises several varieties, which he designates and describes as follows:—

1st. Carbohydrogen, which I would call protocarbohydrogen, consisting of a volume of carbon, and a volume of hydrogen, in one volume. This compound has, however, never been isolated, its existence is inferred.

2d. Deutocarbohydrogen, or olefiant gas, consisting of two volumes of carbon and two of hydrogen, condensed into one volume.

3d. Tritocarbohydrogen, consisting of three volumes of carbon, and three of hydrogen, condensed into one volume. This is by Dr. Thomson considered as constituting the gas evolved from oil, which was, by Dalton, called superolefiant gas.

4th. Tetartocarbohydrogen, consisting of four volumes of carbon, and four volumes of hydrogen, condensed into one volume.

5th. Hexacarbohydrogen, containing, according to Thomson, six volumes of each element, condensed into one volume.

To the gaseous bodies of this group, I might add two others; one, a liquid, known as oil of wine, being the efficient principle in Hoffmann's anodyne, the other as a substance evolved from tar, which has lately attracted attention under the name of paraffin, from parum affinis, or little connected, as it appears to be very little disposed to unite with other substances.

OF FIRE DAMP.

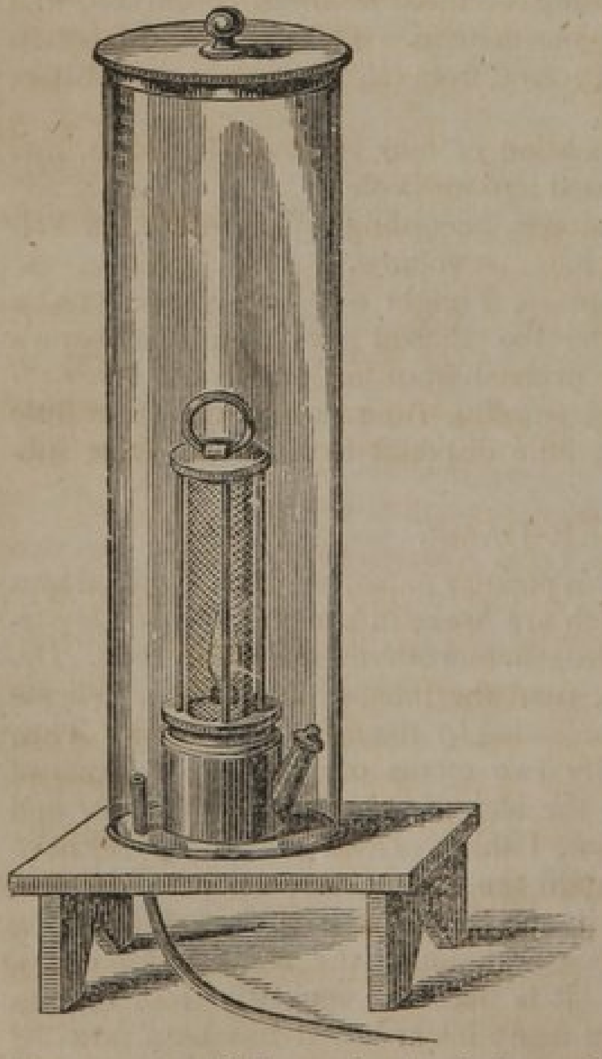
The substance distinguished by this popular name, has been dignified by a variety of appellations, among which are *heavy* inflammable air, *light* carburetted hydrogen, carburetted hydrogen, and bihydroguret of carbon. Dr. Thomson has, in some instances, used the monosyllable di, to indicate proportions, the inverse of those indicated by the monosyllable bi. Thus bichloride of carbon, would signify two atoms of chlorine, and one of carbon, while dichloride conveys the idea of two atoms of carbon, and one of chlorine. Consistently, then, I think, Dr. Thomson should have called this gas, a dicarburet of hydrogen, as the proportions of its constituents are the inverse of those in the bicarburet. This gas has long been known to miners of bituminous coal, under the name of fire damp, as one of their greatest enemies. It is liberated copiously from cavities in the coal, in which, no doubt, in many instances, it has been pent for ages. It is also evolved from the mud of stagnant waters, and is occasionally emitted from fissures in the earth. There is no good mode of forming it artificially. It is a colourless gas, of course, irrespirable, but having more than a negative influence in destroying life. Its specific gravity is 0.5555.

175. OF THE SAFETY LAMP.

In the account above given, of dicarburetted hydrogen, it was mentioned, that it was in mines a source of injury. When existing in the air beyond a certain proportion, it explodes on coming into contact with the flame of a lamp or candle. Hence, as artificial light is necessary, in mines inaccessible to the light of day, the use of candles or lamps, in the ordinary way, has been frequently destructive to the workmen. It had, of course, been the cause of great anxiety to them, and embarrassment to the proprietors of the mines.

In order to avoid the risk attending the use of lamps or candles in mining, a steel mill had been resorted to, in which the rapid revolution of a steel wheel, against a flint, was made to produce a succession of sparks, and of course a feeble light. I believe that the security afforded by this invention was imperfect, and the light insufficient. Explosions have been more frequent in the English mines, of late years, probably in consequence of the greater extent and depth to which they are excavated. While under the painful impression made by some recent catastrophes of this nature, in which many miners had been killed or mutilated, Sir H. Davy exerted himself to discover means of sustaining flame safely, within explosive gaseous mixtures. He soon ascertained that his object might be effected, by enclosing the flame in a cage of wire gauze, so as to allow of no communication with the surrounding medium, which does not take place through the meshes of the gauze. Owing to the conducting power of the wire, the mixture cannot pass through meshes in a state of combustion. Of course the inflammation is confined within the wire gauze.

The method in which I illustrate the operation of the safety lamp, may be easily comprehended from the following figure.



The lamp is seen within a large glass cylinder upon a stool. The cylinder is closely covered by a lid, which will not permit the passage of air between it and the cylinder, and which is so light as to be easily blown off. Excepting the cage alluded to above, the safety lamp differs not materially from those which are ordinarily used. The upper surface of the receptacle, for the oil, forms the bottom of the cage, which is so closely fitted to it, and so well closed every where, as to allow air to have access to the flame only through the meshes of the wire gauze. The cage is enclosed within three iron rods, surmounted by a cap, to which a ring for holding the lamp is attached, as seen in the drawing.

If while the lamp is burning, as represented in the figure, hydrogen, either pure or carburetted, be allowed, by means of the pipe, to enter the glass cylinder, so as to form with the air in it an explosive mixture, there will, nevertheless, be no explosion. It will be found that as the quantity of inflammable gas increases, the flame of the lamp enlarges until it reaches the wire gauze, where it burns more or less actively, accordingly as the supply of atmospheric air is greater or less. It will under these circumstances, often appear as if the combustion had ceased, but on increasing the proportion of atmospheric air, the flame will gradually contract, and finally settle upon the wick, which will burn as at first, when the supply of hydrogen ceases.

If the cage be removed from the lamp, and the experiment repeated in all other respects, as at first, an explosion will ensue, as soon as a sufficient quantity of hydrogen is allowed to enter the cylinder.

OF OLEFIANT GAS,

Or Deutocarbohydrogen; called also, Carburetted Hydrogen, and Hydroguret of Carbon.

This gas received its name in consequence of its being condensed with chlorine, into a liquid, having an oleaginous consistency, although otherwise unlike an oil. It was discovered in the year 1796. It may be obtained by passing the vapour of alcohol through a red hot porcelain tube, or by subjecting a mixture of five parts of sulphuric acid with one of alcohol, to heat in a glass retort. It is invisible, and possesses, like other gases, the mechanical properties of atmospheric air. Its specific gravity is 0.9722. When drawn into the lungs it produces asphyxia. It burns with great splendour, and detonates with oxygen with such violence, that without some precautions it is dangerous to analyze it by the usual processes. I have had several eudiometers broken by it, but have latterly avoided that evil, by exploding the mixture in a rarefied state, into which it is easily brought in some of the instruments which I employ.

The analysis may be performed in the volumescope for analysing the air by means of hydrogen, with a degree of accuracy sufficient for the purpose of illustration. Four volumes of oxygen should be added to one of the gas. The ignition being effected as already described in the case of pure hydrogen, it will be seen that the five volumes are reduced to less than three, and that by the introduction of lime water, these three may be reduced to one residual volume of oxygen. The reason why the residual gas is less than three volumes, is, that the carbonic acid is partially absorbed by the water. As the gas contains in one volume, two volumes of hydrogen, and two of carbon vapour, it will, for the latter, require two volumes, for the former, one volume of oxygen. Of course the hydrogen and the oxygen which combines with it will be condensed, so that after the explosion, unless so far as absorbed by the water, two volumes of carbonic acid will remain mingled with the excess of oxygen.

In the Appendix I shall give an account of some instruments, by which this and other inflammable compounds of carbon may be analysed with accuracy.

176. EXPERIMENTAL ILLUSTRATIONS.

Cork, cotton seed, caoutchouc, nuts, introduced in small quantities into a gun barrel, of which the butt-end has been heated to a bright red heat. Brilliant jet of flame proceeds from the touch-hole. Inflammation of gas extricated by distillation from oil or bituminous coal. Also of olefiant gas. Olefiant gas, mixed with oxygen gas, and exploded in a sliding rod eudiometer. Residue renders lime-water milky.

177. OF GAS LIGHTING.

The gaseous compounds of carbon and hydrogen, have been much applied to the purpose of illumination.

The gas, for this purpose, is obtained by the destructive distillation of bituminous coal, oil, or resinous substances, and is received in gasometers, whence it is distributed through pipes to the burners. See page 106, article 105.

One of the greatest obstacles to the general employment of gas lights, as a substitute for candles and lamps, is the necessity of pipes leading from gasometers, to all situations where the light is wanted. The condensation of the gas into strong metallic receivers, has been resorted to in order to obviate this difficulty. This process may be illustrated by means of the apparatus described for the impregnation of water with carbonic acid.

It is only necessary to exchange the communication with the self-regulating reservoir of carbonic acid gas, for a similar communication with a reservoir of olefiant gas, and the copper vessel being first exhausted of air, to condense the gas into it. The syphon used for the efflux of the impregnated water, is replaced by a tube and cock, terminating in a capillary perforation. Through this, the gas may be allowed to escape in a proper quantity to produce a gas light when inflamed. It has, however, always appeared to me, that the expense of condensing the gas, and of procuring and transporting the receivers, would render this method of affording light, disadvantageous.

Latterly, the loss of gaseous matter, by condensation, has been found so great as to render the process unprofitable.

OF SOME VARIETIES OF CARBOHYDROGEN, AND OF THE BICARBURET OF HYDROGEN.

Tetartocarbohydrogen, hexacarbohydrogen, and bicarburet of hydrogen, were all obtained by Mr. Farraday, from a liquid which was deposited from oil gas, when condensed into vessels under great pressure for the purposes of illumination.

On subjecting the matter deposited as above described, to a very gentle heat, tetartocarbohydrogen is separated in the form of a transparent colourless inflammable gas, with a specific gravity of 1.9444. When cooled to zero, it condenses into a transparent colourless liquid of the specific gravity of 0.627, being the lightest liquid known.

When the liquid remaining, after the extrication of the tetartocarbohydrogen is heated, vapour is evolved, and the boiling point continually rises until the temperature of 176° is attained. Between this temperature and 190°, a large portion distils in the form of a liquid. When this liquid is cooled to zero, it separates into two compounds, one of which becomes solid, while the other continues liquid. The liquid is the compound, which Dr. Thomson calls hexacarbohydrogen, though its composition does not appear to have been well ascertained. It is inflammable, soluble in alcohol, and boils at 176°. The solid compound is the bicarburet of hydrogen. It is at ordinary temperatures a colourless, transparent, volatile liquid, which boils at 186°, and has a specific gravity of 0.85. At 32°, it crystallizes, and when cooled to zero, acquires a consistency like that of loaf sugar.

OF NAPHTHALINE.

Naphthaline is obtained by subjecting to distillation the tar which is formed during the decomposition of bituminous coal. The first products are ammonia, water, and the liquid called coal naphtha; but towards the close of the process naphthaline is obtained.

Naphthaline is a white crystalline substance, with an aromatic smell, and a pungent disagreeable taste.

There are other compounds of carbon and hydrogen; native naphtha, for instance, and oil of turpentine; also many of the essential oils derived from vegetables. Of some of these I shall elsewhere treat; to notice them all would be inconsistent with the limits prescribed to this work.

OF THE COMPOUNDS FORMED BY CHLORINE WITH CARBON AND HYDROGEN.

It has already been stated that olefiant gas received its name in consequence of its being condensible with chlorine into a liquid of an oleaginous consistency. To this liquid the name of chloric ether, has been improperly given, as it indicates a dependency on chloric acid for its constitution or generation, contrary to the fact. Dr. Bache has proposed for it the name of chlorine ether, of which I approve.

Chlorine ether is limpid and colourless, like water, has an agreeable smell, and a peculiar sweetish agreeable taste. Latterly it has been used with advantage in medicine. It consists of one atom of chlorine, and one atom of olefiant gas.

Chlorine combines with several other of the polymeric varieties of carbohydrogen, forming with them compounds of different properties. It also produces two compounds by combining with the bicarburet of hydrogen; one solid, the other liquid.

OF THE BICARBURET OF NITROGEN, OR CYANOGEN.

Cyanogen ranks next to iodine among electronegative bodies, is included among the halogen bodies of Berzelius, and in the basacigen class by me. Being a compound, I have deferred treating of it until now. See pages 98, and 125.

Of the Means of obtaining Cyanogen.

It is obtained by subjecting pure and dry bicyanide of mercury to a low red heat in a porcelain retort, or coated glass tube, and receiving the product over mercury.

Of the Properties of Cyanogen.

Cyanogen is a colourless, transparent, irrespirable gas, which painfully affects the nose and eyes, and has a strong and peculiar odour. Under a pressure of four atmospheres, it becomes a colourless liquid, lighter than water. It may likewise be liquefied, or even solidified by cold. It is characterized by burning with a beautiful violet flame.

It is decomposed by the electric spark, or by an incandescent iron into its constituents, carbon and nitrogen. Alcohol dissolves twenty-three times, and water four and a half times its volume of cyanogen. In the course of a few days the solutions become discoloured, and a brown matter is deposited. The deposition from alcohol, has been found to contain carbon and nitrogen. After obtaining cyanogen from the bicyanide of mercury, a black residuum is found in the retort, which has been conceived to consist of carbon, with a less proportion of nitrogen than exists in cyanogen; but of late, this residuum, and the deposition from alcohol, have been supposed to be isomeric with cyanogen.

When ignited with a sufficient quantity of oxygen, a volume of cyanogen is converted into two of carbonic acid, and one of nitrogen, without condensation. Of course, as each volume of carbonic acid requires a volume of carbon vapour, there must exist two such volumes in one of cyanogen. Hence, as in the case of carbon and nitrogen, each volume represents an atom; cyanogen consists of

two atoms of carbon = 12
and one of nitrogen = 14
—
and its equivalent is 26

OF A NEW COMPOUND OF CARBON WITH NITROGEN.

Mr. Liebig alleges that he has discovered a new compound of carbon and nitrogen, which, if his statements are correct, must probably be considered as one of the basacigen class. It is composed of three atoms of carbon, and five of nitrogen. It was obtained in the pulverulent form, is insoluble in water, and decomposable at a red heat, into cyanogen and nitrogen.

OF THE NOMENCLATURE OF THE COMPOUNDS OF CYANOGEN.

When Prussian blue is digested with a solution of potash, and the resulting solution is filtered while hot, by refrigeration, yellow crystals are deposited, called ferroprussiate or ferrocyanate of potash under the idea that they consist of an acid composed of iron, cyanogen, and hydrogen, in union with an oxide of potassium. Berzelius considers these yellow crystals as a double salt, formed by a "*cyanure*" of iron, and a "*cyanure*" of potassium. The name of this double salt, agreeably to his nomenclature, is "*cyanure ferrosopotassique.*" He alleges the existence of another compound containing the same elements, in which the proportion of cyanogen to that in the first mentioned compound, is as 1½ to 1, and for which his name is "*cyanure ferricopotassique.*"

The existence of these combinations constitutes one instance among many, in which, according to Berzelius, two compounds, each having the same halogen body as an ingredient, form by their union a double salt.

Agreeably to his system, we have double "*chlorures, bromures, fluorures,*" and "*iodures,*" as well as double "*cyanures.*"

Some years ago, Bornsdorf, a skilful and sagacious German chemist, assailed this classification of Berzelius, by showing that some of the "*chlorures*" of the double salts exercised an alkaline, others an acid reaction; and that consequently the double "*chlorures,*" so called by Berzelius, were really simple salts, in which one chlorure acted the part of an acid, another that of a base. Merely on contemplating the facts of the case, as stated by Berzelius, without having any knowledge of Bornsdorf's experiments and conclusions, the conviction arose in my mind that the double haloid salts, of that great chemist, should be considered as compounded of acids and bases. I cannot conceive wherefore Bornsdorf thought it necessary to show that there was, in one of the ingredients of a double "chlorure," an acid, in the other, an alkaline reaction, in order to prove the former to act as an acid, and the latter as a base. It appears to me, as I have stated more fully in my letter on the Berzelian nomenclature, that excepting in the case of the alkalies and alkaline earths, these properties have not been deemed essential to oxacids and oxibases, and that of course they ought not to be required in acids or bases formed by any other of the basacigen class. Agreeably to the definitions of acids and bases, given page 126, and in my letter above mentioned, the "*cyanure*" of iron, being electronegative as contrasted with the "*cyanure*" of potassium, the one must be deemed a cyanobase, the other a cyanacid.

Berzelius extends to all oxides a method of distinguishing their degrees of oxidation, which has been adopted by other chemists, only in the case of the oxides of nitrogen or that of carbon, although generally employed by them in respect to the oxacids. Thus in the Berzelian nomenclature ferrous oxide is the protoxide of iron, ferric oxide the deutoxide, from ferrum, the Latin for iron. He applies this mode of distinction to all the binary compounds of his halogen and amphigen bodies. Thus, we have antimonious chloride, and antimonic chloride; signifying that the latter contains a larger proportion of chlorine than the former. Again: phosphorous bromide, and phosphoric bromide; phosphorous iodide, and phosphoric iodide; in which case, as in the other, the termination in ic, indicates a larger proportion of the electronegative ingredient. But the termination in ide, is only resorted to by him, where the radical is electronegative; that is, in other words, when its oxides go to the positive pole. When the radical is one of those bodies which, when oxidized, go to the negative pole, the termination in *ure* is resorted to; hence, ferrous and ferric "*cyanures*," and ferrous and ferric "*chlorures*." I object to this complicated nomenclature, as founded on the error of not allowing those characteristics of acids and bases, which have been acted upon by chemists in general, and by Berzelius himself, in the case of oxacids and oxibases, to extend to the binary compounds formed by the bodies of the halogen class.

I consider the yellow salt in question, as consisting of a cyanacid containing an atom of cyanogen and an atom of iron, and which I would call cyanoferrous acid united to a cyanobase of potassium, consisting of one atom of cyanogen, and one atom of potassium, and forming a cyanoferrite of potassium. The double salt, consisting of the same elements, but containing both in the acid and base, half an atom more of cyanogen, should, by analogy with the oxacids, have the termination in ic, and of course be designated as cyanoferric acid, and the salts which it forms, as cyanoferrates.

OF THE CYANIC, CYANURIC, AND FULMINIC ACIDS.

An atom of cyanogen combined with an atom of oxygen, forms cyanic acid, which may be obtained in union with potash, by igniting peroxide of manganese with ferroprussiate of potash, or cyanoferrite of potassium, being the salt alluded to above, as consisting of cyanogen, iron, and potassium. The cyanogen and potassium are converted, by the excess of oxygen in the manganese, into cyanic acid and potash, which unite; forming a cyanate of potash. Cyanic acid cannot, however, be obtained from the cyanates, in consequence of its extreme susceptibility of decomposition.

A crystalline substance may be procured from human urine, which is known by the name of urea. It consists of carbon, nitrogen, oxygen, and hydrogen, in the proportion to form one atom of cyanic acid, one atom of ammonia, and one atom of water. When urea is subjected to heat, ammonia escapes, and an acid remains, which was supposed to consist of one atom of cyanogen, and two atoms of oxygen. It was consequently called *cyanic acid;* but it has been recently ascertained by Wohler, and Leibig, that it consists of the elements of the above described cyanic acid, (then called cyanous,) chemically united to the elements of water; an atom of hydrogen, and an additional atom of oxygen, entering into the composition, not as water, but as essential constituents. Under these impressions, a new name, "cyanuric," was given to it. This acid is solid, fixed, inodorous, and nearly tasteless. By combining with two atoms of water, as water of crystallization, it becomes capable of forming large crystals.

When anhydrous cyanuric acid is exposed, in a glass retort, to a low red heat, the extricated vapours being collected in a receiver refrigerated by a freezing mixture, hydrous cyanic acid is obtained. This acid, and cyanuric acid, consist of the same elements in the same proportion, but possess different properties and atomic weights. Hydrous cyanic acid is a colourless, volatile liquid, possessing a penetrating odour resembling that of acetic acid. It vesicates the skin when applied to it, exciting intense pain. Its vapour reddens litmus paper, is inflammable, and so pungent as to produce tears, and cause severe pain in the hands. Cyanuric acid is comparatively inert in these respects, but is far less susceptible of decomposition, as it is not decomposed by solution in boiling nitric or sulphuric acid, while hydrous cyanic acid is decomposed by the addition of water.

Hydrous cyanic acid, at the ordinary temperature of the air, spontaneously undergoes an explosive decomposition, attended by an evolution of heat, and is converted into a solid mass of dazzling whiteness. This mass consists of a variety of cyanuric acid, which differs from that above described, in being insoluble in water or nitric acid, and in being decomposed by sulphuric acid. It is, therefore, to be considered as presenting a case of isomerism.

It is remarkable, that although cyanuric acid consists of the same elements in the same proportion as hydrous cyanic acid, it carries the hydrogen and oxygen which exist in it, in the proportion to form water, into every combination which it forms; while the hydrous cyanic acid, in combining with bases, separates from the water; which must be considered, when in union with this acid, as acting as a base.

To bodies which, although they contain the same elements in the same ratio, yet hold them differently associated, so that in reacting with other agents, they are resolved into, or form compounds differing in composition, the term metameric has been applied. Thus cyanic, and cyanuric acid, are said to be metameric with regard to each other.

Another compound of cyanogen with oxygen, exists in the fulminating mercury of Howard, or the analogous fulminating silver of Descotils. Liebig ascertained these compounds to contain an acid common to both, which he called fulminic acid; but which, agreeably to the analysis made by him and Gay-Lussac, was identified in composition with cyanic acid. Yet, as the latter would not produce fulminating compounds, and differed in its other properties, these acids have been considered as affording another instance of isomerism. Mr. Edmund Davy, however, alleges the existence of nitrogen and hydrogen in fulminic acid.

Fulminic acid is a colourless, transparent, volatile liquid, which reddens litmus, and produces a taste at first sweet, afterwards astringent and disagreeable. Its fumes have a pungent and disagreeable odour, and produce headach when incautiously inhaled.

Besides these acids, M. Liebig has recently discovered another, which is polymeric with regard to cyanuric acid, as it consists of the same elements in the same ratio, though twice as much of each enters into the composition of an atom.

OF THE CHLORIDES, BROMIDES, AND IODIDES OF CYANOGEN.

Chlorine forms two compounds with cyanogen, a protochloride and a perchloride. The protochloride is a colourless, fetid gas, which may be liquefied, and even solidified by cold. In common with several other compounds of cyanogen, it possesses, even when gaseous, the singular property of producing pain by contact with the skin. The perchloride is a white crystalline substance, with an odour resembling that of mice.

Bromine and iodine both form with cyanogen, crystalline compounds. The chlorides and bromides of cyanogen, are energetic poisons.

OF SULPHOCYANOGEN.

It has been stated that the yellow salt usually known as ferroprussiate of potash, is by Berzelius considered, when free from water, as consisting of cyanogen, iron, and potassium; also that I consider it as a cyanoferrite of the cyanobase of potassium. When this salt, desiccated to efflorescence and finely pulverized, is mingled with flowers of sulphur and exposed to a red heat in a porcelain crucible, the iron is displaced; the sulphur and cyanogen uniting, form a compound called sulphocyanogen, and this uniting with the potassium, constitutes a sulphocyanide.

Sulphocyanogen has been isolated by passing chlorine through a solution of sulphocyanide of potassium, or by subjecting that compound to nitric acid. Berzelius considers sulphocyanogen as one of his halogen bodies.

The intense blood red colour which it produces with iron, is the most striking property of sulphocyanogen, and has led to the impression that the sulphocyanide of iron may be the colouring matter of the blood.

Sulphocyanogen is solid, insoluble in water or alcohol, and may, in its anhydrous state, be sublimed without change. It is composed of one atom of cyanogen, and two atoms of sulphur.

Dr. Thomson states that another compound of sulphur and cyanogen exists, containing one atom of sulphur and two atoms of cyanogen. This compound may be obtained in transparent colourless crystals. It is volatile, possesses a strong smell, and is soluble in water. When applied to the tongue, even in a minute quantity, it produces intense pain; and the part touched remains red and painful for some time.

OF SULPHOCYANHYDRIC ACID.

This acid may be obtained from a solution of the sulphocyanide of potassium, by the addition of phosphoric acid. Water is decomposed, the oxygen unites with the potassium, forming potash, with which the phosphoric acid combines, and the hydrogen with the sulphocyanogen, forming sulphocyanhydric acid, which may be separated by distillation. This acid is liquid and colourless, has an acid taste, and potent odour. It becomes solid at 14°, and boils at 216°. It is composed of one atom of sulphocyanogen, and one atom of hydrogen.

OF CYANHYDRIC OR PRUSSIC ACID.

One atom of cyanogen, equivalent 26, with one atom of hydrogen, equivalent 1, forms one atom of cyanhydric acid, equivalent 27.

This acid has been detected in water distilled from bitter almonds, and from laurel leaves; also, from peach leaves or blossoms. Between the odour of these, and that of the acid, when dilute, it would be difficult to discriminate.

Laurel water has long been known as a poison. Water distilled from peach leaves, has been used to impart an agreeable flavour to food. Some peach leaf water, prepared by Mr. Wetherill, gave indications of cyanhydric acid, by producing a blue colour, with a solution of iron.

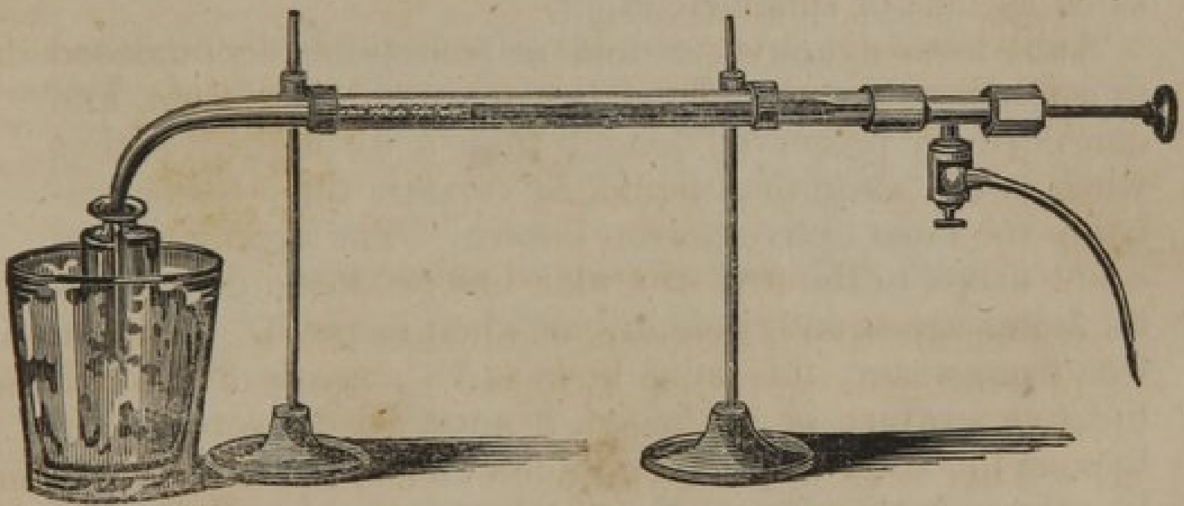
There have been instances, in which noyeau, a cordial made from the kernels of bitter almonds, has proved poisonous, from the presence of cyanhydric acid.

There is a salt consisting of two atoms of cyanogen, and one of mercury, called the bicyanide of mercury. When this salt is subjected to the action of chlorohydric acid, the chlorine forms a chloride with the mercury, while the hydrogen forms cyanhydric acid with the cyanogen.

It may be more conveniently obtained by impregnating with sulphydric acid a solution containing sixty grains of bicyanide of mercury for every ounce of water. The hydrogen unites with the cyanogen, while the sulphur precipitates with the metal. Any excess of the sulphydric acid is easily removed by the carbonate of lead. The apparatus for impregnation with sulphydric acid, has been described already, page 160.

The acid may be procured in its most concentrated form, by exposing the bicyanide in crystals, in a tube, to sulphydric acid gas, and employing a receiver surrounded by salt and snow, to condense the vapour evolved.

178. *Apparatus for the Evolution of Cyanhydric or Prussic Acid.*



Let a tube, three-fourths of an inch in bore, and about two feet in length, be bent at right angles, at about six inches distance from one end. Let the shorter portion be drawn out into a tapering form, with a bore not exceeding a tenth of an inch in diameter. Upon the larger orifice let a brass band be cemented, in which a female screw has been cut, so that a stuffing box, furnished with a corresponding male screw, may be easily fastened air-tight to the band, or removed when desirable. Through the stuffing box an iron rod passes, flattened like an oar at the end, which is within the tube when the stuffing box is in its place. There must likewise be a lateral aperture in the band communicating with the cavity of the tube, and furnished with a gallows screw. The main body of the tube is to be situated nearly level, yet a little inclined towards the curvature, so that the tapering extremity may descend nearly perpendicularly into a tall narrow phial surrounded by a freezing mixture. The horizontal portion of the tube near the bend should likewise be refrigerated. The apparatus being thus arranged, introduce a sufficient quantity of the bicyanide of mercury into the tube, and close it by inserting the stuffing box with its rod. In the next place, by means of the gallows screw, make a communication between the cavity of the tube, and a self-regulating reservoir of sulphydric acid. This gas must be allowed to pass into the tube very slowly, and meanwhile, by means of the rod, the bicyanide is to be stirred. Before long a portion of the cyanhydric acid will be seen in the narrow part of the tube. This serves to regulate the admission of the sulphydric acid, since, when the quantity passing into the tube is inadequate, the liquid will rise in the tube; when too great, it will be expelled from it. By these means, after a little while, all the bicyanide will be decomposed, and a corresponding quantity of acid collected in the refrigerated phial.

Of the Properties of Cyanhydric Acid.

Cyanhydric acid is a colourless liquid, which emits a powerful odour, resembling that of peach blossoms. When perfectly free from water, it is far more volatile than ether, as it boils at 79° F., and evaporates so rapidly, that one portion becomes frozen by the loss of the caloric which the other absorbs, in passing into the aeriform state. Its specific gravity is 0.7058, being nearly the same as that of sulphuric ether.

Anhydrous cyanhydric acid is sometimes decomposed in a few hours, especially if not protected from light, and can never be preserved longer than a fortnight. Either when in the state of a liquid, or vapour, this acid is probably the most active poison known. The application of a few drops to the arm of a man has produced death, and its fumes are equally deleterious when inspired. As when free from water, this acid boils at 79°, nearly 20° below the temperature of the blood, it must be converted into vapour too soon to produce its full effect. From a cavity like the ear, the pure acid must be ejected in vapour immediately. I am therefore under the impression that it is less effectual as a poison, when anhydrous, than when combined with one atom of water.

Upon one occasion, touching the ear of a rat confined in a glass jar, with a drop of the anhydrous acid, the animal, being obliged to breathe the vapour, died instantaneously with a slight sneezing. Yet upon another occasion I injected nearly half a drachm into the ear of a large dog without killing him. I afterwards killed him by injecting a like quantity into his nose. The acid employed was so pure as to freeze by its own evaporation.

The best remedy for it is an aqueous solution of chlorine, or where that is not to be had, ammonia.

Cyanhydric acid is sometimes employed in medicine, though in very small doses, and in a very diluted state.

It has been proposed to detect cyanhydric acid, in cases in which it may have been employed in poisoning, by subjecting the stomach and its contents to distillation with water, and testing the liquid product by copper or iron. I should place much reliance on the characteristic smell of the acid, which is that of peach blossoms, and which may be perceived, not only from the presence of the acid, but likewise from that of any of the cyanides, if subjected to the action of chlorohydric acid.

179. EXPERIMENTAL ILLUSTRATIONS.

The processes for the production both of the aqueous and anhydrous cyanhydric acid exhibited; also, the congelation of the latter by the cold arising from its own evaporation.

OF BORON.

By the addition of sulphuric acid to a saturated solution of biborate of soda (borax) in water, shining crystalline plates are precipitated, consisting of boric acid. From these crystals boron may be obtained either by the action of a powerful Voltaic series, or by first vitrifying them, then pulverizing finely the resulting glass, and afterwards heating the acid thus prepared, in contact with potassium.

180. *Improved Process for the Evolution of Boron from Boric Acid, by means of Potassium.*

By means of an apparatus represented by the annexed engraving, I have succeeded in evolving boron by the reaction of potassium with vitrified boric acid, in vacuo, without encountering the evil of any explosive action, to which the process, as heretofore conducted, in pleno, has been found liable.

A circular brass plate is prepared, like the plate of an air pump, so as to produce with any suitable receivers properly ground, an air-tight juncture. It is supported on the upper end of a hollow brass cylinder, B, with the bore of which it has a corresponding aperture. The brass cylinder is about three inches in diameter, and six inches in height, being inserted at its lower end into a block of wood as a basis. This cylinder receives below a screw, which supports a copper tube, C, of about two inches in diameter, so as to have its axis concentric with that of the cylinder, and to extend about four inches above the plate. The copper tube, thus supported, is closed at the upper termination by a cup of copper, of a shape nearly hemispherical, and soldered at the upper edge to the edge of the tube, so that the whole of the cavity of the cup is within that of the tube. Hence the bottom of the cup is accessible to any body not larger than the bore of the tube, without any communication arising between the cavity of the tube, and that of any receiver placed upon the plate, over the cup and tube, as in the figure.

Into the side of the cylinder supporting the plate, a valve cock is screwed, by means of which, and a flexible leaden tube, a communication with an air-pump is opened or discontinued at pleasure.

The cup being first covered with a portion of vitrified boric acid, as anhydrous as possible, and finely pulverized, the potassium is introduced, and afterwards covered with a further portion of the same acid. A large glass receiver is now to be placed on the plate, secured upon the plate by rods, A, A, concentric with the tube and cup, from the heat of which the glass is to be protected by a bright cylinder of sheet of brass, S, placed around it so as to be concentrical with the receiver and tube.

The apparatus being so far prepared, and the receiver exhausted by means of the air-pump, an incandescent iron is introduced through the bore of the tube, so as to touch the bottom of the copper cup. In a short time a reaction commences, which, aiding the influence of the hot iron, renders the cup and its contents red hot. A deep red flame appears throughout the mass, after which the reaction lessens, and the heat declines.

When the cup has become cold, the air is admitted into the receiver, and the contents are washed with water. If any of the acid has escaped decomposition, it may be removed by boiling the mass with a solution of potash or soda. After this treatment and due desiccation, a powder will remain, having the characteristic colour and properties of boron.

The additional valve cock represented in the figure, puts it into the power of the operator to introduce dry hydrogen for the purpose of more effectually removing atmospheric air, as described in the process for silicon.

Of the Properties of Boron.

Boron is of a dark olive colour, tasteless, inodorous, a nonconductor of electricity, and insoluble either in alcohol, ether, or oils. It is susceptible neither of fusion nor volatilization. When heated in the air to 600° F., it takes fire, and by uniting with oxygen, generates boric acid. Nevertheless only a portion of the boron is oxydated, the remainder being protected by a crust of fused boric acid. If this crust be removed by water, the boron will be found to have undergone a change similar to that produced in charcoal by an intensely high temperature. It is rendered harder, more difficult to ignite, and so much denser, that, although its specific gravity was before only 1.83, it now sinks rapidly in sulphuric acid of the specific gravity of 1.844. Before it has been ignited, boron is slightly soluble in water, and its solution, when evaporated to a certain point, forms a gelatinous mass, which, by complete desiccation, becomes opaque, and assumes the usual appearance of boron.

OF THE COMPOUND OF BORON WITH OXYGEN, CALLED BORACIC, OR MORE PROPERLY BORIC ACID.

The means of procuring this acid, have been mentioned in describing the process for obtaining boron. Borax is a biborate of soda, from which boric acid may be liberated in crystals, as above described, by the superior affinity of sulphuric acid for the soda.

The composition of boric acid appears doubtful, and it is variously considered as consisting of one atom of boron united to two or six atoms of oxygen.

Of the Properties of Boric Acid.

Boric acid is crystalline as first obtained from boron; but forms a glass when deprived by heat of its water of crystallization. It is colourless, inodorous, almost tasteless, and sparingly soluble in water. In the form of an aqueous solution, its agency is weak, and it is in consequence rarely used in that state. In common with silicic, phosphoric, and arsenic acid, being fixed at temperatures at which sulphuric and nitric acid are decomposed, it will at those heats expel them from their combinations, although when water is present, and at low temperatures, it is displaced from combination not only by those acids, but by many others.

Boron, in its habitudes, seems to lie between phosphorus and carbon. In its insusceptibility of volatilization, infusibility, and the temperature requisite for its combustion, it is most allied to carbon: yet boric acid is more analogous to phosphoric, than to carbonic acid. Both phosphoric, and boric acid, are capable of being reduced to a vitreous state, and bear a white heat without being volatilized, while the acid of carbon is naturally aeriform. Boric acid, and the biborate of soda, are of great use in blowpipe assays, as fluxes; and in soldering, as the means of protecting metallic surfaces from oxidation.

181. EXPERIMENTAL ILLUSTRATION.

Saturated solution of borax, decomposed by sulphuric acid. Exhibition of crystals of the acid and biborate: which are severally fused into a glass by the compound blowpipe. Effects of cobalt and manganese upon the colour of the glass, of which a globule is conveniently supported by a platina wire.

OF THE CHLORIDE OF BORON.

The chloride of boron may be obtained by the combustion of boron in chlorine; or by passing a current of chlorine over a mixture of charcoal and boric acid, heated to redness in a porcelain tube.

The chloride of boron is a colourless gas, possessing a strong and peculiar smell. When brought in contact with water, a reciprocal decomposition takes place, and boric and chlorohydric acid result. It forms a white salt with ammonia, and is by some chemists considered as an acid.

OF SILICON, OR SILICIUM.

By heating a mixture of sulphuric acid with powdered Derbyshire spar, and powdered glass, or quartz, a permanent gas may be obtained. When potassium is heated in this gas, silicon is evolved.

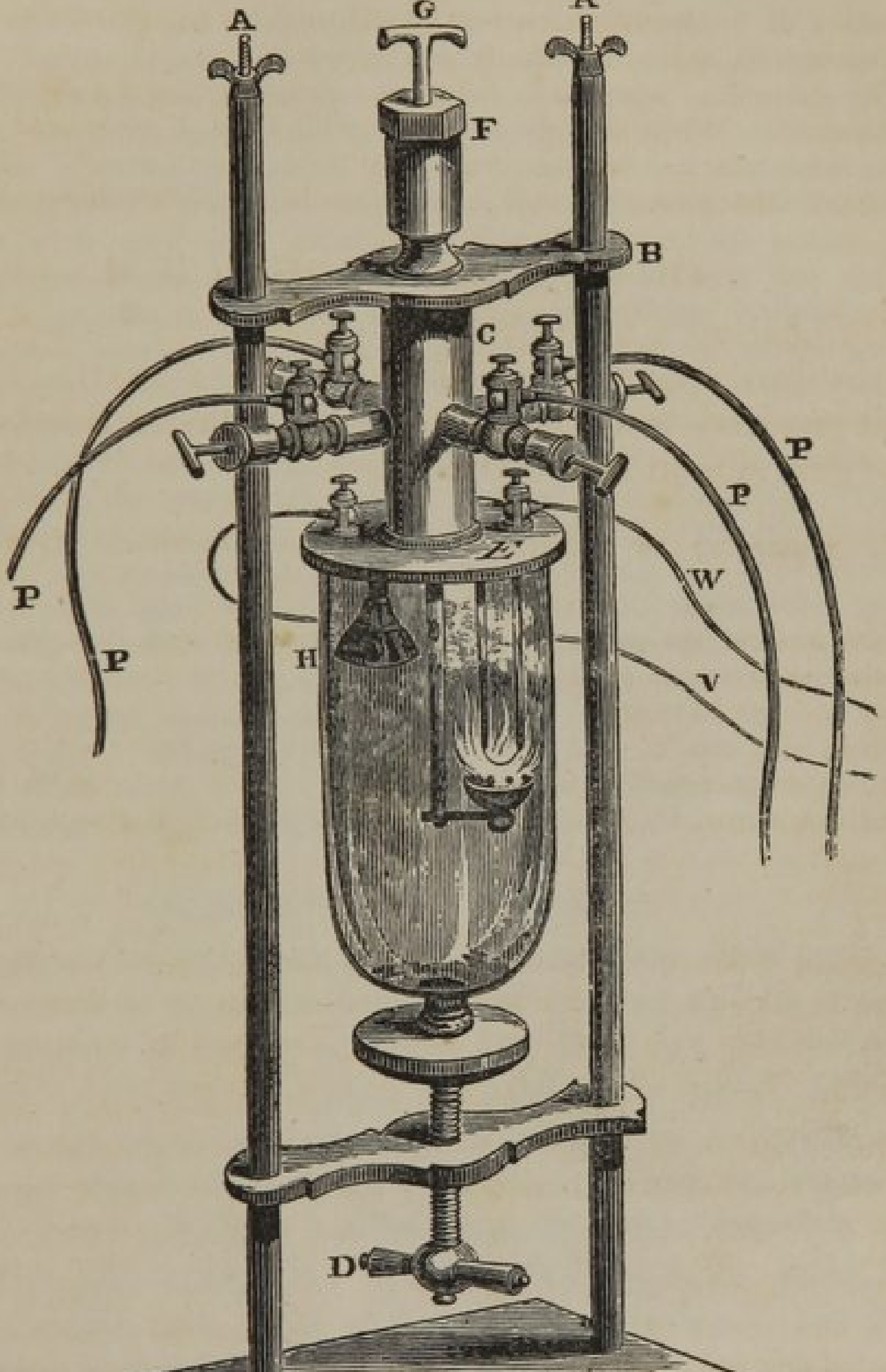
182. *Apparatus for evolving Silicon from Fluosilicic Acid Gas, by means of Potassium.*

Into a stout mahogany block as a basis, two iron rods, A, A, are so planted as to extend perpendicularly, and of course parallel to each other, about two feet in height. Upon these rods, two iron bars are supported horizontally, one, B, near their upper extremities, the other, at the height of about six inches from the wooden basis. In the centre of the lower bar, there is a screw, D, having a handle below the bar, and supporting above it a circular wooden block. Into a hole in the upper iron bar, equidistant from the rods, is inserted a hollow brass cylinder, C, which at the lower end screws into an aperture in a circular plate of brass, E, which is thus supported horizontally a few inches below the bar. By these means, room is allowed for the insertion into the cylinder of four valve cocks, each furnished with a gallows screw. The cylinder is surmounted by a stuffing box, through which a copper sliding rod, G, passes air tight. The brass plate is turned and ground to fit a bell glass of about five inches in diameter, and eight inches in height, which is pressed up when necessary between the plate and the block, by the screw, D, supporting the block. Within the space comprised by the bell glass, and on one side of the centre of the plate, two stout brass wires are inserted, one of them insulated by a collar of leathers, so as to admit of the ignition, by a galvanic discharge, of a small arch of platina wire, which reaches from one to the other. The sliding rod abovementioned as occupying the stuffing box, terminates below the plate, in an elbow which supports a cap at right angles to the rod, at the same distance from the rod as the platina wire; and on the opposite side of it, there is a brass cover, H, for the cap, supported from the plate. The arrangement is such, that by a suitable movement in the sliding rod, made by grasping it by the handle, G, in which it terminates externally, the cup may be made either to receive into its cavity the platina wire, or to adjust itself to its cover, H.

The bell being removed, about sixty grains of potassium, in pieces not

Apparatus for the Evolution of Silicon.

(P. 250.)



containing more than fifteen grains each, are to be introduced into the cup, which is then to be adjusted to the cover, and the bell secured. In the next place, by means of the flexible lead tubes, P, P, P, P, and the gallows screws attached to the valve cocks, establish a communication severally with an air pump, a self-regulating reservoir of hydrogen, a barometer gage, and a jar over the mercurial cistern, containing fluosilicic acid gas. First, by means of the air pump exhaust the bell, and in order to wash out all remains of atmospheric air, admit hydrogen from the reservoir. Again exhaust, and again admit hydrogen. Lastly, exhaust the bell of hydrogen, and admit the fluosilicic acid gas. By means of the gage, the exhaustion is indicated and measured, and by the same means it will be seen when the pressure of the gas within the bell approaches that of the atmosphere. When this takes place, the cocks being all closed, and by means of the process of galvano ignition, (58, 126,) the platina wire being rendered incandescent, the potassium is to be brought into contact with it. A peculiar deep red combustion ensues, evolving copiously chocolate coloured fumes, which condensing into flocks of the same hue, descend throughout the receiver, and are deposited upon the interior surface, so as to create in the mind of the spectator, the idea of a miniature fall of chocolate coloured snow. On removing the bell after the potassium has ceased to burn, the cup which held it is found to contain silicon mixed with the fluoride of potassium, and with this the whole of the chocolate coloured deposition is contaminated. Silicuret of potassium, is likewise found in the cup, since upon the affusion of water, a fetid inflammable gas is evolved, with an odour resembling that of phosphoretted hydrogen, and which must obviously be the analogous compound silicuretted hydrogen. The silicon being insoluble, may be separated from the fluoride by digestion in water. When the potassium employed is of the kind obtained by means of charcoal, it is, as Berzelius alleges, adulterated by carbon. I am under the impression, that strong nitric acid removes this impurity.

Of the Properties of Silicon.

It is of a brown ash colour, without the least trace of metallic lustre; a nonconductor of electricity; infusible; and incapable of being volatilized. It is not liable to be dissolved or oxydized, either by sulphuric, nitric, chlorohydric or fluohydric acid, but is soluble in a mixture of nitric and fluohydric acid. When heated to redness, with the fixed alkaline carbonates, it burns vividly; and when dropped upon the hydrates of potash, soda, or barytes, while in a state of fusion, it explodes. Yet it is unchanged by ignition with chlorate of potash, and exercises but a feeble reaction with nitre, even when heated to redness. In these respects its habitudes are anomalous.

When silicon, as usually obtained, by the aid of potassium, is intensely heated in the air, or in oxygen gas, it burns with a feeble blue flame; but by becoming encrusted with silicic acid, a portion escapes combustion.

This portion is rendered harder, denser, and insusceptible of combustion with oxygen at the highest temperatures. Berzelius suspects the greater combustibility, and inferior density and hardness of silicon, in the state in which it is obtained by the process above described, to be due to the presence of hydrogen, derived from the water employed. In this state, it inflames when ignited in the vapour of sulphur, and forms a sulphide, which is decomposed by water into sulphydric and silicic acid.

OF THE COMPOUND OF SILICON WITH OXYGEN, CALLED SILEX, SILICA, OR SILICIC ACID.

One atom of silicon, with one atom of oxygen, each equivalent to 8, forms one atom of silicic acid.

Of the Means of obtaining Silicic Acid.

Quartz being powdered, and fused with three times its weight of pearlash, a glass is obtained, which, being soluble, forms with water, a liquid called formerly liquor silicum, or liquor of flints. An acid being poured into this solution, silicic acid, slightly contaminated by potash, is precipitated.

To obtain silicic acid, Berzelius advises us to fuse in a platina crucible, equal parts of the carbonates of potash and soda; and to add quartz, finely pulverized, in small successive portions. The effervescence arising from the addition of one portion, is to be allowed to subside before adding another, until effervescence can no longer be excited. The refrigerated mass is to be dissolved in chlorohydric acid, and the solution filtered and evaporated to dryness. To remove all traces of iron or alumine, the dry mass is to be kept moist with chlorohydric acid, during about two hours, and afterwards washed with hot water, and then exposed to a red heat. Silicic acid will remain in a sufficient degree of purity.

Pure silicic acid, in the well known form of rock crystal, is found throughout nature. Its usual crystalline form is a six-sided prism, terminated by a pyramid with six faces.

Of the Properties of Silicic Acid.

Pure silicic acid is white, tasteless, and inodorous, and has a specific gravity of 2.66. Its solution does not redden litmus, and when evaporated to a certain point, forms a translucent jelly. It is soluble when nascent, but insoluble after exposure to heat or desiccation, or in its native crystalline form.

It was first fused by myself, in the year 1801, by means of the compound blowpipe. It has never been volatilized.

183. EXPERIMENTAL ILLUSTRATIONS.

Silicate of potash exhibited; also the solution of it, called liquor silicum, from which silex is precipitated by means of an acid.

OF GLASS. OF THE ANNEALING PROCESS.

OF PRINCE RUPERT'S DROPS.

OF GLASS.

If the proportions in which sand and alkali are used as above mentioned, for the liquor silicum, be reversed, the insoluble compound of silicic acid and alkali, known under the name of glass, is obtained, which, however pure the materials, has a slight tinge of green. This is removed by a due admixture of the red oxide of lead, and black oxide of manganese.

OF THE ANNEALING PROCESS.

A sudden diminution of the quantity of caloric among the exterior particles of a thick piece of glass, in a state of ignition, is not attended by a corresponding diminution of the quantity of this principle, among the particles within, owing to the slowness with which glass conducts heat. Hence, there can neither be a general coherence, nor a uniform arrangement, among the particles, unless the cooling be very slow, so as to allow the refrigeration within and without, to be nearly simultaneous. As it never can be perfectly simultaneous, other things being equal, the annealing will always be defective in proportion as the glass is thicker. Were the articles subjected to radiant heat only, the process would be more effectual, as this, when proceeding from incandescent surfaces, has been ascertained to penetrate, and even to pass through, glass.

By gradually making up a fire of charcoal, at about four inches distance, on each side of a glass tube, of about an inch and a quarter in thickness, and with a very small bore, I was enabled to heat it red hot, without causing a fracture. From its situation, it was subjected to radiant heat only.

OF PRINCE RUPERT'S DROPS.

When glass, in a state of fusion, is dropped into water, the defective states of cohesion and arrangement, consequent to the want of annealing, are at a maximum. Such drops have long been known under the name of Prince Rupert's drops. It is only necessary to break off the slender filament, in which the mass terminates, in order to cause an explosive dispersion of the whole into a coarse powder.

The cohesion of the particles in glass tubes, is often nearly as imperfect, as in Prince Rupert's drops. The slightest mark from a file on the interior surface, or wiping them out, especially if a metallic wire be employed, may cause them to break into pieces. Sometimes the fracture ensues immediately, at other times, not till many hours have intervened.

OF THE CHLORIDE OF SILICON.

When silicon is heated in chlorine, it inflames, evolving heat and light, and a chloride of silicon is formed.

It is a volatile liquid, possessing a sharp and powerful odour. In consequence of the absorption of an excess of chlorine, it is generally coloured yellow. It boils below 212°, and by the addition of water, is converted into chlorohydric, and silicic acid.

OF THE COMPOUNDS OF FLUORINE WITH HYDROGEN, SILICON, AND BORON.

Fluorine was cursorily noticed, page 125. As the theoretic grounds upon which its existence is assumed, cannot be elucidated without a reference to the compounds which it forms with hydrogen, silicon, and boron, I deferred treating of it until the student should be acquainted with those substances.

OF FLUOHYDRIC ACID, GENERALLY CALLED HYDROFLUORIC ACID.

It is supposed that fluorine exists in nature in union with the metals of the earths and alkalies, especially with calcium, a metal of which lime is the oxide. Such compounds are called fluorides. The remarkable mineral, called Derbyshire, or fluor spar, is viewed as a fluoride of calcium.

Not long since, Derbyshire spar was considered a compound of lime with an acid called fluoric acid, and supposed to consist of oxygen, and an unknown radical. Mr. Ampere first suggested the present doctrine, which was soon adopted by Sir H. Davy, and is now, I believe, almost universally sanctioned.

Of the means of obtaining Fluohydric Acid.

When fluoride of calcium is pulverized, and heated in a leaden retort, with twice its weight of concentrated sulphuric acid, the water in combination with the acid, is decomposed; the oxygen and acid form sulphate of lime with the calcium, while the hydrogen produces with the fluorine, fluohydric acid, which passes over in the form of a very volatile acid vapour, and may be condensed in a leaden or silver receiver, surrounded by snow and salt. If received in water, it condenses without refrigeration, and forms a diluted acid.

Of the Properties of Fluohydric Acid.

It is a colourless, limpid liquid, which boils at a little below 60°. When anhydrous, its specific gravity is 1.0609.

It is so volatile, that in a close apartment it cannot be decanted without subjecting the operator to intolerable fumes. This operation must be performed where there is a current of air to carry them off.

It ulcerates the skin with peculiar activity, and corrodes glass so as to trace its course indelibly, in running over the surface. It must be kept in vessels of silver or lead, accurately closed. When received in water it is absorbed, forming aqueous fluohydric acid, and is then more easily preserved. One atom of hydrogen equivalent 1, with one atom of fluorine equivalent 18, is supposed to form one atom of fluohydric acid, equivalent 19.

184. EXPERIMENTAL ILLUSTRATIONS.

Powdered fluoride of calcium, heated with sulphuric acid in a leaden retort, adapted to a receiver surrounded by snow and salt. Same process, substituting a receiver with water, by means of Knight's apparatus. Effect of fluohydric acid upon glass.

OF FLUOBORIC ACID.

It may be obtained by intensely heating a mixture of two parts of powdered fluoride of calcium, with one of vitrified boric acid, in an iron tube. One part of the boric acid is decomposed, of which the oxygen and the remaining portion of the acid forms borate of lime, with the calcium; while the boron unites with the fluorine, forming fluoboric acid gas, which must be received over mercury. Fluoboric acid gas may likewise be procured, by heating in a glass retort two parts of fluoride of calcium, and one of boric acid, with twelve parts of concentrated sulphuric acid. Berzelius, however, states, that when obtained by this method, it is contaminated by fluosilicic acid, arising from the action of the fluorine on the glass. This might probably, however, be avoided by performing the operation in a leaden retort.

Dr. Thomson states, that the best method of obtaining fluoboric acid gas, is one which was suggested by Berzelius. Boric acid is to be dissolved in anhydrous fluohydric acid, and a gentle heat applied to the solution. A reciprocal decomposition takes place, the hydrogen of the fluohydric acid combines with the oxygen of the boric acid, forming water, while the fluorine unites with the boron, and constitutes fluoboric acid gas.

OF THE PROPERTIES OF FLUOBORIC ACID.

Fluoboric acid is a colourless, transparent gas, with a potent odour, and an acid taste. It reddens litmus paper, and is destructive to life; its specific gravity is 2.3622. Water absorbs seven hundred times its volume of this gas. When fluoboric acid is passed into water, the oxygen of a portion of the water unites with the boron, forming boric acid, while the hydrogen combines with the fluorine, producing fluohydric acid. The boric acid precipitates, and the fluohydric acid combines with the undecomposed portion of the fluoboric acid, forming a compound which Berzelius designates as hydrofluoboric acid, but which, according to the nomenclature which I have adopted, should be called *fluohydroboric* acid. If we continue to pass fluoboric acid gas into the water, or partially abstract this liquid by evaporation, until the solution of fluoboric acid becomes saturated, the affinities which were at first brought into play, are reversed. The hydrogen of the fluohydric acid unites with the oxygen of the precipitated boric acid, and the fluorine with the boron, so that we finally obtain a simple solution of fluoboric acid in water. This solution is at first fuming, but on the application of heat it yields up a fifth part of its gas, and then strongly resembles concentrated sulphuric acid in appearance. Like that acid, it carbonizes organic products, in consequence of its affinity for water.

One atom of fluorine equivalent 16, and two atoms of boron equivalent 40, form one atom of fluoboric acid, equivalent 58.

OF FLUOSILICIC ACID.

It may be obtained by adding to the materials for evolving fluohydric acid, one half the weight of finely powdered glass, subjecting the mixture to heat in a glass retort, and receiving the product over mercury, as by water it would be rapidly absorbed.

The oxygen of the silicic acid in the glass, with the sulphuric acid and calcium, forms a sulphate of lime, while the fluorine and silicon, escape in the form of fluosilicic acid gas.

The apparatus which I employ for fluosilicic acid, is precisely the same as that described under the head of ammonia.

OF THE PROPERTIES OF FLUOSILICIC ACID.

Fluosilicic acid is a transparent, colourless gas, with a peculiar and suffocating odour, closely resembling that of chlorohydric acid. It reddens litmus paper, and has a specific gravity of 3.5735. When brought in contact with water, it is rapidly absorbed, and a decomposition takes place similar to that which ensues in the case of fluoboric acid, under similar circumstances. Silicic acid is deposited in the form of a gelatinous mass, and fluohydric acid is produced, which combines with the undecomposed portion of the fluosilicic acid, forming a compound acid, to which, if it be an acid, I would give the name of fluohydrosilicic. If the water, in combination with the fluohydrosilicic acid, is partially removed by heat, fluosilicic acid gas escapes, leaving fluohydric acid in solution.

One atom of fluorine equivalent 18, with one atom of silicon equivalent 8, forms one atom of fluosilicic acid equivalent 26.

185. EXPERIMENTAL ILLUSTRATIONS.

Production of fluosilicic acid shown: also, its absorption by water, and the precipitation of silicic acid, as above described.

On the Reaction of Fluohydric Acid with Fluoboric or Fluosilicic Acid, and on the Nomenclature of the Compounds, formed by the latter on meeting with Oxibases.

The union which ensues between fluohydric acid, and either fluoboric, or fluosilicic acid, agreeably to the preceding statement, may appear anomalous in the way in which it has hitherto been treated. If, however, I am correct in my mode of defining the difference between an acid and a base, (page 126,) the combinations in question will not prove to be anomalous. I deem it consistent to suppose that a fluobase of hydrogen in the one case unites with fluoboric acid, in the other, with fluosilicic acid; so that fluohydroboric acid might be called fluoborate of the fluobase of hydrogen, or more briefly, fluoborate of hydrogen; and in like manner, fluohydrosilicic acid would be called fluosilicate of the fluobase of hydrogen, or briefly, fluosilicate of hydrogen.

When either fluohydroboric acid, or fluohydrosilicic acid, or in other words, either the fluoborate or fluosilicate of the fluobase of hydrogen, is brought into contact with an oxibase, the radical of the latter takes place of the hydrogen, which, with its oxygen, forms water. Thus, in the case of potash, there would result a fluobase of potassium, usurping the place of the fluobase of hydrogen; and of course either a fluosilicate, or fluoborate of potassium, must be formed. Agreeably to the Berzelian nomenclature, these compounds are double salts, the name of one being in the French translation, "*fluorure borico potassique*," that of the other, "*flo-*

rure silico potassique." Many analogous salts, formed by the acids under consideration with salifiable substances, are mentioned by Berzelius; also many others, in which other radicals, in union with fluorine, play a part analogous to that performed by silicon, or boron, in the salts above mentioned.

There are instances in which compounds, usually called bases, act as acids. Of course it is consistent that compounds, usually called acids, should in some instances act as bases. In this respect, a striking analogy may be observed between the union of the oxide of hydrogen, (water) with the oxacids and oxybases; and that of fluoride of hydrogen, with fluacids and fluobases. According to Berzelius, water acts as a base to oxacids; as an acid to oxibases. So I conceive the fluoride of hydrogen acts as a base in the cases above noticed, while it acts as an acid in the compound of hydrogen, fluorine, and potassium, called by Berzelius "*fluorure potassique acide.*" This compound I would call a fluohydrate of the fluobase of potassium, or more briefly, fluohydrate of potassium, as we say sulphate of copper, instead of the sulphate of the oxide (or oxybase) of copper.

OF ZIRCONION OR ZIRCONIUM.

There is a stone, known under the name of the jargon or zircon of Ceylon, from which Klaproth extricated an earth, to which the name of zirconia was given. This earth is an oxide of an elementary body, which has been called zirconion, or zirconium. The termination in um is now only applied by chemists to the names of substances having the metallic character, and has been associated with the name of the element in question, under the erroneous impression, as I consider it, that the radical of zirconia is metallic. It appears to me to be deficient in two very essential characteristics of a metal—I mean metallic brilliancy, and the power of conducting electricity. Carbon, in the form of plumbago, has, in these respects, higher claims to the metallic character.

Zirconion appears to be sparingly distributed throughout our globe, and to have little practical utility. However the following facts, by which its analogy with silicon and boron is demonstrated, appear to me highly interesting. When the hydrate of zirconia is subjected to fluohydric acid, the hydrogen combines with the oxygen, and the fluorine with the zirconion. The resulting fluoride I consider as fluozirconic acid, but it is one of the haloid salts of Berzelius, and is, by that chemist, designated as a "*fluorure.*" This "*fluorure*" combines with other "*fluorures,*" and thus forms, according to Berzelius, double salts, analogous to those formed by the same fluobases with fluoboric or fluosilicic acid. I consider the salts in question as fluozirconates, or in other words, as consisting of fluozirconic acid, and a fluobase.

The analogy thus displayed to boron and silicon, is an additional reason with me for not treating zirconion as a metal, and for not associating with its name that termination, which is employed generally to designate the metallic class.

It was from the fluozirconate of the fluobase of potassium, or what we may briefly call the fluozirconate of potassium, that zirconion was obtained by Berzelius by heating this salt with potassium; in which case the superior affinity of this metal for fluorine, causes the zirconion to be liberated.

By an analogous process, silicon has been obtained by this distinguished chemist from the fluosilicate of potassium.

The most striking difference between the properties of zirconion, and those of boron and silicon, is, that each of these form acids with oxygen, while the oxide of zirconion acts usually as a base.

Of the Properties of Zirconion.

As obtained by the process abovementioned, zirconion resembles charcoal powder, but is rendered impure by the presence of the hydrate of zirconia. This may be removed by the action of chlorohydric acid. Zirconion, when in a state of purity, is a black powder, which, by rubbing and pressure, may be made to unite in scales possessing a brilliancy approaching that of plumbago. When heated in vacuo, and afterwards suffered to cool, it takes fire on the admission of air. Zirconion inflames in the air at a temperature considerably below that of redness, and is converted into zirconia.

OF ZIRCONIA.

Zirconia, when pure, is an infusible white powder, and is so hard as to scratch glass. When subjected to a violent heat it acquires a gray colour, and becomes harder, denser, and insoluble in acids. In this state its specific gravity is 4.3. It is composed of one atom of zirconion, equivalent 30, and one atom of oxygen, equivalent 8.

Some Observations respecting Nomenclature.

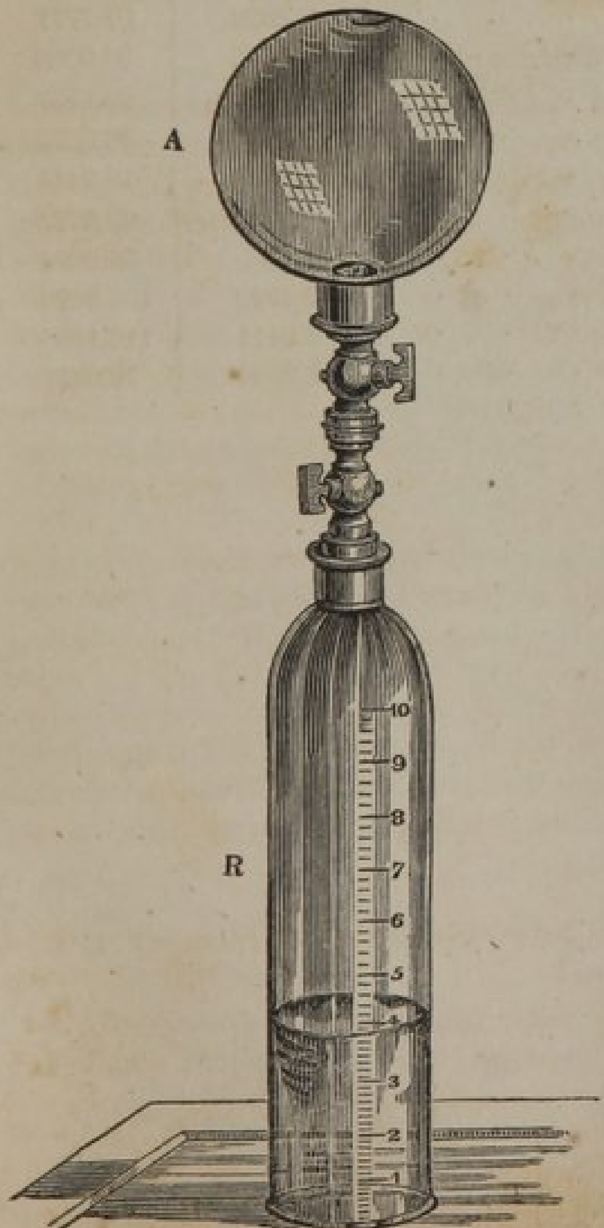
Besides the imponderable elements, and basacigen bodies, I have now treated of hydrogen, nitrogen, phosphorus, carbon, boron, silicon, and zirconion. These last mentioned bodies have in various compilations, been designated as non-metallic combustibles. It may be seen that in my letter upon the Berzelian nomenclature, I object to the appropriation of the word combustible to any class of bodies, conceiving combustion to be a case of chemical combination, in which the reaction between the bodies concerned, is equal and reciprocal. Since the word radical is used to signify the substance which may, by a basacigen body, be converted into an acid or a base, I should prefer to designate the seven bodies above named, as nonmetallic radicals, employing the word metal to designate each metallic radical.

It was mentioned page 113, that the English chemists have generally appropriated the termination uret to the compounds formed by the bodies by them designated as non-metallic combustibles; whence the words sulphuret, selenuret, phosphuret, carburet, boruret, silicuret, &c. Although I give to these bodies, as a class, an appellation different from that employed by those chemists, it must be evident to the student, that to the compounds formed by the bodies in question, I have applied the same names, excepting in the case of sulphur and tellurium, which I have placed in the basacigen class.

186.—METHOD OF ASCERTAINING THE SPECIFIC GRAVITIES OF THE GASES.

I mentioned, page 95, that I would defer illustrating the process for ascertaining the specific gravities of the gases, until the student should be acquainted with them. I shall now proceed with the illustration.

Suppose the globe, A, to be removed from the receiver, R, and exhausted during a temporary attachment to an air-pump, by means of a screw with which the globe is furnished, and which serves also to fasten it to the receiver, as represented in the figure. Being preserved in this state of exhaustion, by closing the cock, let it be suspended from a scale beam, and accurately counterpoised, as in a former experiment, 11. In that experiment, after the globe was counterpoised, air was admitted, and caused it to preponderate decidedly. If in lieu of admitting air, the globe be restored to the situation in which it appears in this figure, so as to be filled with hydrogen from the receiver, R, and afterwards once more suspended from the beam, instead of preponderating decidedly, as when air was allowed to enter, the additional weight acquired by it in consequence of the admission of the hydrogen, will scarcely be rendered perceptible. Supposing, however, that the additional weight thus acquired, were detected, and also the weight gained by the admission of exactly the same bulk of atmospheric air, after a similar exhaustion of the globe, the weights of equal volumes of hydrogen and air would be represented by the weights thus ascertained. The specific gravity of atmospheric air is the unit, in multiples, or fractions of which, the specific gravities of the gases are expressed. Hence the weight of any given bulk of hydrogen, divided by the weight of an equal bulk of air, gives the specific gravity of hydrogen. See page 90. By a similar process, the specific gravity of any other gas may be discovered.



The apparatus for ascertaining specific gravities, above represented, is that which is recommended by Henry. The gas may be more accurately measured, by using one of the volumeters, and a large inverted glass funnel, communicating with a globe, by means of a brass cap, screw, and cock, in the same way as in the apparatus here represented.

The size of the globe, to that of the volumeter, should be such, that the content of the one, taken an even number of times, shall nearly fill the other.

The weight of any given number of cubic inches of air or gas, as 100, for instance, may be known by introducing a certain quantity into the globe, as above described, and noticing the accession of weight: then, as the number of cubic inches introduced, to the weight gained by its introduction, so is 100 to the weight of 100 cubic inches of the fluid.

The number of cubic inches

introduced, may be known by means of the graduation on the receiver, P, or by ascertaining the content of the volumeter in cubic inches, which will of course enable us to know the number of cubic inches introduced by it into the globe.

SPECIFIC GRAVITIES OF THE GASES.

	Sp. gravity at 60 degrees.	Weight of 100 cubic inches in grains.
Air	1	30.5
Oxygen	1.1111	33.8888
Chlorine	2.5	76.25
Protoxide of chlorine	2.4444	74.5555
Hydrogen	0.0694	2.1180
Steam	0.625	19.0620
Chlorohydric (muriatic) acid	1.28472	39.1839
Nitrogen	0.9722	29.6527
Nitrous oxide	1.5277	46.5972
Nitric oxide	1.04166	31.7708
Ammonia	0.59027	18.0035
Sulphurous acid	2.2222	67.7777
Sulphydric acid (sulphuretted hydrogen)	1.1805	36.0069
Carbonic oxide	0.9722	29.6527
Carbonic acid	1.5277	46.5972
Carburetted hydrogen (*light*)	0.5555	16.9444
Olefiant gas	0.9722	29.6527
Cyanogen	1.8055	55.0694
Chloroxycarbonic acid	3.4722	105.9020
Fluosilicic acid	3.6111	110.1385
Fluoboric acid	2.3622	72.0471

OF METALS,

OR

METALLIC RADICALS.

It is to metallic radicals that I deem it expedient in the next place to direct attention. Less than thirty years ago the line of demarcation between metals, and other bodies, was easily drawn. There was then no known metal which had a specific gravity less than six, and of other bodies, none, of which the specific gravity was as high as five. But the discovery of alkalifiable metallic radicals, having a specific gravity less than that of water, annihilated the barrier which had been established on the basis of superior gravity.

Peculiar brilliancy and opacity were in the next place appealed to, as a mean of discrimination; and likewise that superiority in the power of conducting heat and electricity, which was so remarkable in substances of a decidedly metallic character. Yet so difficult has it been to draw the line between metallic and non-metallic radicals, that bodies which are by some authors placed in one class, are by others included in the other. Thus selenium, silicon, and zirconion, have by some chemists been comprised among the metals, by others among non-metallic bodies. In fact nature has not qualified her bodies for distinct classification. It is true that there are those of which the prominent features or qualities are so strikingly different, that we are at first encouraged to think that by associating similar substances with each, we shall form classes not liable to be confounded. Thus gold possesses, in a high degree, all the attributes of a metal, while sulphur is totally devoid of them; yet arsenic, as being decidedly metallic, may on the one side be classified with gold in preference to sulphur, while on the other hand, between arsenic and sulphur, there is in many respects a much greater analogy than between arsenic and gold.

In fact, tellurium, which had been always classified, and which is still considered as a metal, is now associated by Berzelius in his amphigen class, with oxygen, selenium, and sulphur, and has, in consequence, been treated of by me as a basacigen body.

Metals were formerly distinguished as metals and semimetals; the latter appellation having been employed to designate such as were wanting in the mechanical properties of malleability and ductility. Again, the metals which were endowed with the properties just mentioned, were dividedin to noble and base. The noble metals, sometimes called precious from their superior value, were distinguished from the others by their insusceptibility of injury by fire, moisture, or air. Silver and gold were, about a century ago, the only known metals meriting the name of noble, upon the grounds which I have mentioned. To these platinum was subsequently added, and latterly palladium and nickel have been found to have pretensions to be considered as noble, agreeably to the ideas in obedience to which the epithet was originally employed. Subsequently chemical properties became better known, and metals were associated not only in accordance with their own obvious characteristics, but also with a view to their oxides, which in many cases are the only forms under which they are encountered in nature, or employed in the arts. Accordingly the metals are now generally divided with a view to their susceptibility of oxidizement, or the character of their oxides. Among the oxides alluded to, there are some, of which the characteristics are so different, that there can be no hesitation in classifying them separately.

Yet in other members of the same class the characteristics by which they are distinguished are so feeble, that a diversity of opinion has existed as to the genera to which they belong.

I propose to divide metallic radicals into the following classes:

First, metals of the earths proper.
Second, metals of the alkaline earths.
Third, metals of the alkalies, or alkalifiable metals.
Fourth, metals proper.

I will employ the word noble to distinguish metals not liable to be tarnished by exposure to fire, water, or air;

as, for instance, gold, platina, silver, palladium, rhodium, and nickel.

Metals proper, are by Berzelius divided into electronegative or acidifiable metals, and electropositive or basifiable metals. Under the former head he places selenium, arsenic, molybdenum, tungsten, antimony, tellurium, columbium or tantalium, and titanium. Under the head of electropositive, or basifiable metals, he places gold, platinum, osmium, iridium, palladium, silver, mercury, copper, bismuth, tin, lead, cadmium, zinc, nickel, cobalt, iron, manganese, and uranium.

I am under the impression that each of the following metals, being, agreeably to the same authority, capable of forming with a halogen* body the electronegative ingredient in a double salt, should be considered as acidifiable. The metals I allude to are gold, platinum, silver, palladium, iridium, rhodium, uranium, chromium, titanium, molybdenum, manganese, osmium, mercury, nickel, copper, iron, zinc.

When the objects which it may be desirable to study, are too numerous and complicated in proportion to the time and attention which we have to bestow, we may either employ such time as we have, in a cursory, superficial, and indiscriminate examination of the whole, or in a more thorough study of the more important parts. Of the two courses I cannot conceive that any judicious person would hesitate in choosing the latter.

Under this impression I shall treat particularly of the twelve metals proper, included in the following list—gold, platinum, silver, mercury, copper, lead, tin, iron, zinc, antimony, bismuth, arsenic. Besides the metals thus mentioned, there are in the same class, palladium, rhodium, iridium, osmium, nickel, cadmium, chromium, cobalt, columbium, manganese, molybdenum, titanium, tungsten, uranium, and vanadium. Of these I shall give only a brief account, with descriptions and illustrations of their striking and useful properties, where such exist. Of tellurium I have already treated as a basacigen body, page 134.

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* As a name distinguishing chlorine, bromine, fluorine, iodine, and cyanogen, from the other basacigen bodies, is much wanted, I employ the word halogen, applied to those bodies by Berzelius in honour of its author, although I do not concur in the opinions in which it originated.

I have abstracted from Thenard's "Traité de Chimie," the following table, from which the number of metals, recognised at this time, and the periods at which they severally became known to mankind, will be seen, so far as those periods can be ascertained.

Names of Metals.	Authors of their Discovery.	Dates of their Discovery.
Gold	Known to the Ancients.	
Silver		
Iron		
Copper		
Mercury		
Lead		
Tin		
Antimony	Described by Basil Valentine	15th century.
Zinc	First mentioned by Paracelsus	1520
Bismuth	Described by Agricola in	16th century.
Arsenic	Brandt in	1733
Cobalt		
Platinum	Wood, Assay Master, Jamaica	1741
Nickel	Cronstedt	1751
Manganese	Gahn and Scheele	1774
Tungsten	M. M. D'Elhuyart	1781
Tellurium	Müller	1782
Molybdenum	Hielm	1782
Titanium	Gregor	1781
Uranium	Klaproth	1789
Chromium	Vauquelin	1797
Columbium	Hatchett	1802
Palladium	Wollaston	1803
Rhodium		
Iridium	Descotils and Smithson Tennant	1803
Osmium	Smithson Tennant	1803
Cerium	Hisinger and Berzelius	1804
Potassium	Sir H. Davy	1807
Sodium		
Barium		
Strontium		
Calcium		
Cadmium	Stromeyer	1818
Lithium	Arfwedson	1818
Vanadium	Del Rio, 1803—Sefstrom	1830

Of the Generic Characteristics of the Metals.

When newly cut, metals have a peculiar lustre. They are the best conductors of heat and electricity; the worst radiators, and best reflectors, of heat. All combine, directly or indirectly, with oxygen, chlorine, and sulphur, in one or more proportions—forming oxides, chlorides, and sulphides. Probably also they all may be combined with bromine, iodine, and cyanogen. They are all susceptible of solidity and fluidity, and probably of the aeriform state. Mercury and arsenic are easily volatilized; and gold, silver, and platinum, though very difficult to burn or volatilize, are nevertheless dissipated by means of the compound blowpipe, galvanism, or electricity.

Of certain Properties possessed by some Metals, but not by others.

The properties which come under this head, are permanency of lustre in the fire and air—malleability—ductility—elasticity—sensibility to the magnet—susceptibility of the welding process—and of acquiring, by a union with carbon, silicon, or aluminum, the capability of hardening by being suddenly refrigerated from a red heat; also of being hardened by the hammer, and of being restored by heat in the annealing process.

The metals remarkable for permanency of lustre, are gold, platinum, silver, and palladium, called on that account noble, or perfect. Those principally remarkable for malleability, are gold, silver, platina, copper, palladium, iron, tin, lead, and nickel. Among these, iron and platinum only can be advantageously hammered at a very high temperature.

The metals distinguished for elasticity are iron, copper, and silver. Iron, in the state of steel when duly tempered, is pre-eminent for this property.

The metals remarkable for ductility, are gold, iron, (either pure, or as steel,) silver, copper, platinum, tin, and lead. In large rods or pipes, lead and tin are the most ductile.

The magnetic metals are iron, whether pure in the state of steel or in that of protoxide, also nickel, and cobalt. Those susceptible of the welding process, are iron and platinum. Iron only is capable of uniting with carbon, silicon, or aluminum, and hardening consequently by quick refrigeration. Gold and platinum are distinguished by their superior gravity, which is between two and a half, and three times as great as that of iron, tin, or zinc.

All the metals have a specific gravity greater than five, if we except those of the earths and alkalies.

Of the Annealing Process in the Case of Metals.

Malleability, ductility, and toughness, in metals susceptible of the annealing process, are probably dependent on the quantity of caloric remaining in combination with their particles, while in the solid state. When malleable metals are hammered, they give out heat and become harder, more rigid, elastic, and dense, until they acquire a certain maximum of density. This being attained, they are fractured, if the hammering be carried further. Exposed to the fire until softened, on cooling, they are found to have regained the properties of which percussion had deprived them; and they may be again heated, hardened, and condensed, by hammering.

Of Alloys.

This name is given to the compounds formed by the union of different metals. There is always copper in gold and silver coin; and in the metal employed under those names by the smiths and jewellers, there are various proportions of the baser metal. Brass consists of copper and zinc; pewter, of lead and tin, or tin, copper, and antimony.

Of the Oxydability of Metals by exposure to Air or Moisture, with or without Heat.

Gold, silver, platina, palladium, and rhodium, do not become oxidized by exposure to water or oxygen at any temperature, and when oxidized by other means, on being ignited, are reduced.*

Iron, zinc, and tin, are not oxidized by exposure to dry air, nor to water alone, unless aided by a red heat. Of these metals, iron is most acted upon by the joint influence of air and moisture, at the ordinary temperatures of the atmosphere. Copper, tin, and lead, do not decompose water at any temperature, but are oxidized at a red heat, or at temperatures sufficient for their fusion. Mercury is not oxidized by water under any circumstances. It is oxidized by agitation, or by a heat below its boiling point, but when distilled, abandons the oxygen which may have been united to it previously.

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* The verb to *reduce*, has long been employed by chemists to signify the deoxidizement of a metallic oxide, so as to effect its restoration to the metallic state, or that of a *regulus*, to use another word which I shall also employ, to avoid circumlocution, although it is now somewhat antiquated. The verb to revive has been used in the same sense as to reduce.

OF METALS OF THE EARTHS PROPER.

The Metals included under this head, are Aluminum, Glucinum, Yttrium, and Thorium.

OF ALUMINUM, THE METALLIC RADICAL OF THE EARTH, ALUMINE, OR ALUMINA.

A chloride of aluminum was obtained by Oersted, by subjecting to a current of chlorine, an intimate mixture of oxide of aluminum and carbon, heated in a porcelain tube. The affinity of the carbon for the oxygen of the earth, and of the chlorine for the metallic radical, was productive of carbonic oxide, which escaped, and a chloride of aluminum, which remained.

By heating with potassium, a chloride obtained by the process above mentioned, Woehler liberated aluminum through the superior affinity of potassium for chlorine. In this state, aluminum constitutes a grey powder much resembling that of platinum. Some little facets, which have sufficient magnitude to be distinguished, after compression under the burnisher, display a metallic brilliancy. Yet in the pulverulent form, the metal has so little power to conduct electricity, that when interposed in the galvanic circuit, it interrupts the action. It is alleged, however, that in a minute state of division, iron is a nonconductor of electricity, and Turner states, that by fusion, aluminum becomes a conductor. It appears to me, that at best, its claims to the metallic character are not superior to those of carbon in the form of plumbago.

Aluminum burns with a heat so intense, as to cause the fusion of the resulting oxide, which becomes on cooling, hard enough to cut glass. Aluminum is not oxidized when water is evaporated from it at a gentle heat. At a boiling heat it evolves hydrogen feebly, and the evolution having once commenced, continues for some time after refrigeration. With concentrated nitric, or sulphuric acid, aluminum has no reaction at ordinary temperatures; but assisted by heat, forms a sulphate, or nitrate, acquiring oxygen from one portion of the acid, and uniting with the remainder. When subjected to a solution of either potash, soda, or ammonia, aluminum is by the decomposition of the water, converted into alumine, which unites with the alkali, forming an aluminate. On this account, in preparing aluminum, there should not be an excess of potassium; and any potash produced during the process, should be quickly removed by the employment of a quantity of water no larger than necessary.

OF ALUMINE, OR OXIDE OF ALUMINUM.

It is found nearly pure in the gems called by jewellers oriental, and classed by Brongniart under the head of Corindon Telesie. The ruby, sapphire, amethyst, and topaz, of the most beautiful kinds, are thus designated. Of all stony minerals, they have the highest specific gravity, and are only inferior to the diamond in hardness. Differing from each other only in colour, they yield by analysis little else than pure alumine. There are other jewels of the same name and colour, which ought not to be confounded with those here alluded to. As an ingredient in clay, which owes its plasticity, and all its striking qualities to alumine, this earth enters largely into the structure of the terrestrial globe.

There are two native forms of hydrate of alumine. The one found in the United States, in the form of a stalactite, white, semitransparent, called Gibbsite; the other in Siberia, is called Diaspore, from the property of flying into pieces, or even powder, when heated; in consequence, no doubt, of the vaporization of the combined water.

Means of obtaining Alumine.

Berzelius alleges that the alum of commerce, if it contain oxide of iron, should be dissolved and recrystallized several times, or a solution being made, and allowed to stand for some time, the oxide of iron is precipitated in yellow flocks. To the solution of alum at a boiling heat, a solution of carbonate of potash is to be added in excess, and the whole is to be digested at a moderate temperature, to decompose any supersulphate of alumine which the alkali may have precipitated. The precipitate, after having been collected and well washed upon a filter, is to be redissolved by chlorohydric acid, and precipitated by an excess of ammonia, either caustic or carbonated. This second precipitation is necessary, to get rid of a portion of carbonate of potash, with which the alumine forms a triple combination which cannot be decomposed by water. The precipitate produced as last mentioned, is to be collected and carefully washed. When dried it forms a hydrate, which, by a red heat, is converted into pure alumine. One hundred parts of alum, yield a little more than ten of the earth.

In France, a species of alum is used, in which ammonia takes the place occupied by potash in the common alum. By heat, which expels the acid and alkali, pure alumine may be extricated from this compound.

Of the Properties of Alumine.

Alumine is white, plastic when moistened, soft to the touch, adherent to the tongue, inodorous, insipid, and infusible in the furnace. It is the only earth which was fused before the compound blowpipe was invented. Its property of contracting and hardening by heat, was noticed when on the subject of Wedgwood's Pyrometer.

It is remarkable, that although quite insoluble in water, this earth abstracts and retains a quantity of water amounting to 15 per cent. of its weight. It is on this account, that as an ingredient in clay, its influence on vegetation is so beneficial. During rains it becomes saturated with moisture, which it slowly relinquishes in dry weather.

There is a remarkable difference in the appearance of the hydrate of alumine as obtained by precipitation from a concentrated, or a weak solution of alum. In the former case it is a white, friable, spongy powder, which is adherent to the tongue, and by exposure to a red heat, parts with all its water. In the latter it forms a transparent yellow mass, which breaks by the heat of the hand with a smooth and conchoidal fracture, does not adhere to the tongue, or swell by the addition of water. In this state, the hydrate of alumine does not part with all its water, even at a temperature above that of redness.

Alumine has a great affinity for vegetable colouring matters, which it consequently precipitates from their solutions, forming the pigments known under the name of lakes.

Alumine is soluble in solutions of caustic, potash or soda, and even in those of barytes and strontites; but in liquid ammonia, dissolves only to a very small extent. Alumine has an affinity so strong for oxybases, as to be considered as acting the part of an acid in some instances. Triple compounds are formed by alumine with the acid and base of alkaline carbonates, which will bear a low red heat without expelling the acid, or producing a more intimate union between the earth and alkali.

The spinelle ruby, a precious stone, and gahnite, are aluminates; the former of magnesia, the latter of zinc; in which, however, there are six times as many atoms of alumine, as of the other element. The affinity of alumine for magnesia is so strong, that when separated simultaneously from a common solvent, the former cannot be taken up entirely by the alkali, by which the separation is effected. If magnesiferous alumine, after having experienced a red heat, be subjected to chlorohydric acid, a white powder remains, which is an aluminate of magnesia.

Three qualities serve to detect alumine; first, its affinity for potash, and consequent solubility in a solution of that alkali; secondly, the property which it has of giving with sulphuric acid and potash, alum, so readily recognised by its crystallization and taste; thirdly, the property of producing a fine blue colour, when moistened with nitrate of cobalt, and exposed to a strong heat.

This earth and its salts are of great use in dyeing, as mordants to cause the dyes to adhere. The latter in many cases have no affinity for the organic fibres which are to be dyed; but the alumine, combining with both the dye and the fibre, associates them permanently.

In the habitudes of this substance, we have an exemplification of the commutable character of electrochemical characteristics. While with the alkalies and alkaline earths, it performs the part of an acid, with various acids it acts as a base, forming with them compounds, both natural and artificial. Among the former is the mineral generally designated as feldspar, which is composed of silicate of alumine, and silicate of potash. Porcelain is an artificial silicate of alumine. Its existence as a base in alum has been mentioned.

Alumine was named from alumen, the Latin appellation for alum. The specific gravity of alumine is 2. It is composed of one atom of aluminum, equivalent 10, and one atom of oxygen, equivalent 8.

187. EXPERIMENTAL ILLUSTRATIONS.

Alumine precipitated from a solution of alum, by an alkali. Rendered blue by a solution of nitrate of cobalt. Contraction sustained by exposure to heat, illustrated.

OF THE CHLORIDE OF ALUMINUM.

The chloride of aluminum is obtained as I have stated above. It is partially translucid, lamellated in structure, of a greenish yellow colour, and an astringent taste. Litmus is reddened by the action of this chloride. It dissolves in water with a hissing noise. When this solution is highly concentrated, it deposits crystals, which being convertible by heat into alumine and chlorohydric acid, probably consist of one atom of chloride of aluminum, and one atom of water. According to Thenard, the chloride of aluminum forms, with the chlorides of potassium and sodium, compounds indecomposable by a red heat. These may be considered as formed by the union of a chloracid with a chlorobase.

With sulphur, selenium, and phosphorus, aluminum forms some unimportant compounds.

OF GLUCINUM.

Glucinum may be obtained from its oxide glucina, by the same process as that above described for obtaining aluminum. It resembles aluminum in appearance, and in many of its properties, but differs from it in not being susceptible of oxidizement by a solution of ammonia, or by boiling water.

OF GLUCINA.

Glucina is white and tasteless. It is insoluble in water, but forms with it a paste, which is somewhat adhesive, but not sufficiently so to be moulded. It does not harden by exposure to heat.

It is soluble in the caustic fixed alkalies, but not in ammonia. It likewise dissolves in the alkaline carbonates, and in that of ammonia especially, by which it is distinguished from alumine, as well as by its incapacity to produce alum, or to assume a blue colour when treated with nitrate of cobalt. It forms also a fluacid, which, with the fluoride of potassium, precipitates from a hot solution in crystalline plates, in the state of fluo-glucinate of potassium (fluorure glucinico-potassique of Berzelius).

The equivalent of glucina is 26, being composed of one atom of glucinum, equivalent 18, and one atom of oxygen, equivalent 8.

Glucina exists in the emerald, comprehending the beryl and aquamarine, and in the euclase. In consequence of the peculiar sweetness of its salts, it was named glucine, or glucina, from γλυκυς, sweet.

OF YTTRIUM.

It has been procured by a process quite analogous to that described for aluminum. It has a more metallic and crystalline aspect than that metal or glucinum. Its habitudes with oxygen and the acids are perfectly analogous to those of the metals above mentioned. It is liable to be slowly oxidized in a solution of potash, by the decomposition of water. Like glucinum, it is not oxidized by water even when boiling.

OF YTTRIA, OR OXIDE OF YTTRIUM.

Yttria is insipid, infusible, and insoluble in water. It is uncertain whether the yellow tinge, which it usually presents, is appropriate, or produced by impurities. It is rendered snow-white by the presence of a small quantity of sulphuric acid. It is heavier than barytes, being of a specific gravity approaching to 4.842. It is distinguished from other earths by its insolubility in caustic alkalies, while it dissolves in their carbonates, especially that of ammonia, although in a lesser quantity than glucina.

Yttria is principally characterized by its susceptibility of precipitation by cyanoferrite of potassium (ferroprussiate of potash). Excepting thorina, this property is possessed by no other earth.

With acids it forms salts, having a sweet taste, and in some instances the colour of the amethyst. In fact, the best mean of detecting it is the production with sulphuric acid, of crystals having this hue, which are extremely slow to dissolve in water, and which effloresce when heated. Its affinities are more feeble than those of the alkalies or alkaline earths.

This earth has been found only in three Swedish minerals—gadolinite, yttro-tantalite, and yttro-cerite.

Yttrium is composed of one atom of oxygen, equivalent 8, and one atom of yttrium, equivalent 32.

OF THORIUM.

Thorium was first found not many years since, in a single locality, in the state of oxide or earth, combined with silicic acid. It is in the island of Loecun that it was met with, near the little village of Berwig, in Norway. It was found in a mineral resembling obsidian, and called thorite, which contained 57 per cent. of thorina, or oxide of thorium, and in addition, lime, magnesia, iron, manganese, osmium, lead, tin, and a little alkali combined with silicic acid, and water. In making the analysis of this mineral, Berzelius discovered thorina.

From chloride of thorium, as from other chlorides of the same metallic genus, the radical may be evolved by means of potassium and heat. It may likewise be extricated from the double fluoride of thorium and potassium, or fluothorate of potassium. Thorium, in its appearance and in many of its properties, much resembles aluminum, but differs from it in not being oxidized by reaction with boiling water, dilute sulphuric acid, or of alkaline solutions. When heated gently in the air, thorium inflames, and is converted into thorina.

I do not conceive that either thorium or any other of those substances enumerated as convertible by oxidizement into earths proper, are more entitled to be considered as metals, than carbon in the state of plumbago.

OF THORINA.

Thorina is white, tasteless, and inodorous. In common with alumine, glucina, and yttria, it is capable of acting as a base with water. The resulting hydrate of thorina, is by heat convertible into the anhydrous oxide in a state of great hardness.

Thorina may be known from its sulphate being more soluble in cold than in hot water. It is composed of one atom of thorium, equivalent 60, and one atom of oxygen, equivalent 8.

OF METALS OF THE ALKALINE EARTHS.

Under this head are included Magnesium, Calcium, Barium, Strontium.

The reduction of all the alkaline earths has been attempted with various degrees of success, by precisely the same means in each case; the affinity of mercury for the metals, assisted by the divellent attractions of wires, proceeding from the different poles of a Voltaic series.

By means of water, the earth, either pure or in the state of a carbonate or sulphate, was formed into a small cup, in which a globule of mercury was placed. The cup being supported upon a platina dish, communicating with the positive pole of the series, a wire of the same metal, proceeding from the other pole, was introduced into the mercury. After some time, an alloy of the mercury, with the metal of the earth subjected to the process, was obtained. The amalgam, thus generated, was included in a glass tube, bent into the shape of a retort, filled with the vapour of naphtha, and hermetically sealed. The end of the tube in which the amalgam was situated, being heated, while the other end was kept cool, the mercury was separated from the metal.

Barium thus obtained, was a solid dark-gray metal, with a lustre somewhat inferior to that of cast iron. It was fusible and vaporizable at a heat below redness, and when in the state of vapour, acted violently upon the glass. Its specific gravity was such, as to enable it to sink in sulphuric acid. It was rapidly oxidized in the air, and regenerated barytes when thrown into water.

Strontium appears to have been procured in less quantities than barium, but in its properties much resembled it.

Calcium was procured by the process abovementioned, to an extent still less satisfactory than strontium or barium. It is alleged to have appeared brighter and whiter than those metals.

The same means were employed in the instance of magnesia, with still less success; but latterly, Bussy has obtained magnesium from the chloride, by employing potassium agreeably to the method already described in the case of other radicals.

OF MAGNESIUM.

Magnesium resembles silver in colour and fusibility. It is malleable, and has a decided metallic brilliancy. It is oxidized by exposure to the air, or to boiling water. When sufficiently heated in the air, magnesium enters into combination with oxygen, and is converted into its oxide, magnesia. Its specific gravity is greater than that of water.

All the metals of this class except magnesium, decompose water at the ordinary temperature of the air.

OF MAGNESIA.

This earth, in a state of combination, exists in considerable quantities in nature. Dr. Thomson states that a whole range of low hills, consisting of anhydrous carbonate of magnesia, exist in India.

In the state of sulphate or Epsom salt, it is largely obtained from a mineral, found in Maryland and in Lancaster county, called magnesite, which is a silicate of magnesia, iron, and lime; also from the mother water of sea salt resulting in the process of obtaining that chloride from the salt water of the ocean near Boston.

This earth may be precipitated from a solution of Epsom salt, by adding a solution of potash or soda.

It may likewise be obtained from the carbonate, by heat.

Of the Properties of Magnesia.

Magnesia is white, has a feeble alkaline taste, and affects vegetable colours like an alkali, though feebly (157). It is nearly insoluble in pure water, but dissolves, to a considerable extent, in water containing carbonic acid, forming a soluble supercarbonate.

Magnesia is distinguished from the other alkaline earths, not only by being less energetic in its affinities and alkaline properties, but by the solubility of its sulphate.

Magnesia is one of the most fixed and refractory substances in nature, and was deemed infusible until fused by me in 1801, with the aid of the compound blowpipe. The specific gravity of magnesia is 2.3, and its equivalent is 20.

188. EXPERIMENTAL ILLUSTRATIONS.

The precipitation of magnesia from a solution of Epsom salt, exhibited: also its effects upon vegetable colours.

OF LIME OR CALCIA, THE PROTOXIDE OF CALCIUM.

This oxide exists largely in nature, in combination with carbonic acid, forming all the varieties of marble and lime-stone. Some kinds of white marble, especially that of Carrara, so celebrated on account of its employment in statuary, consist solely of this earth combined with water and carbonic acid, uncontaminated by any other matter. The acid and water being expelled by heat, the lime remains in a state of purity. Oyster shells yield very pure lime by heating them to incandescence.

When impure carbonates of lime are exposed to a very high temperature, the matter constituting the impurities is prone to enter into intimate combination with the lime, impairing its causticity, and susceptibility of the slaking process. No doubt this arises from a diminution of affinity for water. The lime of shells is sometimes partially converted into a sulphide, by sulphur derived from the animal matter.

The calcination requires more heat in a crucible, especially if covered, than in an open fire; and if the heat be too sudden, the carbonate may be fused without the expulsion of all the acid, which is afterwards more tenaciously retained. The extrication of the carbonic acid is promoted by a current of steam, or of any other aeriform fluid. But steam is preferable, as it is more easily procured, and cannot be productive of impurity. The rationale is, that homogeneous aeriform particles interfere with each other more than heterogeneous, which, agreeably to the Daltonian doctrine, to a certain extent oppose no resistance to reciprocal intermixture and penetration.

After the first calcination, Berzelius recommends that the lime be slaked, and again calcined in an open crucible.

Quicklime is alleged to produce heat even when triturated with snow.

Of the Properties of Lime.

The colour, taste, and smell, of this earth, are well exemplified in the best kinds of lime used in building, (sometimes called quicklime) which is, strictly speaking, oxide of calcium isolated from the water, and carbonic acid usually united with it as found in nature. This has consequently the property of reacting with water, and producing the phenomena attendant on the process of slaking, during which lime combines with the water with which it is moistened, and becomes a hydrate. The caloric which exists in the water, as the cause of its fluidity, is evolved.

Water takes up about $\frac{1}{700}$ of its weight of this earth, forming lime-water. On this a pellicle is generated, as in the case of barytes, soon after exposure to the air, by the union of the lime with the carbonic acid, which always exists in the atmosphere.

Lime-water dissolves some metallic oxides, those of lead and mercury especially, and operates on vegetable colours like an alkali.

Though lime is precipitated by carbonic acid in the state of carbonate, water, impregnated with this acid, dissolves the carbonate. Oxalic acid is the best test for lime. The fusion of this earth was first accomplished by me with the compound blowpipe, in 1802. The specific gravity of lime is 2.3, and its equivalent is 20.

The hardening of mortar is by Berzelius ascribed to the affinity between the lime and the silicic acid.

Phosphuret of calcium may be made by dropping phosphorus on caustic lime, ignited in a matrass with a long neck. An excess of phosphorus should be employed, and expelled by subsequent distillation. By the affusion of water, this phosphuret gives out phosphuretted hydrogen, which inflames spontaneously. This gas is still more actively evolved when the phosphuret is subjected to muriatic acid. Either chlorine or oxygen combine with the calcium, while the hydrogen of the acid or water unites with a portion of the phosphorus, and assumes the gaseous form.

189. EXPERIMENTAL ILLUSTRATIONS.

Characteristic changes produced in vegetable colours by the solution of the earth in water, called lime-water. A glass of lime-water is not made turbid by air from a bellows, but becomes so on propelling the breath through it. Absorption of carbonic acid by lime-water, shown. Lime precipitated from solutions of its muriate, or nitrate, by sulphuric or oxalic acid.

OF THE PEROXIDE OR DEUTOXIDE OF CALCIUM.

Oxygen is absorbed when passed over lime, heated to incandescence. By adding lime-water to oxygenated water, while acidulated with muriatic acid, Thenard procured crystals of deutoxide of calcium.

OF BARYTES, OR BARYTA, THE PROTOXIDE OF BARIUM.

This earth was named from the Greek Βαρυς, heavy; because the minerals containing it are peculiarly heavy, when compared with other earthy substances.

Of the means of obtaining Barytes.

To procure barytes, Berzelius advises that eight parts of the sulphate, finely pulverized, should be intimately mingled with one of charcoal; and afterwards triturated with two parts of resin, or wheat flower. The mixture is to be kept at a white heat in a Hessian crucible, for three quarters of an hour. The resin is serviceable by coating, while in fusion, all the surfaces of the sulphate, and being subsequently carbonized, leaves every part of the compound in contact with carbon.

The sulphate of barytes deprived of oxygen, becomes a sulphuret of barium, which yields a nitrate of barytes on the addition of nitric acid. The filtered solution by evaporation yields crystals of nitrate, which should be decomposed in a porcelain or platina crucible. This operation is tedious, since the heat cannot be urged beyond a certain intensity, without causing the salt to rise up in a foam, so as to overflow the crucible. If the heat be not applied long enough, Berzelius alleges that a portion of nitrous oxide remains united with the earth, forming a compound which has been mistaken for deutoxide ("suroxide") of barium.

Neither the carbonates nor hydrates of barytes and strontites, are like those of lime, decomposable per se by heat. The addition of carbonaceous matter enables us to decompose them; as it changes the carbonic acid into carbonic oxide, which has no affinity for the earths, and therefore escapes.

Of the Properties of Barytes.

It is acrid, slakes like lime, and is more soluble in water. It is more actively alkaline, both as respects the taste and vegetable colours, than any other earth. It is gray at first, but absorbs water and becomes white. Its aqueous solution is rendered milky by carbonic acid, and by combining with it, becomes covered with a pellicle of carbonate, when exposed to the atmosphere. From its solution in boiling water, barytes crystallizes on cooling.

Solutions of barium, whether in the state of a hydrate, nitrate, or chloride, are very useful as tests for sulphuric acid, which combining with the oxide of barium (barytes) previously existing in the hydrate or nitrate, or formed from the chloride by the decomposition of water, is precipitated by them from any liquid.

Ignited intensely, it absorbs oxygen if exposed to it, and passes to the state of deutoxide. This earth is poisonous; the specific gravity of barytes, is 4. Its equivalent is 78.

190. EXPERIMENTAL ILLUSTRATIONS.

Barytes, free from water, exhibited; also in crystals.

Barytic water rendered milky by the carbonic acid of the breath. Solutions of barytes, and of sulphuric acid, introduced into distinct vessels of pure water, have no effect; but portions mingled, in the same vessel, produce a cloud. Water, coloured by alkanet, turmeric, &c., changed by barytes, as by an alkali.

OF STRONTITES, THE PROTOXIDE OF STRONTIUM.

This earth is very analogous to barytes, in its properties and composition. It is distinguished from barytes, by the red colour which its solutions communicate to flame, by its crystallization, by its being more soluble in boiling water, and less so in cold. Excepting barytes, it is more actively alkaline than any other earth, both as respects the taste and vegetable colours.

Strontites may be obtained from the carbonate or sulphate, by a process in every respect similar to that which has been described as the means of procuring barytes.

The equivalent of this earth is 52.

191. EXPERIMENTAL ILLUSTRATIONS.

Turmeric, alkanet, and red cabbage, changed by strontitic water, as by alkalies.

Red colour of the flame of alcohol, containing strontites, shown.

OF THE DEUTOXIDES OF BARIUM AND STRONTIUM.

When the protoxides of barium and strontium are heated in contact with oxygen gas, they absorb it, and may be converted into deutoxides. When an aqueous solution of these earths is added to oxygenated water, the deutoxides of their metallic radicals are precipitated in a crystalline form.

It was by means of the deutoxide of barium, procured by exposing the protoxide, in a glass tube, to a current of dry oxygen gas, that Thenard was enabled to oxygenate water.

The deutoxide of barium was dissolved in chlorohydric acid. By adding sulphuric acid, sulphate of barytes was precipitated, in which one-half of the oxygen of the deutoxide was retained, the other half being left in combination with the water of the solvent. This operation being repeated several times, the liquid became more and more surcharged with oxygen. Afterwards, the chlorine of the acid was precipitated by sulphate of silver, and the sulphuric acid, thus introduced, by barytes. Finally, the oxygenated water being less vaporizable than in its natural state, by placing the oxygenated liquid in an exhausted receiver over a vessel of sulphuric acid, the oxygen was concentrated, until the liquid held double the quantity essential to it as a protoxide of hydrogen.

OF THE METALS OF THE ALKALIES, OR ALKALIFIABLE METALS.

Under this head Potassium, Sodium, and Lithium, are included.

OF POTASSIUM.

The discovery of potassium and sodium was made by Sir Humphry Davy, in 1807, by exposing their oxides, potash, and soda, to the divellent influence of the Voltaic poles. These metals were afterwards obtained, more copiously, by subjecting the alkalies, in contact with iron in a divided state, to intense heat, in a luted gun barrel. Lately, a farther improvement has been made by heating the alkali intensely, while intermingled with charcoal.*

The alkaline metal, whether it be potassium or sodium, being volatile at any temperature above redness, is extricated in the state of vapour, and condensed in a part of the apparatus, where the heat is below redness.

Of the Properties of Potassium.

Potassium, when newly cut, strongly resembles silver in appearance. It is malleable, and so soft at ordinary temperatures, as to be moulded between the fingers like wax. When cooled to 32° it becomes brittle, and exhibits, when broken, a crystalline fracture. It melts at 106°, and is converted into vapour when heated to a little below redness. When exposed to the air at the ordinary temperature, it absorbs oxygen rapidly, and is converted into potash. This absorption is sometimes so active, especially when aided by friction, as to cause the inflammation of the potassium. I lost once half an ounce, in consequence of attempting to extricate it by dividing the bottle by a file; it took fire, and was entirely oxidized. The af-

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* See Appendix, for my Letter on Brunner's Process for obtaining Potassium.

finity of this metal for oxygen is so strong, that when thrown upon water or ice, it combines with the oxygen, while the hydrogen takes up a certain portion of the potassium, and burns with a beautiful rose coloured flame. Potassium is lighter than water, as its specific gravity is only 0.86. It is a good conductor of heat and electricity.

OF SODIUM.

Sodium resembles potassium in its appearance, and in many of its properties. It retains its softness and malleability when cooled to 32°. A globule of sodium thrown upon water, swims to and fro on the surface with great rapidity, absorbing oxygen, and evolving hydrogen from the water; yet no inflammation ensues. This is probably owing to the rapidity of its motion, which by bringing it in contact with successive portions of water, keeps the temperature below that which is necessary to combustion; since, when the water is thickened with a little gum, which tends to impede the motion of the globule, sodium burns with a brilliant yellow flame. The presence of an acid produces the same result. The affinity of sodium for oxygen, does not appear to be so strong as that of potassium, since, according to Thenard, it is not oxidized when exposed to dry atmospheric air, or oxygen. It melts at 194, and for volatilization, requires a higher temperature than potassium.

Sodium forms a number of alloys with potassium; one of these remains fluid at 32°, and is lighter than naphtha. The specific gravity of sodium, is 0.97223. It is a good conductor of heat and electricity.

192. EXPERIMENTAL ILLUSTRATIONS.

The inflammation of potassium and sodium upon water and ice, exhibited; and the regeneration of the alkali demonstrated by the usual tests. The decomposition of potash, by iron card teeth, heated to incandescence. Apparatus for its evolution, exhibited.

OF POTASH, OR POTASSA, AND SODA, THE PROTOXIDES OF POTASSIUM AND SODIUM.

A ley obtained by the lixiviation of the ashes of inland plants, especially wood, when boiled down, yields the potashes of commerce. Potashes ignited so as to destroy vegetable colouring matter, and other impurities, again dissolved, and boiled to dryness, form pearlash. Pearlash dissolved in water, boiled with quicklime, filtered, and boiled down to the consistency of moist sugar, dissolved in alcohol, and boiled down gradually, and lastly, fused at a red heat in a silver vessel, forms the potash, or, more strictly, the hydrate of potash of chemists. If, as soon as the alcohol has escaped, the residual mass be refrigerated, it crystallizes. After fusion at a red heat, the alkali contains about 20 per cent. of water, existing in it as an acid, and of which, per se, it cannot be deprived by heat.

Berzelius advises the addition of one and a half parts of pure quick lime, to one part of the alkaline carbonate, dissolved in a cauldron, and kept boiling. The lime is not to be added at once, but gradually; as without this precaution, the resulting carbonate of lime retains like a sponge, a great part of the alkali. The liquid is to be tested by means of an acid or lime water, until it ceases to indicate the presence of carbonic acid. After this, it may either be kept in a liquid state, or evaporated till it crystallizes, and preserved in crystals; or being ignited till it becomes red hot, and poured out on a slab, or into moulds, it may be preserved in the state of hydrate. I have used for the purpose last mentioned, the moulds usually employed for casting musquet balls. The spherical form presenting the least surface in proportion to the mass, is favourable for a substance liable to be deteriorated by contact with the atmosphere. When pearlash is resorted to, after the caustic ley has been evaporated to the consistency of moist sugar, in order to get rid of its impurities, it must be redissolved in alcohol. This liquid combines with the pure potash, while a portion of water contained in, or formed from, the alcohol, separates from it in union with the impurities. The alcohol being removed from the potash by distillation, it may be procured in the crystalline form, or in that of a dry hydrate, according to the heat employed.

According to Berzelius, pure carbonate of potash may be procured from bitartrate of potash, whether carbonized by heat, or deflagrated with pure nitre, or by solution and vaporization.

Soda is obtained from the ashes of certain plants which grow on the sea shore, as potash is by the incineration of those which grow inland—also from chloride of sodium, and sulphate of soda.

Soda is purified, and procured in the state of hydrate, or crystals, by a process analogous to that above described for its kindred alkali.

Of the Properties of Potash and Soda.

Potash and soda are of a greyish white colour, and in common with other alkalies, have a peculiar taste. They render tincture of turmeric brown, syrup of violets green, and alkanet blue. Colours changed by acids, are restored by them. They are the opposites of, and antidotes to, acids, and capable of forming with them neutral compounds, or in other words, such as are neither acid nor alkaline. They are incorrectly said to render vegetable blues green, as if this were universally true. Alkanet is made blue by them, while neither litmus nor indigo is made green.

Although potash is more soluble than soda, and is deliquescent, while soda effloresces, yet the salts of soda are more soluble than those of potash. Both cauterize the flesh. Potash is the more active; common caustic is an impure hydrate of this alkali.

The crystallized potash, contains four atoms of water to one of the oxide, of which three only can be expelled by heat. After fusion it may be called, however it may seem paradoxical, an anhydrous hydrate, though not an anhydrous oxide. The hydrate of potash consists of one atom of alkali, one of oxygen, and one of water.

Both potash and soda, fuse when subjected to a red heat. The atomic weight of potash is 48; that of soda 32.

Potash may be distinguished from soda, by its forming salts nearly insoluble in water, with tartaric, or oxychloric acid; while those formed by soda with the same acids are soluble. Chloride of platina causes a yellow, and sulphate of alumine a white, precipitate with potash, but not with soda.

193. EXPERIMENTAL ILLUSTRATIONS.

Characteristic changes produced in vegetable infusions, as in a previous illustration, page 204.

To saturated solutions of potash and soda, or their carbonates, a saturated solution of tartaric acid being added in excess, crystals are yielded by the potash only. Into different salts of the two alkalies, in solution, chloride of platinum being poured, a light yellow precipitate distinguishes the potash.

OF THE PEROXIDES AND SUBOXIDES OF POTASSIUM AND SODIUM.

A peroxide of potassium is produced by the combustion of potassium on a plate of silver in oxygen gas, in which case the metal acquires three times as much oxygen as it holds in the state of potash. The peroxide is also obtained when nitre is intensely heated, or when potassium is deflagrated with nitre.

Two parts of sulphate of potash, and one of lampblack, give a pyrophorus, which ignites with scintillation in the air. This arises, no doubt, from the evolution of potassium, or the formation of its sulphuret.

The peroxide of potassium is of a greenish yellow colour, and possesses most of the properties of the protoxide, excepting that of acting as a base. When brought in contact with water or acids, it is decomposed into potash and oxygen.

The peroxide of sodium is of a greenish yellow colour, and in its properties analogous to the peroxide of potassium, except that at a high temperature it abandons part of its oxygen, and is converted into protoxide. It cannot, therefore, be obtained by burning sodium in an excess of oxygen, since the heat produced by the combustion, would be sufficient to decompose the peroxide, if already formed. In order to procure it, it is necessary to heat soda in contact with oxygen. The peroxide of sodium contains one and a half atoms of oxygen, united to one of metal.

Berzelius mentions that suboxide of potassium may be obtained by heating the metal in a quantity of oxygen inadequate for its saturation; also by exposing to a temperature of about 40° F., a mixture of hydrate of potash and potassium, in equivalent proportions, in which case the metal is oxydized at the expense of the combined water, the hydrogen escaping. The anhydrous protoxide may be obtained in like manner, by heating potassium with a greater quantity of the hydrate.

Turner alleges, however, that the suboxide of potassium is generally regarded by chemists as nothing more than a mixture of potassium and potash.

According to Berzelius, a suboxide of sodium may be obtained by the same means as the suboxide of potassium, substituting the one metal for the other. The same uncertainty, however, prevails with regard to it, as with regard to the suboxide of potassium.

When either potassium or sodium is heated in ammonia, it combines with nitrogen, liberates hydrogen, and the resulting nitruret absorbs ammonia; so that we have a combination of two binary compounds of nitrogen, which may possess, to a small extent, the relation of acid and base. There are, however, no phenomena in chemistry which are more anomalous than those which are associated with the production and evolution of this compound. Nevertheless as its nature is unintelligible even to adepts, I shall not present the details to my pupils.

I hinted, when entering upon the subject of nitrogen, that it would be seen in the sequel, that it was not destitute of pretensions to a place in the basacigen class. It was in reference to the phenomena above alluded to, that I made that remark.

If nitrogen forms the common ingredient in two compounds, one electronegative, the other electropositive, which combine to form a third, it fulfils the condition of a body producing both an acid and a base, and is of course a basacigen body. Yet it has already been pointed out that there is no class, of which some of the members do not display properties which might cause them to be placed in another class.

Of the Combinations of Potassium with Phosphorus.

Phosphorus and potassium, heated together in nitrogen or in hydrogen gas, combine with the phenomena of combustion. In phosphuretted hydrogen, potassium burns, combining with phosphorus, and liberating the hydrogen.

This combination decomposes water, but according to Berzelius, the gas evolved does not inflame spontaneously.

Of the Combinations of Potassium with Carbon, Boron, and Silicon.

The black matter which remains after the distillation of potassium, as obtained by Brunner's process, is alleged by Berzelius to be a percarburet of potassium. When moistened, it inflames, no doubt by decomposing water and evolving potassuretted hydrogen. The black matter which obstructs the tube used in the evolution of potassium by the process above mentioned, is also held to be a carburet.

These carburets I have found useful in purifying naphtha, by its distillation with them. After undergoing this ordeal, potassium may be kept in it with less appearance of reaction. I am under the impression that the carbon which remains in the iron bottle, is imbued with potassium possibly in a state of chemical union. This may be used likewise for the purification of naphtha.

It appears as if, during the reduction of boric acid by potassium, a boruret is formed; since a portion of the mass evolves a gas on being moistened, which has not the smell of pure hydrogen. It is probably a boruretted hydrogen.

A silicuret of potassium is obtained during the decomposition of fluosilicic acid gas. A portion of the liberated silicon combining with potassium, forms the compound in question. This, on being moistened, gives off hydrogen, which has a peculiar odour resembling that of phosphuretted hydrogen. The analogy between these results and those mentioned in reference to boron, is obvious.

OF LITHIUM.

A fixed alkali was discovered, in 1818, by Mr. Arfwedson, to exist in a small proportion, as an ingredient in a mineral called petalite. He afterwards discovered it in two other minerals called spodumene and lepidolite. Allusion to this alkali, and the origin of its name, was made, page 154.

By the influence of the Voltaic pile, decided indications have been obtained of the existence, in lithia, of a metallic radical. To this the name of lithium has been given. Lithium resembles sodium in appearance.

OF LITHIA.

Lithia, known only in the state of a hydrate, is white, caustic, and has all the attributes of an alkali. When lithia, whether in the state of a carbonate, or uncombined, is heated in contact with platinum, the metal is attacked, and a compound formed, which, according to Thenard, probably consists of the oxide of platinum, united to the oxide of lithium, and must of course be a platinate of lithia. Lithia is composed of one atom of lithium, equivalent 10, and one atom of oxygen, equivalent 8.

Lithia is less soluble in water or alcohol, than soda or potash. Its carbonate is less soluble in water than the carbonates of those alkalies. The chloride of lithium is deliquescent, and soluble in alcohol; the phosphate of lithia is insoluble in water, in which respect these compounds differ from corresponding with the combinations with the other fixed alkalies, or their radicals.

OF THE REACTION OF CHLORINE, BROMINE, IODINE, FLUORINE, AND CYANOGEN WITH THE METALS OF THE EARTHS AND ALKALIES.

In the preceding edition of this work, it was mentioned that for magnesium, yttrium, glucinum and thorium, chlorine has not sufficient affinity to expel the oxygen from their oxides, and that it was only in the state of oxide that they could be subjected to the gas. It has been already stated, that Oersted ingeniously contrived to enable chlorine to combine with aluminum, by the co-operating affinity of intermingled carbon, for the oxygen with which, in the state of earth, this metal is united: also, that a similar process had been successfully employed to produce chlorides of glucinum, yttrium and magnesium. The most important consideration, associated with the existence of these chlorides, is their susceptibility of decomposition by potassium, and the consequent isolation of their metallic radicals.

When the oxides of calcium, barium, strontium, potassium, sodium, and lithium are heated in chlorine, these metals are converted into chlorides, the oxygen being displaced. Potassium and sodium burn actively in chlorine, and it appears probable that any of the metals of the alkalies or alkaline earths may, with heat, if not without, be directly combined with any of the halogen bodies. The same combinations may be obtained in the wet way by complex affinity, on presenting their oxides to the acids formed by these bodies with hydrogen.

The chlorides of the metals of the alkalies, and alkaline earths, are all soluble, and some of them deliquescent. When in solution, they contain the same elements as if they were chlorohydrates of oxybases; and are therefore considered as such by some chemists.

The difference between a chloride in solution, and such a chlorohydrate, is rendered evident, by setting down the ingredients agreeably to both suppositions, as follows.

$$\underbrace{\underbrace{\text{Hydrogen, chlorine.}}_{\text{Chlorohydric acid.}} \qquad \underbrace{\text{Oxygen, metal.}}_{\text{Oxide.}}}_{\text{Chlorohydrate.}}$$

$$\underbrace{\underbrace{\text{Hydrogen, oxygen.}}_{\text{Water.}} \qquad \underbrace{\text{Chlorine, metal.}}_{\text{Chloride.}}}_{\text{Dissolved Chloride.}}$$

The soluble chlorides produce precipitates in solutions of silver, lead, or black oxide of mercury. They do not deflagrate with charcoal—nor do they, like sulphates, after being heated with it, yield the odour of sulphuretted hydrogen, on being moistened.

The soluble chlorides of the metals of the alkaline earths and alkalies, excepting that of magnesium, are, by heat, converted into anhydrous chlorides, easily detected by the fumes which they give with sulphuric acid.

Bromine, like chlorine, when heated with any of the fixed alkalies, or alkaline earths, except magnesia, displaces the oxygen and combines with the metallic radical. Like chlorine also, it does not, per se, produce this effect either with magnesia or the earths proper.

Of iodine, the affinities are, in most cases, less energetic than those of chlorine or bromine. Potash and soda are the only oxides of the metals of the earths and alkalies, from which iodine can, with the assistance of heat, expel the oxygen in order to combine with their metals.

The bromides and iodides, when combined with water, may, like the chlorides, be regarded either as in a state of solution or as bromohydrates and iodohydrates. The bromides may be recognised by the red vapours which arise when they are heated in a tube with the bisulphate of potash. Similar vapours would be given out by the nitrites, if treated in the same way, but the bromides may be distinguished from those salts, by their not deflagrating when thrown on incandescent coals.

The iodides may be detected by projecting a portion into a tube containing a small quantity of sulphuric acid, heated nearly to ebullition. By these means iodine, if present, will be made apparent in the form of a violet vapour. Iodine is also displaced from its combinations by chlorine, and when these are, previously to the addition of chlorine, mingled with a paste made of starch, produces a blue colour. It is alleged that sea salt sometimes contains a quantity of iodine adequate to produce this result.

Berzelius states, that when potassium is heated in cyanogen, it is converted into a cyanide, also that the habitudes of sodium are in this respect similar. It is probable that the same result would ensue with all the metals of the alkalies and alkaline earths. Cyanogen is usually generated by the reaction of potash with animal matter, which deoxidizes the alkali, and at the same time furnishes to it the elements of cyanogen, which, in consequence, simultaneously unite with each other, and with the metal, forming a cyanide of potassium.

When the cyanoferrite of potassium is intensely heated, the cyanoferric acid is decomposed. The cyanide of potassium remains mingled with a carburet of iron, and may be extricated by solution, filtration, evaporation, and crystallization. Subjecting the cyanoferrite of sodium to the same process, the cyanide of sodium may be obtained. (See page 241.)

The cyanides may be detected by their power of producing a blue colour, with solutions of the peroxide of iron; also by evolving the odour of peach blossoms, when subjected to chlorohydric acid.

Could fluorine be isolated, it is highly probable that its reaction with the metals of the earths and alkalies would be analogous to that of chlorine. The fluorides, however, differ much from the chlorides in solubility. Some varieties of the fluoride of calcium constitute Derbyshire spar, while the chloride of calcium is a deliquescent salt.

The presence of fluorine in a mineral may, in a majority of instances, be detected by the following process. Let a small portion of it be pulverized and subjected to heat with about twice its weight of concentrated sulphuric acid, in a leaden, silver, or platina cup. Let this cup be covered by a glass plate, coated with beeswax, through which some letters have been traced so as to denude the vitreous surface. After exposure for half an hour, aided by as much heat as can be used without melting the wax, the glass should be relieved from its coating and examined. Then if the portions of the vitreous surfaces, exposed to the fumes, prove to be so corroded as to render the characters traced through the wax distinguishable, the presence of fluorine may be inferred.

Berzelius informs us that when this principle is in combination with silicon, it will not act on glass; hence, he advises that the mineral suspected of containing fluosilicic acid should be subjected to the flame of the blowpipe, at one end of a glass tube, of which both ends are open, so that the fumes produced may be impelled by the blast through the tube from one orifice towards the other. By these means, milky spots will appear on the glass in consequence of the condensation of water containing fluosilicic acid, if it be an ingredient in the mineral.

OF THE REACTION OF SULPHUR, SELENIUM AND TELLURIUM WITH THE METALS OF THE EARTHS AND ALKALIES.

Sulphur unites with all the metals of the alkalies and alkaline earths, so far as the experiment has been tried, whether presented to them in the metallic state, or in that of oxide. Its power of reducing their oxides is greater than that of any other basacigen body; as when present in excess, it acts by its affinity for the oxygen and the metal. (See 4th case of affinity, page 83.) The affinity of the halogen bodies for oxygen, is so inferior to that of sulphur, that when oxygen is expelled from oxides by one portion of them, it does not combine with another, however great the excess in which they may be present.

Sulphides are also formed by deoxydizing the sulphates by carbon or hydrogen, with the aid of heat; by boiling sulphur in water with the earth or alkali to be converted, or by passing sulphydric acid into water, holding the oxide in solution or suspension. When this is done under favourable circumstances, the metal is converted into a sulphobase by the sulphur of one portion of the acid, while the compound thus formed unites with another portion of the acid forming a sulphosalt, denominated a sulphydrate. This view of the subject we owe to Berzelius, who has shown that sulphur, selenium, and tellurium all have the property of forming acids with one set of radicals, and bases with another, and that the sulphacids and sulphobases thus formed, are capable, like oxacids and oxybases of forming compounds which he considers as sulphosalts, or salts in which sulphur performs a part analogous to that which oxygen performs in oxysalts, such as the sulphate or nitrate of potash. (See page 98.)

Formerly it was supposed that when absorbed by an alkaline solution, sulphydric acid (sulphuretted hydrogen) combined with the oxybase, forming what was called a hydrosulphuret. It was also supposed that a sulphide (sulphuret) of an alkalifiable metal by solution in water, would be converted into an oxybase by the oxygen of the water, while the hydrogen, with a double portion of sulphur, forming bisulphuretted hydrogen, would combine with the oxybase.

Through the sagacity and industry of Berzelius, much knowledge has of late years been acquired, respecting the combinations of sulphur with the alkaline metals. He mentions seven compounds, in which, supposing the quantity of the potassium in each to be the same, the quantities of the sulphur are severally 1. 2. 3. $3\frac{1}{2}$. 4. $4\frac{1}{2}$. 5.

To remember the details respecting the means of obtaining, and the characteristics of these sulphides, would be a burthen too great for the memory of those who are not so situated as to take a particular interest in them.

Sulphides of the metals of the earths and alkalies, on being moistened with water, evolve sulphydric acid, and produce this result still more actively on being subjected to chlorohydric acid.

The selenides of metals of the earths and alkalies may, in most cases, be produced by heating the metal with selenium. The selenides of these metals bear a great resemblance to the sulphides, and when heated are reduced to the metallic state, producing the smell of horse-radish.

The tellurides are but little known, and, except so far as they act as telluriacids, or telluribases, unimportant.

OF METALS PROPER.

OF GOLD.

Gold is usually found in nature, nearly pure. It is not liable, like other metals, to be disguised by a union with oxygen or sulphur. The precipitate obtained from a solution of gold coin, in aqua regia, by the green sulphate of iron, is pure gold. This metal is also purified by exposure to heat and air, or to nitric acid, by which means baser metals are oxidized, as in the processes of cupellation and parting.

From the sands, or ores, in which they exist naturally, minute portions of gold are collected, by trituration with mercury, with which they amalgamate. The gold thus secured, is separated from the mercury by distillation.

Gahn inferred the existence always of a quantity of gold in ferruginous pyrites, (sulphide of iron,) sufficient to be detected by a very accurate examination.

Of the Properties of Gold.

Its colour and lustre are well known. Its specific gravity is 19.3. It is the most malleable and ductile metal, and suffers the least by exposure to air and moisture. Gold leaf, which is about 1000 times thinner than printing paper, retains its lustre in the air. Gold leaf transmits a greenish light, but it is questionable, if it be truly translucent. Placed on glass, and viewed by transmitted light, it appears like a retina. It is erroneously spoken of as a continuous superficies.

The colour of gold, according to Berzelius, is rendered paler by fusion with borax; while when fused with nitre, or chloride of sodium, it recovers its yellow colour.

Gold fuses at a low white heat, but requires the temperature produced by the compound blowpipe, by galvanism, or by the explosive power of electricity, to volatilize or oxidize it. Its not being liable to tarnish by exposure, is due to the weakness of its affinity for oxygen or sulphur.

When a solution of chloride of gold is mixed with sulphuric ether, the ether takes the metal from the chlorine retaining it in solution. If iron or steel be moistened with this ethereal liquid, it is productive of a slight gilding.

Phosphorus, carbon, and the baser metals, also hydrogen gas and its compounds, by attraction for oxygen, precipitate gold in the metallic form.

With arsenic, gold combines energetically, absorbing this metal in the form of vapour, at a red heat, without changing colour. Gold loses its malleability by acquiring $\frac{1}{500}$ of its weight of arsenic.

Probably gold may be united with all the metals. It amalgamates readily with mercury. Phosphorus forms a brittle compound with gold. The equivalent for gold is 200.

OF THE COMPOUNDS OF GOLD WITH OXYGEN.

According to the nomenclature employed by Thenard, an oxide consisting of one atom of the radical, and two of oxygen, is a bioxide. In a trioxide, agreeably to the same authority, there are, as the word implies, three atoms of oxygen to one of the radical. I prefer these appellations to those of deutoxide or tritoxide, where the proportions are as above stated. They are more precise and descriptive. These names differ in their meaning from the others above cited, which merely convey the idea that the oxide belongs to the second or third stage of oxidation, whether the proportions be 1 to 2, or 1 to 3, or 1 to 1½, or 2 to 5.

By subjecting a protochloride of gold to a solution of caustic potash, oxygen takes the place of the chlorine and protoxide of gold results. A part of this remains in solution, and is converted into a trioxide and metallic gold. The trioxide of gold is obtained by digesting an aqueous solution of the bichloride with magnesia in slight excess. This oxide, which is capable of acting both as an oxacid, and as an oxybase, in this instance acting in the former capacity, combines with magnesia, and constitutes an aurate, of which the greater part precipitates, while the remainder continues in solution. The precipitate should be washed with water until it ceases to acquire a yellow colour by the addition of chlorohydric acid. It should then be digested with nitric acid, which combines with the magnesia, and thus isolates the trioxide. If the nitric acid, which has been employed, be concentrated, we obtain the trioxide in an anhydrous state, and of a brown colour, but if dilute, as a yellowish-red hydrate.

The protoxide consists of one atom of gold, and one of oxygen, the trioxide of one of gold, and three of oxygen. Hence, agreeably to the example of Thenard, I designate it as a *tri*oxide. Acting as a base, this oxide combines with nitric or sulphuric acid. It is precipitated from these combinations by water, which acts, probably, in this case, as an oxybase of hydrogen.

As an oxacid, trioxide of gold unites with all the alkalies, and alkaline earths. The aurate of ammonia, a compound which explodes by percussion, has long been known under the name of fulminating gold. Berzelius alleges that there are two kinds, one formed with an excess of ammonia, detonates more powerfully; another, formed with a lesser quantity of the alkali, contains chloride of gold, by which its power is enfeebled.

A precipitate, of a beautiful purple colour, may be obtained, either by mixing diluted solutions of the chloride of tin and gold; or by immersing an ingot of tin, or tin foil, in a solution of chloride of gold, containing some free chlorohydric acid. To this precipitate the name of the purple powder of Cassius has been given. I infer from the account of this compound, given by Berzelius, that it consists of gold, tin, hydrogen and oxygen. Respecting the mode of combination, there is some obscurity.

In consequence of this property of producing the purple of Cassius, tin, whether in the metallic state, or that of dissolved protochloride, is the best test for gold.

Berzelius does not consider the purple powder into which gold is reduced by successive electric discharges, as any thing more than metallic gold in a state of minute division.

OF THE COMPOUNDS OF GOLD WITH THE HALOGEN CLASS.

Chlorine exercises a very energetic affinity for gold. A combination between them ensues, whether the metal be heated in the gas, or presented to it in the aqueous solution, or in aqua regia. The liquid which bears this name, is produced by the mixture of chlorohydric with nitric acid. It ought not, however, to be considered as a combination of them. As soon as the mixture is effected, a decomposition of both of the acids commences. All the hydrogen of the one, and part of the oxygen of the other, unite to form water; chlorine and nitrous acid, being disengaged, and more or less evolved; especially if aided by heat. Excepting that it contains chlorine in a higher degree of concentration, which of course enables it to act with more energy, aqua regia does not differ, *in its solvent powers*, from a solution of chlorine in water. It cannot properly be considered as a distinct acid, since *the salts which it produces*, are always chlorides.

The name of aqua regia, or royal water, was given to this solvent on account of its property of dissolving gold, the alleged king of metals. Since the promulgation of the French nomenclature, it has been called nitro muriatic acid; but as this conveys a false idea of its nature, I would call it by its old name, aqua regia, or, if a new name be necessary, I would suggest that of nitraqueous chlorine. Formerly the aqueous solution of chlorine and aqua regia, were the only known solvents of gold. Latterly Gay Lussac has alleged iodic acid to be a solvent of this metal, and by Mitscherlich, the same power is ascribed to selenic acid.

The protochloride of gold is obtained by exposing the trichloride to a gentle heat, which drives off two atoms of chlorine, leaving the gold in combination with the remainder. If the heat be carried too far, it is apt to decompose the protochloride into metallic gold and chlorine. On this account it is better to stop the operation before the trichloride is entirely decomposed, and to wash the resulting mass with water, which removes the trichloride, and leaves the protochloride, which is insoluble in that fluid when cold. A solution of the chlorohydrate, of the trichloride of gold, acting as a chloribase, is obtained when gold is dissolved in aqua regia.

The trichloride may be isolated by heat, which expels the chlorohydric acid. It is of a pale yellow colour, and has an astringent and disagreeable taste. This chloride combines as an acid, with the chlorides of the alkaline metals, forming chloroaurates. Hence I consider this as entitled to the appellation of chloroauric acid. The trichloride of gold, is composed of one atom of gold, and three atoms of chlorine.

Of the Nomenclature of the Chlorides of Gold.

In designating the trichloride of gold by the name of chloroauric acid, and in speaking of its combination with the chlorides of potassium and sodium, &c. as chloroaurates, I find I am supported by the opinion of Thenard, who, in the second and third volume of the new edition of his work, wherever he has occasion to mention the combination of the electronegative with the electropositive chlorides, speaks of the electronegative compound, as playing the part of an acid. Moreover, in the third volume of his work, in treating of compounds, consisting severally of two sulphides, two selenides, or two tellurides, he expresses the opinion that it would be inconsistent to designate these as combinations of sulphacids and sulphobases, if analogous terms are not to be applied to the electronegative and electropositive ingredients, in the double haloid salts of the Berzelian nomenclature.

Dumas, in his Traité de Chimie, in describing the combinations formed by electronegative with electropositive chlorides, represents the former as acting the part of chloracids, the latter that of cholorobases.

Dr. Thomson has adopted views corresponding, in this respect, with those of Thenard and myself, and actually employs, to a great extent, the same language.

Bromine forms with gold, a tribromide, which corresponds in composition and chemical properties with the trichloride of the same metal.

The iodide of gold agrees, in composition and chemical relations, with the protochloride of gold.

The cyanide of gold appears to act as an acid.

OF THE COMBINATIONS OF GOLD WITH SULPHUR.

Gold forms with sulphur a protosulphide and a persulphide. The protosulphide is formed by passing a current of sulphydric acid gas through a boiling solution of the bichloride. It is of a deep brown colour, and is decomposed by heat into metallic gold and sulphur.

The persulphide may be precipitated, by an acid from a solution of the sulphaurate of potassium. It is of a deep yellow colour, and is decomposed by heat. With sulphobases it acts as an acid, but with the more powerful sulphacids as a base.

194. EXPERIMENTAL ILLUSTRATIONS.

Some gold leaf is placed in two glass vessels. Nitric acid being poured into one, and chlorohydric acid into the other, the gold is not acted upon; but when the contents of the two vessels are united, the gold disappears.

Gold dissolved by aqua regia, and precipitated by sulphate of iron, or by chloride of tin. A cylinder of phosphorus, immersed in a solution of the metal, acquires the appearance of a cylinder of gold. Separation of gold from its solution by ether. Effects of the ethereal solution exhibited. Action of mercury on gold leaf.

OF PLATINA, OR PLATINUM.

This metal, in the crude state of its native grains, as it comes from South America, may be dissolved in aqua regia; by which it is converted into chloroplatinic acid.

(See Letter on Berzelian Nomenclature, page 6.) A solution of sal ammoniac being added, an orange coloured precipitate results, of chloroplatinate of ammonium. Ignition developes the metal from this precipitate, but in a divided state. By intense pressure, the minute particles thus procured, are made to cohere, so far as to sustain the welding process. By this they are made to coalesce into a perfectly solid and coherent mass.

According to Berzelius, platinum, as obtained by the process abovementioned, is alloyed with iridium, and inferior to the pure metal in colour, brilliancy, ductility, and malleability; while at the same time it is stronger and more suitable for the purposes for which it is usually employed. It may be obtained pure, by precipitating chloroplatinic acid from its aqueous solution by chloride of potassium, igniting the precipitate, redissolving it, and precipitating again by sal ammoniac; and lastly, by reducing the precipitate by ignition to the spongy form from which, by pressure and the welding process, it may be made coherent and malleable, as in the above mentioned process for obtaining the metal.

Of the Properties of Platinum.

The colour of this metal as ordinarily obtained, is intermediate between that of silver and steel; but when pure, as above stated, in colour and softness it resembles silver, more than when alloyed with iridium. Its specific gravity is 21.53. A cubic inch of it weighs nearly three-fourths of a pound. It is about twice as heavy as lead, being the heaviest body known. It is less ductile and malleable than gold, but harder and more tenacious; though, in these respects, inferior to iron. Like iron, it is susceptible of being hammered and welded at a white heat. It can neither be oxidized nor melted, by the highest temperatures of the air furnace or forge. It was first fused in a focus of the solar rays—afterwards by means of a stream of oxygen gas on ignited charcoal—but much more easily by the compound blowpipe, under which it was first oxidized and dissipated by heat. It fuses and burns easily in the Voltaic circuit, and is dispersed and oxidized by mechanical electricity. It is one of the worst conductors of heat among metals.

In its habitudes with oxygen, chlorine, or the acids, it is analogous to gold, being, like that metal, detected by protochloride of tin, which produces with it a claret colour. It unites so energetically with tin, at a red heat, as to occasion the phenomena of combustion. When in a divided state, as obtained by igniting the chloroplatinate of ammonium, it amalgamates with mercury by trituration.

Platinum combines with boron, silicon, and phosphorus. On account of its infusibility at the highest temperatures produced by the air-furnace, or forge, and insusceptibility of being corroded by the acids usually employed in chemical processes, it is much used by chemists for crucibles, evaporating vessels, and spoons; also in experiments in which Voltaic series are resorted to as a mean of decomposition. I employ it in my galvano-ignition apparatus (see page 58). At high temperatures, it is acted upon by the alkaline hydrates, and almost all metals, especially tin or lead. I had a platina crucible perforated, by fusing in it some flint glass, which consists of lead, silicic acid, and potash.

The equivalent of platina is 96.

OF THE COMPOUNDS OF PLATINUM WITH OXYGEN.

Platinum forms a protoxide, consisting of one atom of metal, and one atom of oxygen, which may be obtained from the chloride, by the addition of potash. It forms also a bioxide, containing two atoms of oxygen to one of metal, as the name implies. The protoxide acts as an oxybase only; the bioxide, both as an oxybase and oxacid. In the last mentioned capacity, it enters into combination with ammonia, in a compound called fulminating platinum, and which we may with propriety call platinate of ammonia, or ammonium. Dr. Thomson alleges the existence of some other oxides of platinum.

Of the Compounds of Platinum with the Halogen Class.

Platinum forms two compounds with chlorine. The protochloride consists of one atom of platinum, and one of chlorine; the bichloride, of one atom of platinum, and two of chlorine.

The protochloride of platinum is obtained by subjecting the bichloride to heat. If the heat be pushed too far, the protochloride is decomposed. This chloride, according to Thenard, combines as a base with chlorohydric acid. As an acid, it combines with the chlorobases. I would therefore call it chloroplatinous acid, and the salts which it forms, chloroplatinites. The chloroplatinous acid is of a grayish colour, and insoluble in water.

The bichloride of platinum may be procured by evaporating a solution of platinum in aqua regia, which yields crystals of the chlorohydrate of the bichloride of platinum, from which the chlorohydric acid may be driven off by a gentle heat. In colour it is a dark reddish brown, and in taste, disagreeable and astringent. It dissolves in water, forming a solution which, when saturated, is of a deep red colour. It combines with a great number of other chlorides, with which it acts the part of an acid, although it is susceptible of uniting with chlorohydric acid as a base. Its properties in these respects, entitle it to the appellation of chloroplatinic acid.

Bromine forms with platinum, a compound analogous in composition to the bichloride of that metal, and which, from its chemical properties, is entitled to the appellation of bromoplatinic acid.

Iodine and fluorine both, form compounds with platinum. The fluoride of platinum acts as an acid; the properties of the iodide in this respect are not known.

Cyanogen forms two compounds with platinum. The percyanide combines with cyanobases as an acid, and of course may be designated as cyanoplatinic acid.

OF THE COMPOUNDS OF PLATINUM WITH SULPHUR.

Platinum combines with sulphur in two different proportions. Both sulphides combine as sulphobases with sulphacids, but the persulphide unites as a sulphacid with sulphobases of the alkalifiable metals.

195. EXPERIMENTAL ILLUSTRATIONS.

Platinum exhibited in the state of native grains, and in the malleable state. Precipitated from its solution by chloride of ammonium, and chloride of tin. A precipitate produced in salts of potash, by chloride of platinum, distinguishes them from salts of soda. Combustion of platinum with tinfoil.

Of the Power of Platinum, and other Metals in a divided or spongy Form, to induce Chemical Reaction.

In the spongy form in which platinum remains after the chlorine and ammonia of the chloroplatinate are expelled, it has the wonderful power of causing the inflammation of a mixture of hydrogen and oxygen gas. I have ascertained that this power is acquired by asbestos, porcelain earth, or charcoal, merely by soaking them in a solution of chloride of platinum, and subsequent desiccation and ignition. Thenard states, that platina filings, platina leaf, or an association of fine platina wires, exercise, in a greater or less degree, the same power as platina sponge.

The pulverulent mass obtained by precipitating platinum by zinc, becomes incandescent in the vapour of alcohol. As the best means of obtaining platinum in that state of minute division in which it is most efficacious in producing this result, Leibig recommends that the chloride should be dissolved in a lixivium of caustic potash, with heat, and that while the resulting liquid is still hot, alcohol should be added in small quantities, stirring the mixture until an effervescence arises from the extrication of carbonic acid. This, however, becomes so active as to render a very capacious vessel necessary for the process. The platinum precipitates in the form of a black powder, which is to be separated from the liquid, and washed successively with alcohol, with a solution of potash, and with chlorohydric acid, and four or five times with water. When dried, the powder resembles lampblack, and soils the fingers. Nevertheless, it consists only of platinum in a state of minute division, since it may be heated to a cherry red in the air, or in oxygen, without losing weight or undergoing any change in its properties. These are, however, destroyed by incandescence, which restores its metallic appearance. Under the burnisher, it becomes slightly of a metallic gray. In aqua regia, it dissolves without leaving any residue.

Its properties are as follows: like charcoal, it condenses the gases in its pores, with a development of heat; and if, after being deprived of air and moisture, by exposure to a vacuum over sulphuric acid, the atmosphere be rapidly admitted, it becomes red hot. It causes the combustion of hydrogen or alcoholic vapour, when in contact with them with access of air, and becomes incandescent on falling on a surface wet with alcohol. If moistened with alcohol, it converts it, at the expense of the oxygen of the air, into acetic acid, and acetic ether. Platinum, however prepared, gradually loses the property of causing a union between oxygen and hydrogen; but this property disappears much more rapidly when exposed to the action of the air, than when protected from its influence. Spongy platinum, moreover, which from its structure does not readily admit air into its pores, remains effective longer than platinum under any other state, unless that in which it is procured by precipitation by zinc, be an exception. Platina leaf, which in the air is rendered powerless in a few minutes, when in the form of a scroll, and included in a close vessel, remains effective for twenty-four hours. The power of producing a union between hydrogen and oxygen, may be restored by immersion in an acid, or incandescence.

Platinum is not the only substance which possesses the property of producing the combination of oxygen and hydrogen. Gold, precipitated from its solution by means of zinc, and subsequently heated to redness, assisted by a temperature of 122°, causes the union of hydrogen and oxygen. Osmium slowly produces the same effect, at a heat a little below that which is necessary in the case of gold. Spongy nickel acts slowly at the ordinary temperature of the atmosphere. Palladium, rhodium, and iridium, produce the same effect on a mixture of hydrogen and oxygen, as platinum, though with less intensity. Charcoal, porcelain, glass, and rock crystal, produce a union between hydrogen and oxygen, at temperatures lower than that at which it would otherwise take place.

196. EXPERIMENTAL ILLUSTRATIONS.

A mixture of hydrogen and oxygen inflamed by platina sponge, or platinated asbestos. Incandescence of platina powder produced by moistening it with alcohol.

OF SILVER.

Silver exists in nature nearly pure, but usually containing a minute quantity of gold, copper, arsenic, or iron. It also exists in alloys, containing various equivalent proportions of arsenic, antimony, tellurium, or gold. It is found, likewise, in the state of chloride, iodide, sulphide and carbonate; and in a variety of galena, the native sulphide of lead, called, in consequence, argentiferous galena. In consequence of its fusibility and insusceptibility of oxidizement, when any metallic alloy, containing it, is exposed to intense ignition with access of air, the silver is separated from any metal which, when thus exposed, is liable to be converted into an oxide. In the small way, this object is effected upon the cupel, in the operation called cupellation. A cupel is a small flat cylinder, made of bone earth obtained by calcination, in the upper surface of which, there is a hemispherical cavity. In this cavity, any gold, or silver, to be refined, is placed with a portion of lead. The cupel is then placed in a small earthen-ware oven, called a muffle, and exposed to a heat sufficient to render and keep the metals fluid. Under these circumstances, the lead is oxidized and vitrified, and promotes a similar change in any other metals present, which are susceptible of oxidizement, under the circumstances in question. The vitreous matter, thus produced, is absorbed by the bone earth. After the process has endured sufficiently, only the gold and silver, or other noble metals, should any be present, can remain upon the cupel. This stage of the process is indicated by the metallic surface being no longer obscured by any film of oxidized matter. As in the cases in which this process is employed, no other noble metals are liable to be present, besides gold and silver, I shall treat of it only in reference to them.

From the alloy purified upon the cupel, the silver may be removed by nitric acid, when the gold does not exceed a fourth of the whole. In order, therefore, to enable the nitric acid to dissolve the silver, the mass is fused with the addition of as much of this metal, as will establish the requisite ratio between it and the gold. This is called *quartation*. The process of separating the metals afterwards by nitric acid, is called *parting*.

If the alloy be subjected to aqua regia, the gold only will be taken up. The silver will precipitate as a chloride, and the parting will be effected the easier, in proportion as the quantity present, of this last mentioned metal, is less.

Silver, contained in argentiferous copper, is extracted by means of lead, in the process called liquation. The alloy is fused with two parts and a half of the metal last mentioned, and cast into thick round cakes. These are subsequently exposed in a reverberating furnace, to a heat sufficient to melt the silver and lead, leaving the copper, which has scarcely any affinity for lead. The silver is afterwards separated from the lead by cupellation.

Pure silver may be obtained from silver coin by various means. The white crystals spontaneously afforded by a solution of the coin in nitric acid, cautiously drained and washed with a portion of water, barely sufficient to remove every vestige of green, yield a solution of pure silver. The residual liquid may be decomposed by copper, and the precipitate redissolved, and crystallized by evaporation, and thus a fresh crop of white crystals may be procured. The whiteness of the crystals may be deemed the criterion of their purity. Silver precipitated by mercury, as in the case of the arbor Dianæ, only requires ignition to render it pure.

Of the Properties of Silver.

Excepting steel, silver is susceptible of the highest degree of metallic brilliancy; and next to gold, it is the most malleable and ductile metal. In metallic whiteness it is pre-eminently beautiful, and in tenacity inferior only to iron, copper, and platina. Its specific gravity is 10.5. It is the best conductor of caloric: fuses at a low white heat: is as difficult to oxidize in the fire as gold, but is more liable to tarnish, when exposed to the atmosphere, from its susceptibility to the action of sulphur and chlorine. Hence it is blackened by eggs or by salt water.

By the compound blowpipe, electricity, or galvanism, silver is fused, oxidized, and dissipated.

Exposed to nitric acid, it is oxidized by one portion, and dissolved by the other. In fact, this acid is its proper solvent. By fusion in a porcelain retort, the nitrate of silver is deprived of its water of crystallization, and is rendered anhydrous, forming the lunar caustic of the shops. It consists of one atom of acid, 54; and one of oxide, 118.

Sulphuric acid, when cold, has no reaction with silver. At a boiling heat, the metal is oxidized at the expense of one portion of the acid; and the oxide, thus formed, is dissolved by another portion, as in the case of nitric acid.

Silver combines with phosphorus, and, in a minute degree, with carbon, and silicon.

Its equivalent is 110.

OF THE COMPOUNDS OF SILVER WITH OXYGEN.

Silver forms two oxides. The protoxide is obtained by decomposing the nitrate by potash or soda. It is of a deep olive colour, slightly soluble in water, and according to Thenard, sufficiently alkaline to render turmeric or syrup of violets green. It revives simply by the influence of heat, and of course is reducible, when heated with those radicals which, under the same circumstances, combine, per se,* with oxygen. When thus reduced, it must of course produce the vivid ignition which is consequent to the presence of pure oxygen.

This oxide, by uniting with ammonia, produces a fulminating compound, so dangerous that few persons have been willing to encounter the risk of making it. This should not be confounded with the fulminate of silver, consisting of the same metal and fulminic acid, treated of in page 243.

The peroxide of silver is formed around a wire, proceeding from the positive pole of the Voltaic series, when a weak solution of nitrate of silver is placed in the circuit. It crystallizes in long needles, endowed with a metallic brilliancy. It does not combine with acids, but when presented to them by a partial relinquishment of oxygen passes to the state of protoxide. This oxide does not act either as a base or an acid. It detonates with phosphorus, if struck with a hammer, while in contact with that substance; and when subjected to ammonia, disengages nitrogen from it, by oxidizing the hydrogen.

The protoxide of silver, consists of one atom of silver, equivalent 110, and one of oxygen, equivalent 8.

Some chemists suppose the existence of a suboxide of silver.

OF THE COMPOUNDS OF SILVER WITH THE HALOGEN CLASS.

Silver unites with chlorine when heated in it, or presented to it in solution. The resulting chloride is one of the most insoluble combinations. Hence, silver is not soluble in aqua regia, or any other liquid containing chlorine; and on this account, soluble chlorides yield a precipitate, when solutions of silver are added to them.

The chloride of silver is white and tasteless, and according to Thenard,

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* These words have long been used by chemists to convey the idea of changes sustained in a mass apparently isolated, or not subjected to the influence of any other ponderable matter.

when exposed to light is decomposed, forming a subchloride. It combines as a base, with the electronegative, and as an acid, with the electropositive chlorides.

It is susceptible of fusion, without decomposition, forming what was called by the old chemists, luna cornea, or horn silver.

Chloride of silver is soluble in liquid ammonia. It may be decomposed by hydrogen, if brought into contact with this gas in its nascent state, as when evolved from zinc or iron, by a diluted acid. It is easily decomposed by the compound blowpipe, supplied with hydrogen and atmospheric air; also by fusion with the fixed alkalies; or when boiled in water with shreds of iron. The formation and subsequent decomposition of the chloride, is one of the modes of obtaining pure silver.

The chloride of silver is composed of one atom of silver, and one atom of chlorine.

Bromine and iodine form, with silver, compounds analogous in composition to the chloride. The bromide and iodide, acting as acids, combine with the bromides and iodides of the alkalifiable metals, acting as bases. A native iodide of silver has been found in Mexico.

Fluorine and cyanogen, both combine with silver; the fluoride acts as a base, the cyanide as an acid.

OF THE COMPOUND OF SILVER WITH SULPHUR.

The sulphide of silver is solid, ductile, easy to cut, of a lead gray, with a metallic brilliancy, more fusible than silver, crystallizable in cubes or octahedra, and indecomposable by fire. It acts as a powerful sulphobase.

This sulphide is produced whenever silver is exposed to sulphur, or sulphydric acid. The blackening of silver spoons by eggs, is ascribed to the existence in the albumen of a minute portion of sulphur. The impression has been entertained, that persons who use the water of the white sulphur springs freely, find silver coin, carried about them, blackened by the sulphur introduced into the blood. This, however, may arise from their frequenting the spring, and thus exposing the silver about their persons to the action of the sulphydric acid gas which is continually evolved from the water. I am, however, far from deeming the fact improbable. It would, a priori, be no more surprising that the blood should be imbued with sulphur, than with mercury.

197. EXPERIMENTAL ILLUSTRATIONS.

Exhibition of an assay furnace and muffle: also of a cupel. Oxidizement and solution of silver in nitric acid exemplified: also its precipitation by chlorides, phosphates, arsenites, arseniates, copper and mercury.

OF MERCURY.

This well known metal is found in nature in the metallic state, pure, and amalgamated with silver; also in the states of sulphide and of chloride. It is obtained principally from cinnabar, the native sulphide, and the most abundant and prolific of its ores, by distillation with the hydrate of lime. In this country it may always be procured nearly pure, in the iron bottles in which it is imported. It is alleged that mercury may be purified by distillation with iron filings. I once distilled several hundred pounds in this way, for my mercurial reservoir, but did not find it to be quite pure afterwards. A better mode is to leave it exposed to dilute sulphuric acid in a porcelain dish, for a month or more. Under these circumstances, any metal having a greater affinity for oxygen than mercury, will be taken up by the acid. When pure, it may be shaken in a white porcelain cup without soiling the surface.

Mercury may be much improved in purity simply by agitation; as for instance, by shaking it in a bottle, allowing it to fall from a great height, or attaching a vessel containing it, to some part of a machine in motion.

Of the Properties of Mercury.

It is the only metal which is liquid at the ordinary temperature of the atmosphere. In colour and brilliancy it resembles, and rivals silver. It freezes into a malleable solid at 39°, and boils at 660°. At the temperature of 60°, its specific gravity is 13.6, but in freezing, increases to 14.4. From some experiments of Faraday, it would appear that mercury vaporizes to a minute extent, whenever the temperature of the air is above 70°.

Mercurial compounds are all volatilizable by heat; and mercurial salts, when moistened and rubbed upon copper, cover it with a film of mercury.

It is alleged that if a drop of any liquid containing mercury be placed upon gold, and touched with the blade of a knife, or a piece of iron wire, the mercury will be precipitated upon the gold.

The equivalents of mercury, and of its compounds, with oxygen, chlorine, and sulphur, are as follows:—

Mercury,	-	-	- equivalent	200
Protoxide,	1 atom mercury	with	1 atom oxygen	208
Bioxide,	1 „	„	2 atoms „	216
Protochloride,	1 „	„	1 atom chlorine	236
Bichloride,	1 „	„	2 atoms „	272
Protosulphide,	1 „	„	1 atom sulphur	216
Bisulphide,	1 „	„	2 atoms „	232

OF THE COMPOUNDS OF MERCURY WITH OXYGEN.

There is still some discordancy in the opinions and language of chemists respecting the oxides of mercury. It has been generally held that there are two oxides of this metal; one black, the other red, the proportion of oxygen to metal by weight being in the former as 1 to 25, in the latter as 2 to 25.

According to Brande's table of equivalents, the atom of mercury = 200, with one atom of oxygen, forms the black oxide or protoxide, = 208, and with two atoms of oxygen forms the red oxide, peroxide, deutoxide, or bioxide, = 216. Dr. Thomson, conceiving the atom of mercury to have only half the weight assigned to it by Brande, considers the black oxide as consisting of 2 atoms of metal, and one of oxygen, and consequently designates it as a suboxide. The difference in this case, therefore, is only hypothetical. But Guibourt has advanced that there is only one oxide of mercury, the black oxide, being composed of the red oxide, and metallic mercury. Donovan, on the other hand, has shown that when a small quantity of calomel is added to a comparatively large quantity of potash, a pure protoxide, or suboxide is obtained.

I shall assume the numbers for mercury and its oxides, to be those above quoted from Brande's table.

The *protoxide* of mercury may be obtained by digesting the protochloride with an excess of potash. The oxygen and chlorine exchange places, and the chloride of potassium, and protoxide of mercury are formed. This oxide may be precipitated from a solution of the nitrate of the protoxide, by the addition of an alkaline solution. It has likewise been supposed to be produced when mercury is subjected to long continued agitation, in contact with air. It is, however, alleged by Berzelius, that the black powder thus obtained, is metallic mercury in a state of extreme division, to which it could not be reduced without the interposition of the oxide, resulting from the presence of a more oxidizable metal: that when the metal is quite pure, and free from the interposition of heterogeneous particles, it undergoes no change by agitation, but that if, under the same circumstances, it be triturated with grease, gum, powdered glass, or sand, it may be reduced to a black metallic powder. He conceives that all the preparations made by triturating mercury with grease, gum, or other viscid substances, contain this metal in a divided state, but not oxidized.

The protoxide of mercury is a black powder, which, by exposure to light, or to the heat of boiling water, is converted into metallic mercury and bioxide.

The bioxide may be procured by long exposure of mercury to a heat sufficient to cause a gentle ebullition, the air having free access. It may likewise be obtained by expelling the acid from the nitrate by heat. Berzelius informs us, that agreeably to the opinion of some respectable physicians, it is only when procured by the former method, that it is fit to be used internally. He attributes this difference to the fact of its sometimes retaining, when obtained from the nitrate, a small portion of nitric acid. This oxide, when in mass, is of a beautiful red colour, but when powdered, it assumes a yellowish appearance. It is decomposed into metallic mercury and oxygen, at a heat a little below redness. In water it is slightly soluble, and its solution has the property of rendering syrup of violets green.

Both the oxides of mercury act as bases. The bioxide forms with ammonia, a fulminating compound.

Of the Reaction of Acids with Mercury and its Oxides.

When nitric acid, whether cold or hot, concentrated or dilute, is brought into contact with mercury, one portion of the acid is decomposed, imparting oxygen to the metal; the oxide thus formed, being dissolved by the remainder of the acid. When the metal is in excess, the protoxide is principally formed. When the acid is in excess, the bioxide predominates. Usually, more or less of each oxide is formed.

Whether concentrated or dilute, cold sulphuric acid does not react with mercury; but when the concentrated acid is boiled on this metal, the phenomena are analogous to those which ensue in the case of nitric acid. One portion of the acid yields oxygen to the metal, another combines with the oxide thus created.

As in the case of nitric acid, we may have the oxybase of mercury in the state of protoxide, or bioxide, accordingly as the acid or the metal is in excess, or as the time allowed for oxidizement is greater or less.

Each oxide of mercury forms three salts with nitric acid. When washed with hot water, the bisulphate of the bioxide, yields a yellow compound known under the name of turpeth mineral. It is a subsulphate, consisting of two atoms of oxide and one of acid.

Although generally in the metallic state, mercury has no reaction with acids; yet in the state of an oxide, it is no doubt liable to be combined with any of them. About one hundred mercurial salts are mentioned in Thomson's Inorganic Chemistry. Respecting these compounds, without a special motive, it would be worse than useless for a medical student to burthen his memory. But it is fortunate, that in this branch of our knowledge, we are aided by analogy, and that we are enabled, when we hear of an oxacid, to infer that the formation of a corresponding salt with each oxide of mercury, is possible. Moreover, agreeably to the received principles of chemical nomenclature, we are enabled to assign to the compound thus imagined, a name which would be recognised by any other chemist.

In the metallic state, mercury has no reaction with acids, having hydrogen for their radical, called hydracids by some chemists. Yet, excepting the case of water, and that of the earths proper, it may be assumed that, when any metallic oxide is presented to any of the hydracids,* water will be formed by the oxygen of the one, and the hydrogen of the other, while the metal and basacigen body will unite, and in a majority of instances, the metal will acquire the same number of atoms of the basacigen body, as it relinquishes of oxygen.

It follows, of course, that on subjecting a mercurial oxide to chlorohydric, bromohydric, iodohydric, fluohydric, cyanhydric, sulphydric, selenhydric, or telluhydric acid, chlorides, bromides, iodides, fluorides, cyanides selenides, or tellurides, will generally, if not universally, result.

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* Although I do not concur in the theoretic views which led to the employment of the word hydracid, yet as a convenient name for acids, of which hydrogen is the radical, I shall occasionally use it. It is only by the same plea that the retention of the word oxygen can be justified by those who do not consider it as an acidifying principle.

When a solution of chloride of sodium, and nitrate of the protoxide of mercury are mingled, the oxygen of the oxide, and chlorine of the chloride exchange places; so that protochloride of mercury (calomel) precipitates, while the oxygen and sodium uniting, remain in solution, and in union with the nitric acid.

If the solution of chloride of sodium be added to a solution of the nitrate of the bioxide, the two atoms of oxygen in this oxide, will exchange places with the chlorine in two atoms of the chloride; so that the mercury will, for two atoms of oxygen, acquire a like number of atoms of chlorine, and be thus converted into one atom of bichloride, or corrosive sublimate, which will remain in solution, if there be enough water present. Thus the quantity of chlorine transferred, is regulated by the quantity of oxygen in the oxide employed, the protoxide producing the protochloride, the bioxide the bichloride.

The complex affinity which causes these changes, operates either in the wet or dry way; that is, whether the substances be mixed in solution, or sublimed together. The bisulphate of the bioxide of mercury produces these results, when sublimed with certain compounds of chlorine, as chloride of sodium, for instance. Corrosive sublimate is thus procured; and by trituration with mercury, a second sublimation, and washing in boiling water, may be converted into calomel; or the bisulphate, triturated with a further portion of the metal, being converted into protosulphate, by sublimation with common salt, forms calomel directly.

The process for the manufacture of the protochloride, has been improved by causing its nascent vapour to be mingled with steam; which, interposing between the particles, prevents them from adhering as they condense. They are thus obtained in a state of more minute division than could be effected by trituration, and the aqueous particles in condensing, combine with, and remove, any particles of corrosive sublimate which may be generated simultaneously with those of the calomel. Calomel thus prepared, is distinguished as Howard's hydrosublimate.

Chlorine does not combine with mercury in the indirect mode abovementioned, only. A jet of chlorine burns spontaneously in mercurial vapour, forming a bichloride.

The chlorides of mercury may likewise be obtained by subjecting the oxides to chlorohydric acid, in which case the hydrogen of the acid, and oxygen of the oxide, form water, while the mercury and chlorine unite; the protoxide giving rise to the protochloride, the bioxide to the bichloride, as already explained.

The processes for manufacturing these important compounds of mercury, are very numerous. They have, however, but one object—that of presenting chlorine and mercury to each other, in due quantities, and intimately mingled. When the chlorine is in excess, corrosive sublimate is formed; when the metal predominates in quantity, calomel.

The protochloride is white and crystalline, but usually more compact than corrosive sublimate. It is tasteless, inodorous, and unalterable by exposure to the atmosphere if protected from light, but by this is blackened, and partially reduced, no doubt, to the metallic state. It is blackened by alkaline solutions, by the generation of protoxide, and when the surface is removed, it appears yellow, so that a scratch made with the nail, is productive of a yellow streak. It is less volatile than the bichloride. This chloride acts as a base.

Corrosive sublimate is white, more or less crystalline, and transparent; soluble in about twenty parts of cold water, but more so in hot water, whence crystals are obtained by refrigeration. It dissolves in two parts of alcohol, and in three parts of ether, by weight. It is not soluble either in sulphuric or nitric acid. On the application of heat, it sublimes unchanged. When added to an alkaline solution in excess, a yellow hydrated bioxide of mercury precipitates. The proportions being reversed, as when an alkaline solution is dropped into the solution of this chloride, a compound of the bioxide and bichloride is precipitated, which is of a brick red colour. Berzelius designates this compound as a chlorure mercurique basique, while Thenard gives it the name of bioxido chlorure. The latter appellation, changed to oxychloride, in order to render it consistent with the nomenclature adopted in this work, and more easy to pronounce, I shall employ for this, and for analogous compounds formed with other metals.*

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* This compound probably furnishes one, among many other instances, in which

Ammonia throws down from a solution of the bichloride, a compound called ammoniated mercury, in the United States Pharmacopœia; but more generally known as hydrargyrum precipitatum album, or white precipitate.

This is now considered by Thenard as a compound of ammonia, with the bioxide and the bichloride of mercury.

The bichloride of mercury has a most nauseous metallic taste, and is a virulent poison. The best antidote for it is albumen, which may be given in the form of the white of eggs, diluted with water. This chloride, acting as an acid, combines with the chlorides of ammonium, potassium, sodium, barium, and magnesium. As a base it combines with chlorohydric acid, forming a crystalline compound which effloresces and is decomposed when exposed to the air. The bichloride is composed of one atom of mercury, and two of chlorine.

A salt, long known under the antiquated appellation of sal alembroth, and formed by mixing solutions of sal ammoniac and corrosive sublimate, is now, by Berzelius, considered as a double salt, and by Bonsdorf, a chlorohydrargyrate. This last mentioned name accords with the definition of acidity and basidity* which I have premised.

OF THE BROMIDES, IODIDES, FLUORIDES, AND CYANIDES OF MERCURY.

As respects the means of their production, the ratio of their constituent atoms, and their qualities in general, there is the greatest analogy between the compounds formed by mercury with the halogen class. Hence, having treated particularly of the chlorides, I shall treat with the utmost brevity of the compounds named at the head of this article.

Bromine forms two compounds with mercury. The protobromide is white, pulverulent and insoluble. It is obtained by the reaction of the bromide of potassium with the nitrate of the protoxide of mercury.

The bibromide is formed by subjecting mercury to the action of bromine and water. It is soluble, crystallizable, fusible, capable of volatilization, and colourless. With the alkaline bromides it acts as an acid.

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an electropositive compound of one basacigen body, (see page 97,) unites with an electronegative compound of another.

It might indeed be alleged, that in this case the metal acts the part of a basacigen body, agreeably to my definition, (see page 126,) as it enters into two compounds, one electronegative, the other electropositive, which form a tertium quid. This view of the subject corroborates the remark, which I have elsewhere made, that nature has not fitted her bodies for distinct classification, and that consequently there will be cases, in which some of the bodies associated in one class, will appear to belong to another.

* I believe that this word basidity is unauthorised, but as among chemists there is nearly as much occasion for it, as for its well known correlative acidity; and as any reader who understands the one, cannot fail to interpret the other, I hope that this innovation will be deemed justifiable.

The protiodide of mercury is obtained by the reaction of the iodide of potassium with the nitrate of the protoxide of mercury. It is olive coloured, insoluble in water, and corresponds in composition with the protoxide.

The *biiodide* of mercury may be procured by adding the iodide of potassium to a solution of the bichloride of mercury. A reciprocal decomposition takes place, and the biiodide of mercury and the chloride of potassium are formed. The biiodide is fusible, volatile, and of a transcendently beautiful scarlet colour. As an acid, it combines with the iodides of many of the earths and alkalies, and with the iodides of zinc and iron. As a base, it unites with iodohydric acid. It consists of one atom of mercury, combined with two atoms of iodine.

Another iodide exists, containing less iodine than the biiodide, but more than the protoiodide.

Although cyanogen does not combine with mercury directly, a bicyanide is obtained when the bioxide of this metal is digested in water with Prussian blue. I shall more fully explain this process in treating of iron.

The employment of the bicyanide in the evolution of cyanogen and cyanhydric acid, has already been mentioned. The bicyanide of mercury forms combinations with the alkaline cyanides, in which it plays the part of an acid.

The fluoride of mercury is obtained by the action of fluohydric acid on the bioxide. It acts both as an acid and base. It is yellow, volatile, and when volatilized in platina or glass vessels, corrodes them. If subjected to water, it is resolved into a soluble and an insoluble compound.

OF THE COMPOUNDS OF MERCURY WITH SULPHUR.

Agreeably to the list of equivalents at the head of this article, mercury forms with sulphur, a protosulphide, and a bisulphide. When a weak solution of the nitrate of the protoxide of mercury is impregnated with sulphydric acid, the protosulphide is produced in the form of a black precipitate. It appears to be an unimportant compound. The protosulphide acts as a sulphobase.*

The bisulphide may be generated by impregnating with the same gas a solution of the bichloride. Thus obtained, it resembles the protosulphide in assuming a black colour, which may, however, be changed to red by sublimation.

The bisulphide (artificial cinnabar) is procured in the large way by fusing one part of sulphur, stirring in gradually, six or seven of mercury, and subjecting the re-

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* Guibourt, who has been mentioned as questioning the existence of more than one oxide of mercury, has alleged his disbelief in the existence of more than one mercurial sulphide; the black sulphide being, in his opinion, a mixture of the red with the metal. Seftstrom controverts this allegation, and Thenard, citing his opinions and that of Guibourt, inclines in favour of those of Seftstrom. Thenard alleges that at least the protosulphide exists as a base in combination with sulphides, acting of course as sulphacids, agreeably to my definition, page 126.

sulting black mass to the process of sublimation in close vessels.

Kirchoff procured cinnabar by a long continued trituration of mercury and sulphur with a solution of caustic potash, aided by a gentle heat.

It is attacked neither by sulphuric, nitric, nor chlorohydric acid, nor by caustic alkaline solutions, but when subjected to chlorine, either in an aqueous solution, as in aqua regia, or in the gaseous form, it is converted into a bichloride of mercury, and a bichloride of sulphur.

Berzelius alleges that the bisulphide performs the part of a base in combining with the aeriform sulphacids. It also forms compounds with the bichloride, bibromide, biiodide, and the bifluoride of mercury.

Equal parts, by weight, of mercury and sulphur, triturated together, form a black mass, called, from the colour, Ethiop's mineral, which is now considered as a mixture of bisulphide of mercury and sulphur.

OF THE PHOSPHURET OF MERCURY.

In its habitudes with mercury, phosphorus displays that analogy with sulphur which is in general so remarkable. It forms, according to Berzelius, a red and a black phosphuret. The latter results from the digestion of bioxide of mercury with phosphorus and water. The former from exposing phosphorus to the vapours of the bichloride of mercury.

OF THE ALLOYS OF MERCURY WITH OTHER METALS, OR AMALGAMS.

All metals combine with mercury, directly or indirectly. Its compounds have the generic name of amalgam. In the case of gold, silver, zinc, lead, tin, and bismuth, the amalgamation is rapidly effected. It is less easily produced with copper, unless when this metal separates mercury from the acids. It is difficult to unite mercury with platinum, and still more so with iron; owing, probably, to the great difference in fusibility.

Mercury unites energetically with the metals of the alkalies. In the case of sodium, a species of combustion ensues, so that the mass becomes red hot, and when sodium is thrown upon mercury, it is repelled with violence, and a disengagement of light.

The amalgam of potassium is an efficient instrument in the evolution of ammonium.

198. COMBUSTION OF MERCURY WITH CHLORINE.

Let there be a glass globe, furnished with a neck and tubulure, and holding about two gallons of chlorine. Into the neck, let a trumpet shaped tube, reaching to the bottom, be fastened, air tight, by means of a cork.

Let another tube, about fifteen inches in length, and tapering towards one end, so as to form a capillary orifice, be fastened, at the other end, into the tubulure of the globe. Provide a globular receiver, R, with a neck on one side, and a perforation, on the other side, opposite the neck.

Let the lower part of this vessel be occupied by about a gill of mercury, and exposed to a chauffer of coals, so as to fill the whole cavity of the vessel with the vaporized metal. Under these circumstances, introduce the pipe, D, proceeding from the tubulure, into the neck of the receiver, so that the capillary orifice may be near the perforation; and immediately afterwards pour chlorohydric acid into the tube, B. This will subject the chlorine to pressure, without absorbing it, and consequently cause it to escape in a jet from the capillary orifice in the pipe. Hence, mingling with the vaporized mercury, it will produce a feebly luminous flame.

Instead of using the globe and its appendages, I have, in a majority of instances, employed a tubulated retort, with a long narrow beak, for the production of the jet of chlorine. The retort being sufficiently supplied with manganese, and a glass funnel with a cock, being fastened into the tubulure; as much chlorohydric acid is allowed to enter through the funnel, as will generate a sufficient quantity of chlorine to produce a jet from a capillary orifice, in which the beak of the retort is purposely made to terminate. The beak of the retort being made to occupy the place of the tube, represented in the figure as proceeding from the globe, the experiment is, in other respects, the same as that above described.

199. EXPERIMENTAL ILLUSTRATION.

Ebullition and distillation of mercury. Its compounds with oxygen and sulphur exhibited. Action of nitric acid, and of sulphuric acid, on the metal. Resulting salts, subjected to hot water. Black oxide, and red oxide, severally dissolved in nitric acid. Chlorohydric acid precipitates calomel from the one, but occasions no precipitate in the other. Alkalies produce a black precipitate in the nitrate of the black oxide, or protoxide; an orange precipitate in the nitrate of the red oxide or bioxide. Similar results obtained, by adding them to calomel and corrosive sublimate; the first giving the black, the last the red oxide. Solutions of the different mercurial oxides precipitated by the iodide of potassium. Inflammation of chlorine with mercurial vapour. Explosion of fulminating mercury.

OF COPPER.

Copper is occasionally found in nature, in the metallic state, also in the states of oxide, carbonate and sulphide.

Of the Means of obtaining Copper.

It is obtained principally from the sulphide. The sulphur being acidified and volatilized, and the metal oxidized by torrefaction, the resulting oxide is decomposed by heat and charcoal.

The copper of commerce contains, according to Berzelius, a minute portion of sulphur and carbon. It may be purified by solution in concentrated boiling chlorohydric acid, and subsequent precipitation by a bright plate of iron.

Of the Properties of Copper.

The lustre and peculiar colour of this metal, are too well known to need description. Excepting titanium, it is the only red metal. It is very malleable and ductile, and is next to iron in tenacity. Its specific gravity is nearly 9; it fuses at a white heat.

If a current of ammoniacal gas be passed over copper, heated to bright redness in a tube, the gas is decomposed, and the copper becomes brittle, although its weight is but slightly, if at all, increased.

This change is supposed to be due to a different aggregation of the particles of the copper, induced by the formation and subsequent decomposition of a nitruret of copper.

Alloyed with a small quantity of tin, copper forms bronze—with a larger quantity, bell metal. Fused with zinc, or subjected to the vapour of this metal, as evolved from calamine when heated with charcoal, it is converted into brass.

The blade of a knife, or any bright piece of iron, or steel, is a test for copper, in solution, as a film of this metal will be precipitated upon the iron or steel, and communicate to it the appearance of copper. Ammonia, when added in excess, produces a blue colour in water containing a very minute quantity of copper, (see page 83,) but I have ascertained that it requires twice as much copper to produce a blue tinge with ammonia, as to produce with the cyanoferrous acid of the cyanoferrite of potassium, the appropriate hue of the cyanoferrite of copper, which is a peculiar rich reddish brown. With this test I have detected copper in the rain water proceeding from the spout of a copper roof.

Phosphorus combines with copper in various proportions, forming unimportant compounds. When present in a small quantity, it has an effect upon this metal similar to that which carbon has on iron, rendering the copper hard enough for cutting instruments. Carbon and silicon both combine with copper.

The equivalents of copper and its compounds, with oxygen, chlorine, and sulphur, are as follows:—

Copper,					64
Protoxide,	1	atom copper with	1	atom oxygen,	72
Bioxide,	1	”	2	”	80
Quadroxide,	1	”	4	”	96
Protochloride,	1	”	1	”	100
Bichloride,	1	”	2	”	136
Protosulphide,	1	”	1	”	80
Bisulphide,	1	”	2	”	96

Of the Compounds of Copper with Oxygen.

According to Thenard, there are three oxides of copper, a protoxide, a bioxide, and a quadroxide.

Every one is familiar with the appearance of the *protoxide*, since it forms the dull red exterior coating of copper, as it comes to us from the manufacturer. When this oxide is subjected to liquid chlorohydric acid, a double decomposition ensues, and water and a protochloride of copper are formed, the latter remaining in solution. Subjected to nitric acid, the protoxide is bioxidized by one portion of the acid, and dissolved by the other. By igniting the bioxide with metallic copper, the anhydrous protoxide is produced. On mingling solutions of potash and of the protochloride, an orange coloured hydrate of the protoxide precipitates. It is difficult to wash and dry this compound without partially bioxidizing the metal.

The bioxide of copper, is of a brownish-black colour. It is formed upon sheet copper, when exposed to a bright red heat with access of air. To obtain it, however, Thenard recommends that the nitrate or sulphate be intensely ignited in a stone-ware retort, by which means the acid is volatilized, and the bioxide remains. This oxide is formed when copper is dissolved in nitric or sulphuric acid, and enters into combination with them, forming a nitrate, or sulphate.

Thenard alleges that it is soluble in ammonia, only when combined with water, or some acid, and that it is insoluble in the fixed alkalies, whether hydrous, or anhydrous.

That the fixed alkalies promote its oxydizement, is evident; since sheet copper, or brass, moistened with alkaline solutions, always becomes green in the air. I think it probable, that carbonic acid co-operates in producing this result.

The quadroxide of copper is formed by mingling the bioxide (deutoxide) of hydrogen, with a weak solution of nitrate of copper, and adding just enough alkali to decompose all the nitrate. These conditions being realized, a brownish-yellow gelatinous mass subsides, which, after being washed upon a filter with cold water, and dried in the vacuum of the airpump over sulphuric acid, forms the quadroxide in question. This oxide is inert as to taste and smell.

The protoxide of copper, acts feebly as a base; the bioxide, energetically. The quadroxide neither plays the part of a base nor that of an acid.

Nitric acid diluted nearly to the specific gravity of 1.2, bioxidizes and dissolves copper, producing a blue solution, which yields, by evaporation, elegant blue crystals.

The ignition which ensues when these crystals are pulverized, moistened, and rolled up in tinfoil, has been adduced as an exemplification of the influence of water in promoting chemical reaction.

The crystals of the nitrate of copper, are of a deeper blue than those of the sulphate, and are deliquescent. At a moderate temperature, these crystals fuse, and lose a part of their water of crystallization.

Sulphuric acid, boiled on copper, oxidizes and dissolves it, as nitric acid does, without heat. The resulting compound forms the blue crystals of bisulphate, called in commerce blue vitriol, or blue stone.

A compound is obtained by triturating bisulphate of copper with carbonate of ammonia, called cuprum ammoniatum (ammoniated copper) in the Pharmacopœias.

This contains the ammoniacal sulphate of copper, with some portion of the carbonate undecomposed. It may be a mixture of ammoniacal sulphate, and ammoniacal carbonate of copper. It is designated as ammoniated copper, in the United States Dispensatory, and the authors allege, that there is some obscurity respecting the mode in which its ingredients are associated. It has been stated above, that the oxide of copper is not soluble in ammonia, unless united with water, acting as hydric acid, or some other substance capable of performing the part of an acid. Berzelius mentions that the bioxide of copper may be kept in a bottle containing liquid ammonia, without tinging it blue; but that the introduction of only a few drops of any ammoniacal salt, the carbonate for instance, causes the well known striking blue colour of cuprum ammoniatum, or of the aqua sapphirina. He also alleges that cuprum ammoniatum contains the ingredients in such proportion, that the alkali saturates twice as much acid as the copper.

Of the Compounds formed by the Oxides of Copper with Acetic Acid.

The oxides of copper form salts with almost every acid, whether mineral or vegetable. Among these, none are better known than its combinations with acetic acid, of which one is designated in commerce as verdigris, the other as distilled verdigris, or crystals of Venus.

Crude verdigris, is a mixture of the acetate and biacetate of copper, with some impurities.

By digesting the acetate in water, other compounds of inferior importance are obtained, containing various proportions of acid.

The biacetate crystallizes readily, and in the crystalline form, has received the name abovementioned; Venus having been one of the names given to copper, by the old chemists.

The acetate consists of one atom of each constituent, while the biacetate consists, as its name implies, of two atoms of acid, and one of oxide.

The salts of the bioxide of copper, are all of an intensely blue or green colour. This does not appear to be true in the case of the protoxide, since, according to Berzelius, when verdigris is subjected to heat, colourless crystals of the acetate of the protoxide sublime, so as nearly to fill the beak of the retort. Thenard alleges that when the hydrated protoxide is subjected to liquid ammonia, a colourless solution of it results.

OF THE COMPOUNDS OF COPPER WITH HALOGEN BODIES.

A chlorohydrate of the protochloride of copper acting as a chlorobase, may be prepared by the action of chlorohydric acid, on a mixture of the bioxide of copper, and finely divided metallic copper. From this chlorohydrate, the protochloride may be precipitated by water. It is likewise produced by heating the bichloride in close vessels, by which one-half of the chlorine is expelled. This chloride may also be obtained from the bichloride, by digestion in chlorohydric acid with copper shreds or filing. When thus evolved, it subsides in crystals, which can only be dried in vacuo over sulphuric acid; as in the air they are converted into a compound of the protoxide with the bichloride, for which, as I have already stated, I shall adopt the name of oxychloride.

The protochloride is soluble, crystallizable, and fusible by heat. It consists of one atom of copper, and one of chlorine.

The bichloride may be formed either by the reaction of chlorohydric acid with the bioxide, or by the combustion of copper, wire or leaves, in chlorine. It is of a blueish green colour, and an astringent taste. It is crystallizable, fusible, and decomposable by heat. This chloride attracts moisture, and is very soluble in water. Characters written with a solution of it, remain invisible until heated, when they become yellow. It constitutes, of course, a species of sympathetic ink.

The bichloride acts as an acid with the chlorides of potassium, ammonium, and other chlorobases, forming with them, chlorocuprates.

No compound of copper with bromine, is mentioned by Berzelius or Thenard. Those formed with iodine, appear feeble and unimportant. With fluorine, copper forms two compounds, a protofluoride, and a perfluoride. The protofluoride acts as a base, the perfluoride both as a base and an acid. Cyanogen enters into combination with copper, in two different proportions.

OF THE COMBINATION OF COPPER WITH SULPHUR AND SELENIUM.

Copper forms with sulphur, a protosulphide, containing one atom of metal, and one of sulphur, and a bisulphide, in which, as its name implies, one atom of copper is united to two of sulphur. The former may be produced by the fusion of the metal, or its oxide with sulphur. It is found pure in nature, and likewise combined in definite proportions with the sulphides of antimony, arsenic, bismuth, and iron, in which case the sulphur is usually divided equally between the metals. Berzelius alleges this sulphide to be a powerful sulphobase. Yet, in its combination with the sulphide of iron, it cannot be supposed to act as a base, as iron is more electropositive than copper. The affinity between the last mentioned sulphides, is so energetic, that the resulting sulphocuprate cannot be decomposed by the united action of carbon, and a fixed alkali.

The bisulphide of copper is formed, when a solution of the metal is precipitated by sulphydric acid. This bisulphide is alleged to act as a sulphobase.

Copper, by fusion with various sulphides of the alkalifiable metals, is made to unite with several proportions of sulphur, but the resulting compounds are unimportant.

The union of copper with selenium is productive of heat and light, in which respect, as in others, the analogy between selenium and sulphur is sustained. The resulting compound is a protoselenide. It is found in nature, but does not appear to have any striking qualities. A biselenide is formed when copper is precipitated by selenhydric acid.

200. EXPERIMENTAL ILLUSTRATIONS.

Solution of copper in nitric acid, and its precipitation by iron. Effect of ammonia on a solution of copper; also of cyanoferrite of potassium.

OF LEAD.

Lead is found in nature, in union with sulphur and with oxygen, and likewise united in the state of an oxybase, severally with chromic, sulphuric, phosphoric, molybdic, carbonic, and arsenic acids.

Of the Means of obtaining Lead.

Lead is procured chiefly from the native sulphide known among miners and mineralogists under the name of galena, which is the most abundant and prolific of its ores. The metal is liberated from galena by exposing it to the flame of a reverberatory furnace, which, oxidizing and expelling the sulphur, liberates the lead from combination with it, partially in the state of oxide, principally in the metallic state. The protoxide of this metal in a semivitrified state, called litharge, is largely obtained in the process of cupellation, already described as the means of procuring silver from argentiferous galena, or from alloys in which it exists in union with more oxidizable metals.

From any of its oxides, the metal is easily obtained by heat and charcoal.

In the small way a great majority of its combinations will yield a metallic globule, by exposure on charcoal, to the deoxydizing, or carbonaceous flame of the blowpipe.

Of the Properties of Lead.

The colour, lustre, and malleability of this metal, are well known. It fuses at about 600° F. Its specific gravity is 11.352. In large masses it is pre-eminently ductile, as it may be drawn into pipes of four inches bore; but it is too deficient in tenacity to be drawn into fine wire. It is very useful to chemists, being employed to construct the chambers and vessels, used in the manufacture of sulphuric acid and chlorine. Lead combines with carbon, silicon, and phosphorus.

OF THE COMPOUNDS OF LEAD WITH OXYGEN.

The following are the only known compounds of lead with oxygen.

Suboxide, or *dross*, probably	2 atoms lead,	208	
	1 atom oxygen,	8	
		—	216
Protoxide,	,, 1 ,, lead,	104	
	,, 1 ,, oxygen,	8	
		—	112
Bioxide,	,, 1 ,, lead,	104	
	,, 2 ,, oxygen,	16	
		—	120
Minium consists either of	1 atom Protoxide,	112	232
	and 1 ,, Bioxide,	120	
	or of		
	2 ,, Lead,	208	
	and 3 ,, Oxygen,	24	

The protoxide of lead, as we find it in the shops, under the appellation of litharge, is of a yellow colour when in mass, but when pulverized, assumes a reddish tinge. In the pulverulent form it is known in commerce by the name of massicot. It appears to be soluble in pure water, but is rendered insoluble by the presence of the smallest quantity of chloride of sodium or of any earthy matter. The protoxide of lead plays the part both of an acid and a base. In the latter capacity, it unites with the more powerful acids; in the former, with the earths and alkalies.

When the protoxide of lead is powdered and heated nearly to redness, and then suffered to cool slowly, it is converted into a substance called minium or red lead, which is largely consumed as one of the materials of flint glass. Formerly minium was considered as a distinct oxide, and to this view of its composition Berzelius inclines. Thenard alleges, upon the authority of experiments made by Dumas, that it consists of three atoms of lead united to four atoms of oxygen, and infers that it is a compound of one atom of the bioxide, and two of the protoxide. Thomson considers it as a sesquioxide, consisting, as the name implies, of one atom of metal, and one and a half of oxygen.*

When minium is exposed to a red heat, it evolves oxygen, and is converted into the protoxide.

The bioxide of lead is obtained by the action of nitric acid on minium. According to one view of its composition, the nitric acid removes the protoxide in consequence of its greater affinity for it; according to another view, one portion of the minium is decomposed, and yields its oxygen to another portion, forming a bioxide. It is certain that, at the close of the operation, a bioxide and a nitrate of the protoxide are obtained.

The bioxide is of a flea colour, and is convertible by heat, first into minium, and then into the protoxide. When triturated with sulphur, inflammation ensues. According to Thenard, this oxide never acts as a base, and but seldom as an acid.

Berzelius alleges that the gray pellicle (dross) which forms on the surface of lead, when exposed to the air, and which accumulates in greater quantities when the metal

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* Sequioxides probably consist of two atoms of metal and three of oxygen, since a half atom cannot exist consistently with that physical indivisibility in ultimate atoms, which forms the basis of the atomic theory.

is heated, is a suboxide of lead. This suboxide is likewise obtained by the decomposition of oxalate of lead by heat. Some recent experiments of Mr. Boussingault, tend to confirm this opinion.

The habitudes of lead with nitric, sulphuric, or chlorohydric acid, are so analogous to those of mercury, already described, that I do not deem it necessary to do more than point out the analogy; at the same time mentioning that, in the case of lead, no compounds are formed by oxacids, with any oxide besides the protoxide; and that the resulting compounds have an insolubility more marked and invariable. Excepting the acetate and nitrate, there is scarcely an important compound formed by an acid with this metal, which is soluble in water; and consequently there are no important soluble salts besides those formed with acetic and nitric acid, which do not, by complex affinity, precipitate lead from its solutions.

OF THE COMPOUNDS OF THE PROTOXIDE OF LEAD WITH ACETIC ACID.

Lead is oxidized and dissolved by acetic acid, and forms the acetate, called, in commerce, sugar of lead.

This name was given to the acetate of lead in consequence of its taste, which is sweet and astringent. It is crystallizable, soluble in water, and decomposable by heat.

The acetate of lead, consisting of one atom of oxide, and one atom of acetic acid, by digestion with the protoxide, whether in the form of litharge, or of massicot, may take either one, or two, additional atoms of oxide, forming a diacetate consisting of two atoms of oxide and one of acid, or a trisacetate, consisting of three atoms of oxide, and one of acid.

By *boiling* a solution of the acetate upon an excess of the protoxide, an "hexacetate" may be obtained, consisting of six atoms of oxide and one of acid. This compound may be produced also, by decomposing the acetate by an excess of ammonia. It forms, when dried, a white powder, slightly soluble in boiling, but insoluble in cold water.

Goulard's extract, of which one "*fluidrachm*" is, agreeably to U. S. Pharmacopœia, to be added to a pint of distilled water, to make lead-water, is usually considered as a diacetate, and called the subacetate; but from the formula, it must be evident it may contain enough oxide to make it partially, if not wholly, a trisacetate.

It appears to me that medical practitioners, if not ignorant of the difference which exists in composition between these acetates, are too inattentive to the possible diversity of their effects.

When an acetate, containing more than the proportion of one atom of oxide to one of acid, is brought into contact with carbonic acid gas, a precipitate ensues of carbonate of lead. Hence lead-water may be used as a test for carbonic acid, producing results on breathing into it, or upon adding it to a solution of any carbonate, analogous to those produced by lime water under like circumstances.

OF THE CARBONATE OF LEAD.

When exposed to the fumes of vinegar, which consist of acetic acid, and carbonic acid gas, lead is oxidized by the acetic acid, and combines with the carbonic acid, forming ceruse, or the white lead of commerce.

According to Thenard, the best process for obtaining the carbonate of lead, is to pass carbonic acid through a solution of the diacetate. Half the lead is precipitated in the state of carbonate, and the remainder continues in solution as an acetate. The solution of acetate is reduced to a diacetate by boiling it with oxide of lead, and subjected to carbonic acid, as before. In this way carbonate of lead of the best quality is procured without losing any of the acetic acid. The carbonate of lead is found in nature.

OF THE COMPOUNDS OF LEAD WITH THE HALOGEN CLASS.

The analogy between the habitudes of lead and mercury with acids, alluded to above, is not greater than that which exists between their habitudes with the halogen bodies. Analogous reciprocal decompositions ensue, whether solutions of the soluble oxysalts of lead or mercury be mingled with solutions of chlorides, bromides, iodides, fluorides, or cyanides of the alkalifiable metals.

The chloride of lead is white, crystallizable, soluble in thirty times its weight of water, and has a sweet and astringent taste. When exposed to a red heat, it melts and forms a mass formerly called plumbum corneum, from some resemblance in its appearance to that of horn. If the heat be pushed to redness, and the access of air be permitted, the chloride is partially volatilized, and the remainder is found to consist of oxide and chloride, or, in other words, to constitute one of those compounds called, by Thenard, oxido chlorures, and which I call oxychlorides. Several other oxychlorides exist, containing the oxide of lead, united to the chloride in various proportions. One of these is found native in England.

The bromide, iodide, fluoride, and cyanide of lead, which may, as abovementioned, be generated by means analogous to those by which the chloride is obtained, are of too little practical importance to make it expedient to notice them particularly.

The fluoride acts as a fluobase, the cyanide as a cyanobase. The former combines with the fluacids of boron and silicon, the latter with cyanoferrous acid.

OF THE COMPOUNDS OF LEAD WITH SULPHUR AND SELENIUM.

Sulphur forms three compounds with lead, a disulphide, a protosulphide, and a persulphide. Of these, the only compound which I deem it proper to notice, is that which has already been adverted to as the principal ore of lead, called galena. This sulphide may be formed, artificially, by heating lead and sulphur together. The protosulphide of lead is tasteless, inodorous, indecomposable by heat, and less fusible than lead. It acts as a sulphobase, and is composed of one atom of lead, united to one atom of sulphur.

The selenide of lead may be procured by exposing lead, mingled with selenium, to heat. When thus obtained, it is gray, but by friction it becomes polished, and white, like silver. It is found in nature.

201. EXPERIMENTAL ILLUSTRATIONS.

Solution of lead in nitric acid. Its solutions precipitated by sulphates, chlorides, phosphates, and chromates. Also by sulphydric acid. Precipitation of carbonate of lead, from the subacetate, by the carbonic acid of the breath. Galena decomposed by the blowpipe flame.

OF TIN.

This metal is found in the state of oxide, and in that of sulphide. The sulphide is rare, and contains much copper. The ore of tin, which is the principal source of the metal, is a bioxide which is reduced by heat and charcoal. Tin is sold in commerce under the name of *block* *tin*, to distinguish it from tinned iron plates, vulgarly called tin.

Of the Properties of Tin.

The colour and lustre of this metal may be seen in utensils newly made of tinned iron. It is very malleable and ductile; tin foil being only $\frac{1}{1000}$th of an inch thick. Tin tarnishes slightly by exposure to the air. Its specific gravity is 7.9. It melts at 442° F. It is distinguished by producing a peculiar crackling noise, when its ingots are bent to and fro.

Equivalents of tin and its compounds with oxygen, chlorine, and sulphur, are as follows:—

Tin					58
Protoxide	1	atom metal,	1	oxygen,	66
Bioxide	1	,,	2	,,	74
Protochloride	1	,,	1	chlorine	94
Bichloride	1	,,	2	,,	130
Protosulphide	1	,,	1	sulphur	74
Bisulphide	1	,,	2	,,	90

OF THE COMBINATIONS OF TIN WITH OXYGEN.

The protoxide of tin, consisting of one atom of metal and one of oxygen, may be procured by adding potash to the protochloride of tin. A reciprocal decomposition takes place between the oxide of potassium and chloride of tin, which results in the formation of the chloride of potassium, and protoxide of tin. The former remains in solution, and the latter precipitates in the state of a white hydrate. From this hydrate the water may be expelled by heat, a grayish black anhydrous protoxide is thus obtained, which is liable, by contact with an ignited body, to take fire, and consequently to be converted into the bioxide. The hydrate is likewise combustible, though in a less degree.

The hydrated bioxide of tin may be speedily obtained by the reaction of tin foil, or tin powder, with concentrated nitric acid, which is decomposed with great violence, bioxidizing the metal without dissolving it. This oxide may be obtained in the same hydrated state, by precipitation from the bichloride by an alkali. The hydrates thus obtained, though in composition the same, are different in properties. Both are soluble in alkalies, but only the latter is soluble in acids. This diversity continues even after they are severally dissolved by alkaline solutions, and subsequently precipitated by acids. These hydrated bioxides of tin are therefore conceived to present a case of isomerism. (See page 217.)

We may convert the bioxide, as obtained by means of nitric acid, into the other modification, by first changing it into a chloride, and then precipitating it by potash.

According to Thenard, if the precipitated bioxide be subjected to heat, it becomes insoluble in acids.

An anhydrous bioxide of tin may be obtained by subjecting tin to intense heat, in contact with air. It is white, infusible, and indecomposable by heat. It reddens moistened litmus paper when placed on it. This oxide is frequently found crystallized in nature. It is employed in the arts for the manufacture of enamel, and, under the name of putty, in grinding glass, and in making a paste for hones. The bioxide of tin acts both as an oxacid and as an oxybase, combining, under favourable circumstances, with either acids, or alkalies. Its atomic composition must be sufficiently evident from its name.

Concentrated sulphuric acid, when cold, exercises no action on tin, but with heat, dissolves it, disengaging sulphurous acid gas, and forming a sulphate of the protoxide or bioxide.

The addition of concentrated nitric acid to powdered tin, is followed by a rise of temperature, a decomposition of the acid, the evolution of nitrogen, nearly pure, and the formation of the bioxide of tin. If the nitric acid be diluted so as to have a specific gravity of 1.114, and the temperature be prevented from rising by cold water, or other refrigerating applications, no gas is disengaged, since an atom of water being decomposed simultaneously with an atom of acid, the nitrogen and hydrogen, which are thus liberated, unite to form ammonia. This combines with the nitric acid, so that at the close of the operation we obtain the nitrate of ammonia, mingled with the nitrate of the protoxide of tin.

OF THE COMPOUNDS OF TIN WITH THE HALOGEN CLASS.

A crystalline hydrate of the protochloride of tin, may be obtained by subjecting this metal, in a divided state, to the action of chlorohydric acid, and then crystallizing the resulting solution by evaporation. The protochloride may be procured in an anhydrous state, either by subjecting this hydrate to a temperature sufficiently high to drive off the water, or by exposing a mixture of the bichloride of mercury and metallic tin, to a red heat. When exposed either in the solid state, or in that of solution, to the action of the air, or liquids containing oxygen, the protochloride attracts that gas, and is converted into an oxychloride. (See note, page 307.)

It is possible that in this case a portion of the protochloride is decomposed, the chlorine forming a bichloride with the remainder, and the liberated metal uniting with the oxygen.

The protochloride of tin acts as an acid. It is composed of one atom of tin, and one of chlorine.

The bichloride of tin, may be obtained in the anhydrous state, by gently heating a mixture of metallic tin with the bichloride of mercury. The bichloride is a colourless liquid, possessing an acrid taste. It is volatile, and when exposed to the air produces dense and suffocating fumes. It is still occasionally called by its ancient name of the fuming liquor of Libavius. By the addition of one-third of its weight of water, this bichloride forms a solid crystallizable hydrate, which, nevertheless, dissolves on the addition of a sufficient quantity of water.

Iodine, bromine, and fluorine, severally combine with tin in two proportions. The perfluoride of tin acts as a base.

The cyanides of tin have never been isolated. Berzelius, however, states, that they exist in combination with those of iron, in which case they probably play the part of cyanobases.

OF THE COMPOUNDS OF TIN WITH SULPHUR AND SELENIUM.

The protosulphide of tin is obtained by heating in a crucible, three parts of finely divided tin, and two of flowers of sulphur. This sulphide is solid, crystallizable, indecomposable by heat, less fusible than tin, and acts as a sulphobase. It is composed of an atom of tin, united to an atom of sulphur.

The bisulphide of tin is obtained by exposing to heat in a coated glass matrass, a mixture of two parts of tin, one and a half of sulphur, one of mercury, and one of sal ammoniac.*

The bisulphide of tin, generally known as aurum musivum, or mosaic gold, is of a beautiful golden yellow. When exposed to a red heat, it is decomposed. It acts feebly as a sulphobase, and powerfully as a sulphacid. This sulphide, when spread on the surface of the cushion of electrical machines, has been found to increase their exciting power.

According to Berzelius there is a third sulphide, which contains a quantity of sulphur, intermediate between those which exist in the protosulphide and the bisulphide.

A gray selenide of tin may be procured by gently heating finely divided tin with selenium.

202. EXPERIMENTAL ILLUSTRATIONS.

Exhibition of tin, and of tin foil; also of the fuming liquor of Libavius. Reaction of nitric acid, or nitrate of copper with tin powder. Solution of tin by chlorohydric acid, and effects of the chloride thus obtained on some other metallic solutions. Decoloration of ink, and Prussian blue. Ammonia evolved by a solution of tin in dilute nitric acid.

OF BISMUTH.

This metal is found in nature, in the metallic state; usually, however, containing a little cobalt and arsenic, and sometimes sulphur. It is also found in the state of sulphide.

Of the Means of obtaining Bismuth.

According to Cleaveland, the only ore of bismuth which is explored, is that in which it exists in the metallic state. From this it is evolved by exposure to a wood fire, under which a hole is made to receive the melted metal.

According to Berzelius, the bismuth of commerce contains iron and arsenic, and perhaps other metals. In order to purify it, it should be dissolved in nitric acid; the clear solution resulting, should be mingled with water, by

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* Berzelius suggests that the mercury probably acts by bringing the tin into a state of more intimate mixture with the sulphur, and the sal ammoniac, by carrying off, in consequence of its volatility, the heat which is evolved during the union of the sulphur with the tin, and which would otherwise be sufficient to decompose the bisulphide, were it already formed.

which hydrated subnitrate of bismuth only, is precipitated. The precipitate being dried, is reduced with the aid of black flux, and a gentle heat.

Of the Properties of Bismuth.

Bismuth is brittle, easily reduced to powder, and of a silvery white colour, tinged with red. It is pre-eminent for the facility and regularity with which it crystallizes. Its fracture is always crystalline. Thenard alleges, that when quite pure, its crystals are cubes, which are so associated as to form a four-sided inverted pyramid, in which the faces resemble stairs. Its specific gravity is 9.82. It is usually considered as unmalleable; yet, Turner alleges that it may be hammered into plates while warm. Excepting mercury and tin, it is the most fusible of the metals proper. Its fusing point is 476°. It is oxidized when kept in fusion in the air, but not otherwise, unless the air be moist, in which case it is tarnished. Bismuth combines with phosphorus, and probably in a minute degree with hydrogen.

The action of sulphuric, or nitric acid, on bismuth, is very similar to the action of the same acids on tin. Nitric acid, perhaps, acts more violently on the former metal, than on the latter; since the addition of a small quantity of concentrated nitric acid to powdered bismuth, causes the evolution of so much heat as to raise the temperature of the mass to redness. The hydrated subnitrate of bismuth, obtained as above mentioned, by subjecting the nitrate to water, is of a fine white colour, and has been called magistery of bismuth. If chlorohydric acid be present in the solution, the precipitate assumes the form of minute scales, of a pearly lustre, called pearl white. These precipitates have been used as pigments, to improve the complexion; but are liable to be rendered black by sulphydric acid.

OF THE COMPOUNDS OF BISMUTH WITH OXYGEN.

There are two oxides of bismuth; one is a protoxide, consisting of one atom of metal, and one of oxygen; the other, a "*sesquioxide;*" composed, consequently, of one atom of metal, and one and a half of oxygen.

The protoxide may be obtained by heating bismuth with access of atmospheric oxygen, or by the calcination of the nitrate. When the subnitrate (magistery) of bismuth is subjected successively to a caustic alkaline solution, and to cold water, it forms a white hydrated protoxide of bismuth. This oxide, when anhydrous, is yellowish, fusible at a red heat, devoid of affinity for atmospheric oxygen, and is easily reducible when heated with carbon or hydrogen. It acts as a base.

The sesquioxide of bismuth is obtained by boiling the protoxide with a solution of the chloride of potassium or sodium;† it is of a deep brown colour, and at a temperature a little below the boiling point of mercury, is decomposed. The sesquioxide of bismuth, acts neither as a base nor as an acid.

OF THE COMPOUNDS OF BISMUTH WITH THE HALOGEN CLASS.

Either directly, or indirectly, compounds of bismuth may be produced with all the halogen bodies.

In chlorine, this metal takes fire spontaneously, forming a compound which, from the butyraceous consistency assumed in melting, received from the old chemists the appellation of the butter of bismuth. This chloride may also be obtained in the anhydrous state, by heating three parts of the bichloride of mercury, with one of bismuth. The anhydrous chloride is white, volatile, and deliquescent. When subjected to water, a white insoluble oxychloride* is formed.

A crystalline hydrate of the chloride of bismuth, may be formed by dissolving bismuth in aqua regia, and evaporating the solution. The chloride of bismuth is composed of one atom of bismuth, and one of chlorine.

Bromides of bismuth may be obtained by heating bismuth with bromine. Iodides may be produced in like manner.

Fluorine and cyanogen, both combine with bismuth. The cyanide, however, is known only in a state of combination.

OF THE COMPOUNDS OF BISMUTH WITH SULPHUR AND SELENIUM.

Bismuth forms a bisulphide, when heated with sulphur. At the moment when the combination takes place, a great deal of heat is evolved. It is crystallizable, less fusible than bismuth, and possesses the metallic lustre, and a grayish-yellow colour.

When selenium is heated with bismuth, a crystalline selenide is formed of a silvery white colour.

203. EXPERIMENTAL ILLUSTRATIONS.

Bismuth, and its oxide, exhibited. Its hue, and habitudes with the blowpipe, compared with those of zinc, antimony, and arsenic.

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* By oxychloride, I mean, as already stated, a compound consisting of an oxide, and a chloride, called by Thenard, oxido chlorure; by Berzelius, chlorure basique.

† Thenard, Traité, Vol. 2, page 484.

OF IRON.

This metal is found abundantly in nature, principally in union either with sulphur or oxygen.

Large masses of iron have been observed to fall to the earth at different times, and in various countries. Besides these metallic masses, a great number of stony bodies called meterolites, or aerolites, have fallen in like manner. In the latter, iron always exists both in the state of protoxide, and in that of metallic globules. The iron in these globules, and in the masses abovementioned, always contains nickel or cobalt, or both. Native metallic iron has also been found in small quantities, but does not contain nickel or cobalt. Iron is one of the most generally distributed substances in the creation, and in the state of oxide, probably the most universal colouring matter.

Four species of ferruginous minerals are very abundant in nature; magnetic oxides and sulphides, and sulphides and oxides which are not magnetic.

Since ferruginous minerals, if not magnetic in the first instance, become so by exposure to the flame of the blowpipe; the magnet is a most useful test for iron. The ores of iron consist principally either of the sesquioxide, or of a compound of this oxide with the protoxide, called the black or magnetic oxide. The means of extricating iron from its ores, will be mentioned in treating of the compounds of iron with carbon, which will on that account be treated of first.

Of the Properties of Iron.

The mechanical properties of iron are too well known to need description. It is the most tenacious substance in nature, especially as steel, and the hardest among the malleable metals. Its ductility is greater than its malleability. Few metals are more easilily oxidized by the joint agency of air and moisture. It is nearly as difficult to fuse as platina. Its specific gravity is 7.788.

Remarkable Combustibility of Iron when minutely divided.

Iron in the pulverulent form in which it is reduced from the sesquioxide by means of hydrogen, is liable to become ignited by the access of atmospheric oxygen, even after it has been completely refrigerated. This result is more likely to ensue, if a little alumine has been previously mixed with the oxide, since this prevents the union of the particles, and thus keeps them in that state of minute division which is favourable to the success of the experiment. I have found that the mass obtained from perfectly pure Prussian blue, will not ignite spontaneously, though consisting of iron and carbon in a state of minute division; but the presence of a small quantity of alum which enters into the composition of Prussian blue, as usually prepared, is sufficient to qualify it for the formation of a pyrophorus.

It appears that a pyrophorus consisting of carbon and iron, may be obtained by calcining the oxalate of this metal in close vessels.

OF THE COMPOUNDS OF IRON WITH CARBON, BORON, SILICON, AND PHOSPHORUS.

When ferruginous salts containing carbon as a constituent, are exposed to heat without access of air, the iron and carbon are left in a state of combination in various proportions. These carburets are liable to take fire when warmed in the air.

The process of evolving iron from its ores, comes under the fourth case of affinity, in which one body in excess, combines with two others previously united. The carbon with which the ore is ignited, combines both with the oxygen and metal, converting the one into a fusible carburet, called cast iron, the other into carbonic acid. The proportion of carbon in cast iron varies from 1 part in 25, to 1 part in 15. In commerce, there are four known varieties of cast iron; the white, the black, the gray, and the mottled. In the white there is the least carbon, in the black there is the most, and probably in the other kinds, less than in the black, and more than in the white kind.

It should, however, be understood, that cast iron is probably never a pure carburet. Usually, it contains silicon and manganese, and frequently magnesium and phosphorus. This last mentioned element, renders the iron less malleable at a high temperature. From cast iron, the malleable metal is extricated by exposure to heat and air, by which carbon and silicon, when present, are oxidized; the one being separated as a silicate of iron with the scoria, the other escaping as carbonic acid.

In some cases, malleable iron is obtained directly from the ore, by means of heat and charcoal.

Pure malleable iron is converted into steel, by being heated in contact with charcoal in ovens without access of air. The process is called cementation. By these means, iron acquires from $\frac{1}{50}$ to $\frac{1}{120}$ its weight of carbon. The bars are blistered by the operation as they are seen in commerce. Broken up and welded, they form shear steel. Fused, they form cast steel.

It would appear that silicon is a frequent, if not a necessary ingredient, in steel. According to Berzelius, the presence of manganese and phosphorus, is essential to the formation of good steel. Damask steel is a peculiar species, which possesses the property of exhibiting waving lines on its surface, when acted on by an acid. It is alleged by Thenard, that some experiments which have recently been made, tend to prove that this is owing to the presence of two carburets of iron, one of which is blackened by the acid, while the other resists its action. I think it more probable, that the appearance in question is owing to a mixture of iron and steel. It has, however, been ascertained that a peculiar variety of this steel, called wootz, which comes from India, contains aluminum, and may be imitated by the introduction into steel, of a minute portion of that metal.

A silicuret, and probably a boruret of iron, may be obtained by heating iron with a mixture of charcoal and silicic or boric acid.

A phosphuret of iron is produced, when phosphate of iron is heated with lampblack. It resembles iron in colour, and is brittle and is fusible by the blowpipe.

Equivalents of Iron and its Compounds with Oxygen, Chlorine and Sulphur.

Iron	- - - - -	28
Protoxide,	1 atom metal 1 atom oxygen	36
Sesquioxide, or Red oxide,	1 ,, 1½ ,,	40
Magnetic or Black oxide,	2 ,, 2½ ,,	76
Or one atom protoxide and one atom sesquioxide		
Protochloride,	1 atom metal, 1 atom chlorine	64
Sesquichloride,	1 ,, ,, 1½ ,, ,,	82
Protosulphide,	1 ,, ,, 1 ,, sulphur	44
Sesquisulphide,	1 ,, ,, 1½ ,, ,,	52
Bisulphide,	1 ,, ,, 2 ,, ,,	60

OF THE COMPOUNDS OF IRON WITH OXYGEN.

Iron forms two oxides—a protoxide, and a sesquioxide; the former consisting of an atom of each constituent, the latter, as the name implies, of one atom of metal, and one and a half atoms of oxygen. Both these oxides act as bases.

The protoxide is formed during the solution of the metal in diluted sulphuric acid. The reaction which ensues under these circumstances, is always attended by the evolution of hydrogen, arising from the decomposition of water in combination with the acid,* the oxidation of the metal and the formation of a sulphate of the protoxide.

The protoxide, by these means, produced in union with the acid, forms a green solution, which, by evaporation, yields crystals of the same colour, known in pharmacy

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* I infer that the atom of water which, by a union with the anhydrous acid, constitutes the "aqueous" sulphuric acid of Berzelius; or in other words, the acid of the shops of S. G. 1850, acts as an oxybase; so that the result may be ascribed to the exchange of one radical for another; an atom of iron taking the place of an atom of hydrogen. Agreeably to this view of the subject, the aqueous acid should be regarded as a sulphate of hydrogen.

as green vitriol, or sulphate of iron. From a solution of this salt, the protoxide may be precipitated by an alkaline solution, in the state of a white hydrate. From this hydrate the water cannot be expelled either by heat or desiccation, without causing the protoxide to acquire oxygen, either from the water in union with it, or the air.

In consequence of this avidity for oxygen, solutions of this oxide become gradually more or less solutions of the sesquioxide, exchanging their grass green colour for that of red wine.

The protoxide appears to exist in chalybeate springs, and in its nascent state, to be soluble in water, although I do not find that other chemists are aware of the fact. Its existence in them is ascribed usually to the presence of carbonic acid, but I have observed it in the water of the Yellow-Springs, which gave no precipitate with lime-water.

We have only to make a pile of silver coin, alternated with disks of sheet iron, in a glass tumbler, supplied with water, in order to impart to the latter the property of chalybeate spring water. In the tumbler, as in those springs, the red oxide will soon be seen precipitating and tinging with its appropriate hue, both the liquid and the vessel.

As light promotes the further oxidation, and consequent precipitation, of the iron, the solution of the protoxide, by the means which I have described, will be more permanent in an opake vessel.

There does not appear to be any mode in which the protoxide of iron can be isolated.

The sesquioxide, or peroxide of iron, also called the red oxide, from its colour, which is a dingy blood-red, exists in nature, in great abundance, forming, sometimes, large beds or masses, at others, botryoidal, or mammillary concretions.

Ochres consist of alumine mixed with the sesquioxide of iron, either uncombined with water, or in the state of a hydrate.

The sesquioxide is, as we have stated in treating of the protoxide, spontaneously produced by the absorption of oxygen by the protoxide when exposed to the air. In fact, by the addition of nitric acid to any ferruginous solution, the iron becomes more or less peroxidized. On the other hand, it may be partially deoxidized, and restored to the state of protoxide by digestion with iron filings, or the addition of the protochloride of tin. Hence the addition of this chloride to ink, destroys the colour by reducing the iron to the state of protoxide, which, with tannic acid* (tannin) and gallic acid, forms a compound comparatively colourless. Probably taking half an atom of oxygen from each atom of the sesquioxide of iron, the tin in one portion of the chloride, gives up its chlorine to another undecomposed portion of the chloride, while the resulting oxide and bichloride of tin combine, forming an oxychloride.

When a solution of the chloride of gold is added to a solution of the protoxide of iron, the gold probably relinquishes its chlorine to one portion of the iron in the protoxide. The oxygen consequently displaced peroxydizes another portion of the iron, so that metallic gold precipitates, and the chloride and oxide of iron combining, in the state of an oxychloride remain in solution.

The destructive distillation either of nitrate or sulphate of iron, evolves the sesquioxide. It has been stated in treating of sulphuric acid, that it was originally obtained by these means, from copperas or green vitriol, the sulphate of the protoxide of iron. The oxide which remains after the expulsion of the acid, has long been known as the colcothar of vitriol. To render it free from all remains of acid, it should be washed in water.

The protoxide and sesquioxide of iron combine in various proportions. The scales, called finery cinder, which fly off during the forging of incandescent iron, consist of four atoms of protoxide, and one of sesquioxide. The oxide formed by subjecting iron at a red heat to steam, is a compound of an atom of each oxide.

The native magnetic oxide of the mineralogists, is, according to Thenard, the same as that obtained when iron is oxidized by steam.

The same author alleges that neither the hydrate of the protoxide, nor sesquioxide, are magnetic; this quality being exhibited only when the two oxides are associated in the proportion of one atom of sesquioxide to one of protoxide.

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* As I concur with Berzelius, in considering tannin an acid, it would be inconsistent not to give it the appropriate appellation of tannic acid.

Of the Reaction of Iron with certain Acids.

The reaction of iron with sulphuric acid, when hot, and concentrated, is quite analogous to that already described as taking place between that acid, and mercury, copper, lead, &c. The reaction of iron with this acid, when dilute, has been mentioned and explained above.

In its habitudes with nitric acid, iron resembles tin and bismuth. If the acid employed be concentrated, and the iron be minutely divided, an explosion sometimes ensues.

With the gallic and tannic acids, as existing in the infusion of galls, the sesquioxide of iron produces a purple or black colour, in other words, ink. With succinic acid the sesquioxide yields a brown precipitate, with benzoic acid, an olive coloured precipitate, and with the meconic or sulphocyanhydric acids, a blood red colour.

There seems, however, to be some obscurity respecting ink. The colour of this useful liquid is ascribed to two acids, but we are not informed whether it could be made with either alone; and if so, with which the best; or if both are requisite, in what proportions they should be present.

OF THE COMPOUNDS OF IRON WITH THE HALOGEN CLASS.

Chlorine forms with iron a protochloride and a sesquichloride, which correspond in composition with the oxides of this metal.

The anhydrous protochloride may be obtained by passing chlorohydric acid gas over iron filings heated to redness in a glass tube. A hydrated protochloride may be procured by the action of liquid chlorohydric acid on iron filings. The protochloride, in its anhydrous state, is of a pale green colour, astringent, crystallizable, very soluble in water, and volatilizable by heat. When exposed to the action of the air, it absorbs oxygen, and forms an oxychloride, consisting of the sesquioxide, and sesquichloride.

The hydrated sesquichloride of iron is produced when the sesquioxide of iron is exposed to the action of chlorohydric acid. It may be obtained in the anhydrous state by heating iron filings in an excess of chlorine. Thus obtained, it is volatile and deliquescent.

Bromine and iodine each form compounds with iron, which no doubt correspond in composition with its oxides and chlorides.

There are two fluorides of iron which act either as acids or bases.

The protocyanide of iron is formed by exposing the cyanoferrite of ammonium, which is a compound of the cyanides of iron and ammonium, to heat in a retort. The cyanide of ammonium, which is volatile, passes over, leaving the protocyanide of iron in the form of a grayish-yellow powder. This cyanide acts as a powerful cyanacid, combining in that capacity with the cyanides of almost all the metals. It also combines with cyanhydric acid, but whether as the acid or the base, appears to me doubtful. I incline to the opinion that it acts as an acid, forming a cyanoferrite (of the cyanobase) of hydrogen.

The sesquicyanide of iron is obtained by mingling a solution of the fluosilicate of the fluobase of iron with a solution of the cyanoferrite of potassium. A fluosilicate of the fluobase of potassium precipitates, and the sesquicyanide of iron remains dissolved. Its solution is of a deep brownish-yellow colour, and an astringent taste. If we attempt to obtain it in the solid form by desiccation, it is partially decomposed, and converted into Prussian blue.

When the cyanide of potassium is mingled in solution with a ferruginous salt, a precipitate ensues, well known under the name of Prussian blue, having been first accidentally discovered at Berlin. It would seem that to perfect the colour of this precipitate, both oxides of iron should be present, so that the protoxide may produce the protocyanide, and the sesquioxide the sesquicyanide. These cyanides, by their union, form the compound in question.*

OF THE COMPOUNDS OF IRON WITH SULPHUR AND SELENIUM.

Iron forms with sulphur a protosulphide, a sesquisulphide, and a bisulphide. Moreover the protosulphide combines in various proportions either with the bisulphide or the metal.

A hydrated protosulphide is alleged to be formed during the combustion which arises from triturating with moisture two parts of iron filings, with one and a half of sulphur. This hydrated protosulphide is liable to absorb oxygen with a rapidity so great as to produce ignition. Owing to this

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* Berzelius designates Prussian blue as the "cyanure ferroso ferrique," being one of his double salts. It has been mentioned that when potash is digested in water with Prussian blue, a yellow crystalline salt results, which I call cyanoferrite of potassium. In fact the cyanogen of the sesquicyanide of iron, and the oxygen of the potash, exchange places, so that a cyanide of potassium and oxide of iron are produced. With the former the protocyanide of iron combines, forming another double salt according to the Berzelian nomenclature, but according to that which I adopt, a cyanoferrite (of the cyanobase) of potassium. In the last mentioned state of combination, agreeably to my definition of acidity, the protocyanide acts as an acid; and hence I have called it cyanoferrous acid. It seems questionable whether, while in combination with the sesquicyanide of iron, this protocyanide can be considered as acting as an acid, more especially as the sesquicyanide also combines with the cyanide of potassium, and has therefore claims to be considered as cyanoferric acid. However I think it would on the whole be most consistent to allow the name which I have given to the protocyanide, when in union with the cyanide of potassium, to follow it into its combination with the sesquicyanide of iron, which however for the present it were better to designate as Prussian blue, rather than cyanoferrite of iron.

property, its presence in bituminous coal beds sometimes causes them to take fire spontaneously.

Native protosulphide of iron is of rare occurrence—the magnetic and bisulphides are abundantly found in nature, especially the latter, which is one of the most common minerals. From its resemblance to gold, it is frequently mistaken for that metal by inexperienced observers. When intensely heated, a portion of its sulphur sublimes, and hence it is one of the sources of that important material.

It is alleged by Thenard that there are two varieties of the bisulphide, which, though identical in composition, are dissimilar in their crystalline forms and in their properties. Of these varieties only one is susceptible of spontaneous reaction with air and moisture, and consequent conversion into a sulphate. To a similar transformation of this and other sulphides, we are indebted for the greater part of the green vitriol, or sulphate of iron used in the arts. Beds of these minerals in a state of spontaneous decomposition, are to be met with in every country.

By exposure to a current of sulphydric acid, the sesquioxide of iron is converted into the sesquisulphide, provided the temperature be not above 212°. At a higher temperature a bisulphide results.

According to Thenard, one of the compounds formed by the union of the protosulphide and bisulphide, is found in nature, and called magnetic pyrites. It is also formed, as he alleges, when iron in a state of intense ignition is presented to sulphur, and when either the sesquisulphide or bisulphide is fused.

In fact it would seem that he considers none of the other sulphides as magnetic, although the presence of a greater proportion of iron in the protosulphide would lead us to expect in it a greater susceptibility of magnetic influence. Berzelius however considers the protosulphide as magnetic.

The selenide of iron is formed by causing the vapour of selenium to pass over iron filings heated in a glass tube. It has a metallic brilliancy, and a deep gray colour approaching to yellow.

204. EXPERIMENTAL ILLUSTRATIONS.

Iron dissolved by chlorohydric and sulphuric acid. Red and magnetic oxide of iron exhibited, and their solutions precipitated by galls, and by cyanoferrite of potassium. Effects of protochloride of tin on the colour of the precipitates. Ores of iron rendered magnetic by the blowpipe.

OF ZINC.

This metal exists in nature in four states. In that of sulphate, silicate, carbonate, and sulphide. Either as a silicate or carbonate, it is known in mineralogy under the name of calamine; its sulphide is called blende.

The metal is obtained from calamine by heating this ore with charcoal. It may be purified by distillation.

Of the Properties of Zinc.

Zinc is of a brilliant metallic white colour, slightly tinged with the hue of lead. Its structure is strikingly crystalline. Its specific gravity is about 6.86. Under ordinary circumstances it is not malleable, but may be laminated by rollers at a heat somewhat above that of boiling water. It melts at about 680° F., volatilizes at a higher temperature, and may be distilled by being intensely heated in a stone ware retort. By exposure to the atmosphere it is slightly oxidized, but at a white heat burns rapidly with intense light, the resulting oxide being volatilized in fumes. Water is rapidly decomposed when passed in the state of steam over ignited zinc, or when presented to it together with a due proportion of sulphuric or chlorohydric acid. Zinc combines with carbon and phosphorus.

The equivalents of zinc, and of its compounds with oxygen, chlorine, and sulphur, are as follows:—

Zinc,		32
Protoxide,	1 atom metal, 1 oxygen,	40
Peroxide, doubtful.		
Chloride,	1 atom metal, 1 chlorine,	68
Sulphide,	1 ,, ,, 1 sulphur,	48

OF THE COMPOUNDS OF ZINC WITH OXYGEN.

The protoxide of zinc is formed during the combustion of the metal in atmospheric air. From the lightness and fleeciness of its texture, when obtained in this way, it was formerly called nihilum album, and lana philosophica. The protoxide may be obtained from one variety of the ore called calamine, by heating it, to expel carbonic acid. To prepare it as it is presented to us in the shops, the ore is roasted, pulverized, and levigated. A better process, as I conceive, is that of collecting the woolly matter produced by the combustion of the metal. But to either of the modes above mentioned, I should prefer that of precipitating the oxide from the sulphate in solution, by liquid ammonia.

The peroxide is obtained by the same means as the quadroxide of copper, which it resembles in many of its properties. The protoxide usually acts as a base, though in some cases it may act feebly as an acid. The peroxide performs the part neither of a base nor of an acid.

The action of sulphuric acid on zinc, is similar to the action of the same acid on iron. When subjected to nitric acid, zinc takes all the oxygen from one portion of the acid, while the protoxide thus formed, is dissolved by another portion; meanwhile the nitrogen escapes with a violent effervescence. Professor Emmet has recommended the reaction of this metal with the nitric acid in nitrate of ammonia, as an excellent method of procuring pure nitrogen.

If the solution of acetate of zinc, obtained by the reciprocal decomposition of the acetate of lead, and sulphate of zinc, page 83, be clarified by subsidence, or filtration, and then evaporated, the acetate of zinc may be obtained in the crystalline form. It will also be in a state of purity, if the materials have been used in the equivalent proportions, or with a slight excess of the acetate of lead. Pure acetate of zinc may also be obtained by the process for forming the arbor saturni, as in that process, after a sufficient time, the lead is completely displaced by the zinc, which remains in solution.

The acetate of zinc is also obtained, agreeably to one of the formulas of the Pharmacopœias, in a tincture, or in other words, in an alcoholic solution, by subjecting a mixture of sulphate of zinc and acetate of potash, in equivalent proportions, to that solvent. The mixture of the salts is followed by a reciprocal decomposition, analogous to that produced by the mixture of sulphate of zinc, and acetate of lead, excepting that the resulting sulphate of lead is quite insoluble in water, and separates by precipitation, while in the other case, both of the resulting salts, being more or less soluble in water, alcohol is employed to separate them. This liquid does not dissolve the sulphate of potash, while it readily takes up the acetate of zinc.

OF THE COMPOUNDS OF ZINC WITH THE HALOGEN CLASS.

Anhydrous chloride of zinc is formed during the combustion of zinc in chlorine. It was formerly called the butter of zinc from its consistency. It is of a grayish-white colour, translucid, astringent, fusible at the temperature of boiling water, and volatilizable at a red heat. By dissolving zinc filings in chlorohydric acid, and evaporating the solution to dryness, we may obtain this chloride in the state of a hydrate.

Zinc combines with iodine, fluorine, and cyanogen. The cyanide acts as an acid, the fluoride both as a base and an acid.

OF THE COMBINATIONS OF ZINC WITH SULPHUR AND SELENIUM.

The sulphide of zinc may be obtained by heating the sulphate to whiteness with a carbonaceous paste. It is difficult to combine zinc directly with sulphur, but when the vapour of sulphur is passed over incandescent zinc, a combination takes place with a violent commotion, and the evolution of so much heat as to volatilize part of the zinc. The same result ensues when zinc filings are suddenly and intensely heated with the persulphide of potassium, or the powdered bisulphide of mercury.

The sulphide of zinc is solid, yellow, tasteless, less fusible than zinc, and indecomposable by heat alone, but is reducible by intense ignition with charcoal. It is a powerful sulphobase.

When the sulphate of zinc is decomposed at a low red heat, by hydrogen, an oxysulphide, or in other words a compound of the sulphide and oxide is formed.

When the vapour of selenium is passed over zinc heated to redness, the union of the two substances takes place with violence, being attended by the phenomena of active combustion. The resulting selenide is a yellow powder.

205. EXPERIMENTAL ILLUSTRATIONS.

Zinc subjected to diluted sulphuric, and diluted chlorohydric acid, severally. Arbor Saturni, produced by it, in a solution of acetate of lead. Combustion of the metal, in an incandescent crucible. Its habitudes with the blowpipe exhibited. Reaction of zinc filings and bisulphide of mercury.

OF ARSENIC.

This metal is found in nature in combination with oxygen, sulphur, and various metals. It is sold in commerce under the name of cobalt, and in the state in which it bears this name, it is full of crevices, and so much tarnished or blackened by oxidizement, both internally and externally, that it is not possible, even by a fresh fracture, to see the true colour or lustre of the metal.

In order to attain this object in perfection, the cobalt (as it is absurdly named) should be pulverized coarsely, and introduced into a glass tube sealed at one end. The tube should be less than half full. Thus prepared, it should be placed within a cylinder of iron, closed at the base. The but-end of a gun barrel will answer. The space between the iron and the glass should be filled with sand, and another gun barrel applied, so as to receive any fumes which may arise, and conduct them into a chimney. That portion of the glass tube which contains the arsenic, should be kept red hot for about half an hour. After the apparatus is quite cool, the metal will be found in crystals of great splendour, occupying that portion of the glass tube, which is next the part heated to redness.

Of the Properties of Arsenic.

Exposed before the blowpipe, arsenic is distinguished by burning before it fuses, and emitting copious white fumes of arsenious acid, which have the odour of garlic. Such fumes are easily produced, by projecting a portion of the metal upon a hot iron, or by subjecting it in any other way to heat and air. They are evolved on a large scale, during some metallurgic operations, and after being subjected to a subsequent distillation, constitute the arsenious acid or white arsenic of the shops. This metal is extremely brittle, and when newly sublimed, has the colour and brilliancy of polished steel. It requires less heat to vaporize than to fuse it; so that it cannot be melted without the aid of a pressure greater than that of the atmosphere. Thenard alleges, that it may be sublimed in a retort filled with nitrogen, at the temperature of 356°. I am under the impression, that the nitrogen must co-operate as a solvent in this result, taking up the metal in a warmer part of the retort, and depositing it in the colder part. I have ascertained that metallic arsenic, situated in a glass tube immersed in melted lead, is not volatilized, unless so far as it may be oxidized; and, moreover, in my efforts to obtain the arsenical ring, I have remarked that it is formed just beyond the part of the tube which is reddened by the heat.

The following table gives the equivalents of arsenic, and of its compounds with oxygen, chlorine, and sulphur.

Arsenic,						38
Suboxide, doubtful.						
Arsenious acid,	1	atom metal	$1\frac{1}{2}$	atoms	oxygen,	50
Arsenic ,,	1	,,	$2\frac{1}{2}$	,,	,,	58
Sesquichloride,	1	,,	$1\frac{1}{2}$	,,	chlorine,	92
Protosulphide,	1	,,	1	,,	sulphur,	54
Sesquisulphide,	1	,,	$1\frac{1}{2}$	,,	,,	62
Persulphide,	1	,,	$2\frac{1}{2}$	,,	,,	78

Of the Compounds of Arsenic with Oxygen.

According to Berzelius, the black matter which obscures the brilliancy of metallic arsenic on exposure to the air, is a suboxide. Thenard seems inclined to consider it as a protoxide; while by other chemists it is treated as a mixture of arsenious acid and the metal, as when exposed to heat or to acids, it yields arsenious acid, and arsenic in the metallic form. But as it appears that arsenious acid is a compound of oxygen and the metal, in a ratio to indicate $1\frac{1}{2}$ atoms of the former to one of the latter, it would be reasonable to infer the existence of a compound consisting of an atom of each. Besides, it has been ascertained by Berzelius, that the exposure of arsenic to air, never causes an absorption of more than eight per cent. of oxygen, while the white oxide contains thirty-two per cent. It seems very improbable, that, under the same circumstances, one portion of the metal should absorb thirty-two per cent. of oxygen, while another portion should absorb none.

Arsenious acid is formed, when arsenic is ignited in the air. It is milk white, has a rough and slightly acid taste, followed by a flavour feebly sweet. When heated in open vessels to a low red heat, arsenious acid softens, sublimes, and condenses in the form of a white powder; or, when the vessels are large, and the operation slow, in regular octaedral crystals.

Arsenious acid is soluble in water, but not to any great extent. Berzelius states, that a saturated solution of it in boiling water, in which the deposition of crystals has commenced, contains but a twelfth or thirteenth of its weight. There is much uncertainty, and some mystery, respecting the extent of its solubility in cold water. Berzelius quotes an observation made by Fischer, that the portion employed is never entirely dissolved; and that as the ratio of the water to the acid increases, this being always in excess, the quantity dissolved lessens; 80 parts of the former, take up $\frac{1}{90}$ of its weight; 160 parts, $\frac{1}{180}$; 240 parts, $\frac{1}{280}$; and a thousand parts, only $\frac{1}{1200}$. Arsenious acid, when subjected in close vessels to a heat approaching to redness, fuses into a transparent glass of the specific gravity of 3.699, unchangeable in dry air, but gradually becoming white and opake, in a humid atmosphere.

In the last mentioned state, it appears to be more soluble in boiling water, and to be retained in solution to a greater extent than in the transparent state. The transparent acid reddens litmus, while by the opake, litmus previously reddened may be restored to its original colour.

These varieties of arsenious acid, are therefore considered as isomeric.

Arsenious acid is a most virulent poison. It is found in nature, both in the crystalline form, and in that of a white powder. By digestion in aqua regia, or in strong nitric acid, evaporation of the resulting solution to dryness, and subsequent ignition nearly to redness in a platina crucible, arsenious acid acquires one additional atom of oxygen, so that a compound is formed in which the metal is to the oxygen, as 1 to 2½. This compound is arsenic acid.

Arsenic acid is solid, white, and caustic; it reddens litmus paper. When exposed to heat, it melts into a glass; but if the heat be pushed to redness, it is decomposed into arsenious acid and oxygen gas. This is a more powerful acid, a more virulent poison, and more energetic in its affinities, than arsenious acid. Like other fixed* acids, when aided by heat, it expels the volatile acids from their combinations. It forms with certain metallic oxides, salts which crystallize in the same form as the corresponding phosphates; whence, as I have elsewhere stated, arsenic and phosphoric acid, are said to be isomorphous. Of such bodies, one may be substituted for the other in crystalline compounds, without altering the form of the resulting crystals.

Arsenic acid is deliquescent, and much more soluble than arsenious acid; yet after being vitrified by heat, it does not dissolve completely at first, but deposites a white powder, which by frequent stirring, finally dissolves. In consequence of this, and some other differences in their properties, it has been supposed that the melted and unmelted arsenic acids, are isomeric with regard to each other.

Arsenious and arsenic acid, severally combine with the metallic oxides. A biarseniate of potash is formed, when arsenious acid is deflagrated with nitrate of pot-

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* The word fixed, is employed by chemists to convey the idea of a body which will bear a high temperature without decomposition or volatilization.

ash. Fowler's solution, or the Liquor Potassæ Arsenitis of the U. S. Pharmacopœia, is made by boiling the arsenious acid and carbonate of potash, of each 64 grains, with a pint of distilled water, and adding four "*fluidrachms*" of the spirit of lavender. The arsenious acid displacing the carbonic acid, forms with the alkali, an arsenite of potash. This solution produces a yellow precipitate of nitrate of silver, without the aid of ammonia, as the place of this base is supplied by the potash.

Either the arsenites, or arseniates, yield precipitates with solutions of copper or silver, and destroy the blue colour of the iodide of starch. In the instances of copper and silver, an arsenite, or arseniate, of those metals is formed. The arsenite of copper is of an apple-green colour, and forms a pigment called Scheele's green. The arsenite of silver is yellow; the arseniate, brick-red.

When cold, sulphuric acid does not react with arsenic; but when warm, the acid is decomposed, and arsenious acid formed.

The reaction of nitric acid with arsenic, is similar to the reaction of sulphuric acid with the same metal, except that it takes place without the aid of heat, and that the arsenious acid which is at first produced, is finally converted into arsenic acid.

OF THE COMPOUNDS OF ARSENIC WITH THE HALOGEN CLASS.

By the direct reaction of chlorine with arsenic, or by the distillation of this metal with the bichloride of mercury, a sesquichloride of arsenic is obtained. If in this process, the protochloride of mercury be substituted for the other, a chloride containing less chlorine than the sesquichloride is generated, and by the reaction of the metal with an excess of chlorine, a perchloride is alleged to result.

The sesquichloride is a colourless fuming liquid, of an oleaginous consistency, quite analogous, both as to the means of evolution, and its properties to the bichloride of tin, or fuming liquor of Libavius.

Bromine and iodine severally form compounds with arsenic, which correspond in composition with the sesquichloride.

The fluoride of arsenic is a colourless fuming liquid, which probably consists of one atom of arsenic, and one and a half of fluorine.

OF THE COMPOUNDS OF ARSENIC WITH SULPHUR AND SELENIUM.

There is scarcely any limit to the number of proportions, in which arsenic and sulphur appear to combine; yet Berzelius admits the existence of but five distinct sulphides, and Thenard recognises only three; a protosulphide, a sesquisulphide, and a persulphide. By the union of these, severally, with various quantities of the metal, or of sulphur, all the other compounds are supposed to be produced.

The proto, sesqui, and persulphide severally combine with sulphobases, as sulphacids.

The protosulphide of arsenic, known in commerce by the name of realgar, may be obtained by heating a mixture of two parts of sulphur and rather less than three and a half of arsenic. It is procured in the large way by distilling arsenious acid with sulphur. It is tasteless, crystallizable, less fusible than arsenic, and of an orange-red colour. When heated in close vessels, it volatilizes unchanged, but if the air be admitted it is converted into arsenious and sulphurous acid. It is found native.

The sesquisulphide is obtained by adding chlorohydric acid to a mixed solution of sulphide of potassium and arsenite of potash. The oxygen of the arsenious acid, and of the potash unite with the hydrogen of the chlorohydric acid, the chlorine unites with the potassium, and the sulphur with the arsenic. The chloride of potassium remains in solution, while the arsenic and sulphur precipitate in the state of sesquisulphide, and in the form of beautiful yellow flocks.

The sesquisulphide is found in nature, and is known in commerce under the name of orpiment. It is crystallizable; when heated gently in close vessels it melts, and if the heat be further elevated, volatilizes, and may be condensed unchanged. If the access of air be permitted during the operation, sulphurous and arsenious acid are formed.

The persulphide of arsenic is formed by passing sulphydric acid gas through a solution of arsenic acid in water. It is yellow, and resembles orpiment. It is fusible, volatilizable, and capable of reddening litmus.

When arsenic is dropped into selenium previously liquefied by heat, a selenide is produced. If this selenide be subjected to distillation at a red heat, a perselenide is obtained.

OF THE COMPOUNDS OF ARSENIC WITH PHOSPHORUS AND HYDROGEN.

A phosphuret of arsenic may be formed by heating phosphorus with this metal. It is black and brilliant.

If the experiment of the philosophic candle be repeated, some powdered arsenic being intermingled with the usual materials, the hydrogen, in its nascent state, will unite with the arsenic, forming arsenuretted hydrogen. Hence the gaseous jet, when ignited, will produce a flame of a dismal, pale, bluish-white, evolving arsenical fumes, and the characteristic odour of arsenic. A more accurate process for generating this gas, is that of dissolving an alloy of tin and arsenic, in chlorohydric acid.

If a mixture of two parts of sulphide of antimony, two parts of bitartrate of potash, and one of arsenious acid, be kept at a red heat in a covered crucible, an alloy may be obtained, which will evolve arsenuretted hydrogen as soon as moistened. To obtain arsenuretted hydrogen, it is only necessary to introduce a small portion of the alloy into a bell glass, replete with fresh boiled water. The gas is gradually evolved, and, of course, collected in the bell glass.

Arsenuretted hydrogen is highly inflammable, in common with all other aëriform compounds of hydrogen. It is extremely deleterious to life, being injurious when liberated in quantities too small to be immediately annoying to the operator. It is productive of nausea and vomiting, sometimes of constipation, sometimes of purging. As palliatives of these evils Berzelius recommends warm tea, and sulphydric acid gas.

Though at ordinary temperatures, a permanent gas, arsenuretted hydrogen at 40° F., condenses into a liquid. It consists of one volume of arsenic, and one and a half of hydrogen. A ten thousandth part of this gas, may be detected in a gaseous mixture, by the metallic pellicle which it causes upon a solution of corrosive sublimate.

Oil of turpentine appears to form a crystalline compound, by reacting with arsenuretted hydrogen.

A solid compound of arsenic with hydrogen, has been made by subjecting an alloy of potassium and arsenic to water; and likewise by the decomposition of water by the Voltaic series, one of the wires, employed for the purpose, terminating in a piece of arsenic immersed in that liquid.

206. EXPERIMENTAL ILLUSTRATIONS.

Appearance and habitudes of arsenic, in its metallic and crystalline form, contrasted with those of zinc, antimony, and bismuth. Arsenious acid, and its solutions, exhibited: also, Fowler's solution, or arsenite of potash. Arsenious and arsenic acid, in solution, added to large vessels of clear water, and detected by sulphydric acid, or by ammoniacal nitrate of silver or copper. Same acids precipitated by lime water. Exhibition of Scheele's green, or arsenite of copper. Combustion of arsenuretted hydrogen displayed.

Of the Means of detecting Arsenic in Food or Drink, or in the Contents of a Stomach, in cases where Poisoning is suspected.

In respect to arsenic, the most important subject of attention is the means of detecting this metal, in cases in which it may be used as a poison.

The first steps are of course directed to the collection and preservation of all the matter which may have come from the patient in vomiting, or which may be obtained by opening the stomach. As it is usually in the solid state of arsenious acid that this poison is administered, both the matter thus obtained, and the surface of the stomach should be rigidly examined, in order to detect any particles which may remain in that state. Berzelius counsels us especially to scrutinize those spots in the stomach which appear to have been inflamed, in order to ascertain if there be not particles of the poison lodged in them.

In the next place, the whole mass collected and preserved, as above advised, should be thrown into water, which, while stirred to cause the suspension in it of the lighter portions of the matter, should be poured off together with that lighter matter from the heavier subsiding portion. The liquid thus separated should be filtered, and both the resulting filtered solution, and the heavier matter, which may have sunk to the bottom of the vessel, should be evaporated to dryness in an appropriate oven, or in a vessel kept hot by boiling water. The whole being quite dry, it should be introduced into a glass or porcelain vessel; and adding a sufficient quantity of strong nitric acid to cover the mass, it should be subjected to a heat adequate to cause a brisk reaction. This should, if necessary, be sustained by further additions of the acid, until there be no longer any inorganic matter undecomposed.

As nitric acid can have no other effect upon arsenic, than that of converting it into arsenic acid, in which state it is less volatile than in any other; this process tends at the same time to annihilate the organic impurities, and to secure the metal. Thus the matter to be assayed is much diminished in bulk, and if it contain arsenic must hold it as arsenic acid, which is more soluble than arsenious acid. Hence, if the dry mass be digested with water, a solution may be obtained, which, being filtered, may be precipitated by lime-water. The arseniate of lime which precipitates, being dried, should be mingled with about one-fourth of its weight of powdered charcoal, and introduced into a glass tube, sealed at one end. The mixture having been made to settle down to the sealed end, within as narrow limits as possible, a little cotton wick must be fastened to the end of a wire, by twisting the wire so as to form one end into an eye, and passing the wick through the eye, and winding it about the end of the wire, until a plug of cotton be made just large enough to slide in the tube, like a piston. For greater security, the wick may be wound about the wire so that one end may be held in the hand. By means of the piston, thus formed, the portion of the tube not occupied by the mixture, may be wiped clean. The tube should now be subjected to the flame of a spirit lamp, the piston being retained in it, as near the mixture as it can be without being injured by the heat. The heat should be applied, at first, to the anterior part of the mass, proceeding to the posterior part afterwards; and as soon as the whole ceases to give out aqueous vapour, the piston should be passed quickly down so as to wipe away the moisture condensed, together with any accompanying foulness. The piston being again beyond the reach of the heat, the part of the tube containing the mixture should, by the aid of a blowpipe, be exposed to a temperature as high as the glass will bear. If there be arsenic in the mixture, it will now appear in a bright metallic ring, just beyond that part of the tube which was heated red hot. On cutting the tube at the part where the ring appears, and heating it by a spirit lamp, the alliacious smell of arsenic will be perceived, if this metal be present, and the same smell will be experienced on igniting the cotton of the piston abovementioned.

The process thus described is that which I employed in the analysis of some matter sent to me from Westchester, by Dr. Thomas; having been obtained from the stomach of a woman poisoned by her husband. I afterwards repeated it successfully at Westchester, in presence of

Dr. Thomas and another physician, and upon their evidence of the result so obtained, the murderer was convicted. Before his execution he confessed himself to be guilty.

Where no arsenic can be detected in the contents of the stomach, it may be found in the membranes, or coats. Hence, in making the examination for arsenic, the stomach should be boiled in nitric acid, until all the organic matter is destroyed.

Very minute quantities of arsenic may be detected by the aid of silver, or copper, in solution. With silver, arsenic acid gives a brick-red, arsenious acid, a yellow precipitate. With copper, arsenious acid produces a very striking green precipitate of arsenite of copper, called Scheele's green. Sulphydric acid gas produces, with either acid, a yellow precipitate of sulphide of arsenic. As these results are precarious, and liable to be produced by other causes, they should not be considered as conclusive evidence.

In the case of the murder abovementioned, I found that the arsenic acid, as procured from the contents of the stomach, would not assume the appropriate hue in precipitating with silver, whether before or after its union with lime. Instead of a brick-red, it was of a muddy colour. By Dr. Feutchwanger, who was present during many of my experiments, this was ascribed, correctly, as I believe, to phosphoric acid. It has been stated, that it is difficult to separate these acids when associated, from their isomorphism; or, in other words, crystallizing in the same form.

By simple affinity, neither silver nor copper can be precipitated from their solutions in acids, by arsenic, or arsenious acids. Hence, an alkali must be present, either in union with the arsenical acids, or with the metallic salt. This object is attained conveniently, by the addition of ammonia to the nitrate of silver or copper, as with either of those metals, that alkali forms a soluble ammoniacal nitrate

207. EXPERIMENTAL ILLUSTRATIONS.

Small portions of arsenious acid, or of the arseniate of lime, mingled with powdered charcoal, and subjected to heat in a glass tube. Arsenical ring produced and exhibited.

OF ANTIMONY.

Antimony sometimes occurs in nature in the metallic state, or in that of oxide, and exists abundantly as a sulphide. It is in fact the sulphide that is called antimony in commerce, the metal being designated as the regulus of antimony.

The ores of this metal had been known for a long time; but for its extrication from them, the world is indebted to Basil Valentine, who lived towards the close of the fifteenth century. Since that period, from its utility in medicine, it has been eminently an object of investigation.

Of the Means of obtaining Antimony.

Metallic antimony may be obtained by mingling the sulphide with two-thirds of its weight of bitartrate of potash, and one-third of its weight of nitre, and deflagrating the mixture in a red hot crucible. The oxygen of the nitre converts the sulphur into sulphurous acid, which escapes, while the alkali of both the salts operates as a flux, or in other words, promotes the fusion of the mass. The carbon of the tartaric acid counteracts the oxidizement of the metal.

Charcoal intimately intermingled either with carbonate of potash, or soda, may be used instead of the bitartrate.

Antimony thus obtained, is not quite pure. To render it so it may be dissolved in aqua regia, precipitated by water in the state of oxychloride, and revived by ignition with bitartrate of potash.

Of the Properties of Antimony.

Antimony is so brittle as to be easily pulverized. It displays a crystalline structure, and may be crystallized by the process resorted to in the case of sulphur. When newly fractured, it is of a bluish white colour, and very brilliant. If it be rubbed between the fingers, they acquire a perceptible odour. Its specific gravity is 6.7. It fuses a little below a red heat. When thrown in a state of fusion upon a board, it is dispersed in a multitude of ignited globules, which emit copious fumes of oxide, and leave their traces upon the board. The temperature of the globules seems to be supported by their own combustion.

According to Berzelius, the purity of antimony is indicated by a silvery whiteness, and a granular or fine lamellar texture; whereas the metal otherwise does not excel tin in whiteness, and is coarsely lamellar, almost as if susceptible of cleavage.

The equivalents of antimony, and of its compounds with oxygen, chlorine, and sulphur, are as follows:—

Antimony						65
Sesquioxide,	1	atom	metal,	1½	oxygen,	77
Antimonious acid,	1	„	„	2	„	81
Antimonic „	1	„	„	2½	„	85
Sesquichloride „	1	„	„	1½	chlorine	119
Perchloride,	1	„	„	2½	„	155
Sesquisulphide,	1	„	„	1½	sulphur,	89
Bisulphide,	1	„	„	2	„	97
Persulphide,	1	„	„	2½	„	105

OF THE COMPOUNDS OF ANTIMONY WITH OXYGEN.

The *sesquioxide* of antimony may be obtained by exposing the metal to heat with access of air, by moderately roasting the sulphide, or by subjecting the sesquichloride to water, in which case a powder precipitates, called powder of Algaroth, from the name of the physician who first recommended it to public attention. This powder being an oxychloride, by digestion with the carbonate of potash is converted into the sesquioxide.

It may also be obtained by the reaction of the metal with diluted nitric acid, afterwards repeatedly digesting the resulting subsalt in water until this liquid no longer reddens litmus.

In the form in which the sesquioxide is obtained by heat and air, it received formerly the name of argentine flowers of antimony.

When obtained from the oxychloride, the sesquioxide has a tinge of gray. If, as procured by this last mentioned method, the sesquioxide be heated, it takes fire, and is converted into antimonious acid. The sesquioxide acts feebly, both as an acid and a base. Combined with bitartrate of potash, it constitutes tartar emetic, and is the only compound of antimony with oxygen, which is considered as medicinally efficacious.

Antimonious acid is generated by digesting antimony in nitric acid, evaporating the liquid to dryness, and calcining the residue; or by thoroughly roasting the sulphide of antimony with access of air. Antimonious acid is white, tasteless, infusible, fixed, indecomposable by heat, and insoluble in water.

When nitric acid is added to a solution of the antimonite of potash, the antimonious acid is precipitated in the state of a hydrate. In this state, it reddens litmus paper.

Anhydrous antimonic acid is obtained by subjecting the oxychloride to the action of nitric acid, and afterwards heating the resulting mass to expel any excess of this acid. By deflagrating the metal with four times its weight of nitre, dissolving in water the resulting mass, and afterwards adding nitric acid, which combines with the alkali, hydrous antimonic acid is procured.

Anhydrous antimonic acid is yellow, tasteless, and insoluble in water. When hydrous, it is white, and has the property of reddening litmus.

Just at the moment when certain antimonites and antimoniates, subjected to a low red heat, lose their water of crystallization, they give birth to a transient light as vivid as would result from a true combustion. Yet they incur in consequence no change in weight. Their colour is rendered brighter, and they become less susceptible of decomposition by acids. This result ensues especially with the antimoniates of copper, cobalt, and zinc.

Sulphuric acid, when cold or diluted, does not react with antimony, but when warm and concentrated, is partially decomposed, evolving sulphurous acid, and forming a sesquioxide of the metal, with which the undecomposed acid combines. By water the acid may be for the most part removed from this sulphate, so as to cause in it an excess of oxide so great as to render it competent for the production of tartar emetic by digestion with the bitartrate of potash. In this case the excess of oxide in the sulphate, and excess of acid in the bitartrate, unite, converting the latter salt into the double tartrate of potash and antimony.

The reaction of diluted nitric acid with antimony is quite analogous to that already described in the case of bismuth. According to Berzelius, a subnitrate results, which may be decomposed by water as above stated, and converted into a hydrated sesquioxide. But Thenard informs us that if this metal be subjected to nitric acid (undiluted?) it is converted into hydrous antimonious acid ("acide antimonieux blanc et hydraté").

OF THE COMPOUNDS OF ANTIMONY WITH THE HALOGEN CLASS.

The *sesquichloride of antimony*, may, as Thenard alleges, be obtained by distilling the metal with the bichloride of mercury; also by the reaction of aqua regia with metallic antimony, and subsequent distillation of the resulting liquid, collecting the product in a fresh receiver when it becomes oleaginous in its consistency. He recommends as preferable, however, the action of chlorohydric acid on the sesquisulphide with heat, allowing the sulphydric acid gas to escape into the fire. The resulting liquid is to be decanted, and concentrated by heat in a retort, until it acquires an oleaginous consistency.

The sesquichloride has been designated as the butter of antimony. It is white, semitransparent, very caustic, fusible below a boiling heat, and crystallizable in tetrahedrons by refrigeration. It is volatile at a heat below redness, and deliquescent, so as to be liquefied by exposure to air. It has already been mentioned that by subjecting this chloride to copious affusion of water, (eight times its weight according to Thenard) an oxychloride results, formerly called the powder of Algaroth.

The *deutochloride of antimony*, agreeably to the last mentioned author, exists only in combination with chlorohydric acid.

The *perchloride of antimony* is formed by the combustion of the metal in chlorine. It is a yellow liquid, sending forth thick fumes into the air, with a strong and disagreeable smell. It attracts moisture, and is, in consequence, at first converted into a white crystalline mass, but is afterwards liquefied by a further accession of humidity. Yet by exposure to a large quantity of water with heat, it is decomposed, and deposites, consequently, hydrated or hydrous antimonic acid. This process is recommended as the best for obtaining this compound.

OF THE COMPOUNDS OF ANTIMONY WITH SULPHUR AND SELENIUM.

It has been stated that antimony is procured principally from the native sesquisulphide which is found in the shops under the name of the metal, the latter being distinguished as the regulus.

This compound may be formed from its ingredients, by heating the metal in a state of division, with sulphur. The sesquisulphide is more fusible than metallic antimony, is crystalline in texture, has a metallic lustre, and a bluish-gray colour. It may act either as a sulphacid, or as a sulphobase. With the sulphides of the alkalifiable metals it forms compounds, which may be designated as hyposulphantimonites.

The sesquisulphide, and sesquioxide of antimony, enter into combination with each other in different proportions, forming compounds which must be called oxysulphides, consistently with the nomenclature adopted in the case of the analogous compounds of oxides with chlorides.

When the sesquisulphide of antimony is roasted, or in other words, exposed to heat with access of air, it becomes more or less oxidized, according to the duration of the exposure, the degree of heat, and the supply of air. If, after the roasting has continued for some time, the temperature be raised so as to fuse the mass, a vitreous compound will result, the composition of which will vary according to the ratio of the oxide to the sulphide, at the time of effecting the fusion. According to Thomson, when the ratio of the former to the latter is as five to one, the compound has the name of crocus of antimony; when the ratio is as three to one, it has been called liver of antimony. This name is given by Berzelius, to a compound of the sulphides of antimony and potassium.

If the sulphide of antimony, instead of being poured out as soon as it is melted, be kept for a great length of time in a state of fusion in an earthen crucible, it derives a portion of oxide of iron and silicic acid from the crucible, and thus forms a transparent mass of a yellow hyacinth colour, commonly called the glass of antimony. This glass, according to Thenard, is a mixture of oxysulphide of antimony, with the silicate of antimony and iron.

By the reaction of the sesquisulphide of antimony with the alkalies, either caustic or carbonated, and either in the wet or the dry way, a complicated reaction ensues, by which the antimony of the sulphide is more or less oxidized, the metal of the alkali more or less sulphurized; while the residual sulphide of antimony, acting as a sulphacid, combines more or less with the resulting sulphobase of the alkalifiable metal.

The extent to which the sesquisulphide, in the resulting sulphosalt, can be retained by the sulphobase in an aqueous solution, appears dependent upon temperature. Hence, whether the sulphosalt be produced in the dry way, and dissolved in hot water, or be generated by boiling the ingredients in this liquid, the sesquisulphide precipitates by refrigeration.

Under the name of Kermes mineral, the precipitate thus obtained was so much in vogue in France, about a century ago, as to induce the government of that country to purchase from a surgeon of the name of La Ligerie, the art of preparing it.

Thenard alleges, that it appears from the analysis of Henry, Jr., that the composition of Kermes varies according to the process employed for its production. When prepared by boiling the sesquisulphide in a solution of *carbonate* of potash, or soda, Kermes may be considered as an hydrated oxysulphide; but when procured, either by boiling the sesquisulphide in a solution of potash or soda, or by *fusion* with them or with their carbonates, and subsequent solution in hot water, it is a hydrated sesquisulphide, which contains very little, if any, oxide. As obtained by precipitation from tartar emetic by sulphydric acid, it is a pure hydrated sesquisulphide. After the Kermes has precipitated, a portion of the sesquisulphide still remains in union with the sulphobase. Hence, on the addition of an acid, a further precipitation takes place, both of the sesquisulphide of antimony, and the sulphur of the sulphobase; and these, either by combination or mixture, constitute the golden sulphur of antimony, another well known pharmaceutical preparation.

According to the analysis of Henry, Jr., as quoted by Thenard, the composition of Kermes, when obtained in the wet way, by carbonated soda, is as follows:

Sesquisulphide of antimony, - - - -	62.5
Sesquioxide of antimony, - - - -	27.4
Water, - - - - - - -	10
Soda, - - -	

Upon the whole it is inferred, that the sesquisulphide, in precipitating by refrigeration as abovementioned, combines with water in all cases; and that when the process is conducted in the wet way, by means of a carbonated alkaline solution, the precipitating hydrated sesquisulphide combines also with sesquioxide, forming an oxysulphide. The presence of carbonic acid in union with the alkali is requisite, in order to enable the menstruum to form and dissolve while hot, a double carbonate of the alkali and sesquioxide. The latter being thus taken up with the aid of heat; subsequently, in consequence of the refrigeration and its affinity for the hydrated sesquisulphide precipitates in combination with this sulphide as already mentioned.

The officinal preparation called precipitated sulphuret of antimony, is obtained by adding diluted sulphuric acid to a solution of the sesquisulphide of antimony in a boiling caustic solution of potash. A precipitate results which may be considered as a mixture of Kermes mineral, and golden sulphur of antimony.

The *bisulphide of antimony* is obtained, according to Thomson, by dissolving antimonious acid in chlorohydric acid, and subjecting the resulting liquid to sulphydric acid. I infer that two atoms of chlorohydric acid, acting on an atom of antimony, in union with two atoms of oxygen, will be productive of a bichloride, and that this will be converted into a bisulphide, by reaction with the sulphydric acid.

The bisulphide being resolvable into the sesquisulphide, and sulphur, by heat, cannot be produced by the fusion of its constituents. It is of an orange-red colour, and acts as a sulphacid.

The *persulphide of antimony* is obtained by passing sulphydric acid through a diluted solution of the perchloride of this metal, to which tartaric acid has previously been added. Its colour resembles that of the bisulphide, though somewhat paler.

The selenide of antimony is obtained by heating this metal with selenium. Like the sulphide, it is capable of entering into combination with the oxide.

208. EXPERIMENTAL ILLUSTRATIONS.

Antimony and its sulphide exhibited, and exposed to the blowpipe; also, the crystals and solution of tartar emetic, Kermes mineral, golden sulphur, and precipitated sulphuret of antimony exhibited. Antimony subjected to acids. Kermes mineral also precipitated from a solution of tartar emetic by sulphydric acid.

Of the Tartrate of Potash and Antimony, usually called Tartar Emetic.

Before concluding the subject of antimony, I deem it expedient to subjoin the following extract respecting tartar emetic, the most useful of all the antimonial preparations. It is quoted from an article upon antimony, furnished by my friend Dr. Bache for the American Cyclopedia of Practical Medicine, edited by Dr. Hays.

"Tartar emetic, called correctly the tartrate of antimony and potassa in the Dublin and United States Pharmacopœias, is a colourless, inodorous salt, possessing a nauseous styptic taste, and crystallizing usually in rhombic octohedrons. When prepared by means of the nitro-muriatic oxide,* its crystals have the appearance of tetrahedrons. As it occurs in the shops, it is in the form of a white powder, formed by the pulverization of the crystals. The crystals, when exposed to the air, effloresce slightly and become opake. Tartar emetic is insoluble in alcohol, but dissolves in fourteen times its weight of cold, and about twice its weight of boiling water. Its aqueous solution reddens litmus, and undergoes spontaneous decomposition by keeping. According to Berzelius, the protoxide† is precipitated from the solution of this salt by sulphuric, nitric, or muriatic acid, but not by the alkalies. Agreeably to Turner, a little pure potassa throws down the protoxide from a solution of tartar emetic, but takes it up again, if added in excess. According to the same authority, the alkaline carbonates throw down the protoxide also, but much more completely. Turner also admits that the mineral acids throw down a precipitate; but instead of considering it, with Berzelius, the protoxide, he states it to consist of cream of tartar and a subsalt of antimony. It must be recollected, however, that on trying any of these precipitations, the solution of the antimonial salt must be strong, and the several precipitants not added too freely, otherwise they will produce no effect.

"Tartar emetic is precipitated in a very characteristic manner by sulphuretted hydrogen, which throws down an orange-red precipitate, consisting of hydrated sesquisulphuret of antimony.

"When tartar emetic is pure, it should exhibit its appropriate crystalline appearance, and be entirely soluble in distilled water. Its solution should not be precipitated by muriate of baryta,‡ oxalate of ammonia, acidulous nitrate of silver, or acidulous acetate of lead. A precipitate by the first reagent indicates sulphuric acid; by the second, lime; by the third, muriatic acid; and by the fourth, cream of tartar. The most usual impurities which it contains, are uncombined cream of tartar, tartrate of lime, silica and iron, and sulphate of lime. Cream of tartar is present, usually either from its having been used in excess in preparing the salt, or from fraudulent admixture. Tartrate of lime is derived from the cream of tartar, which always contains this impurity, as found in the shops. It is apt to form on the surface of the crystals of tartar emetic in crystalline tufts, which are easily brushed off. Silica and iron are liable to be present when glass of antimony has been employed in preparing the antimonial salt, and the evaporation has been carried too far. Sulphate of lime is sometimes an impurity, when tartar emetic has been prepared by means of the subsulphate. According to Serullas, tartar emetic, as ordinarily prepared, and all the other antimonial preparations, usually contain a minute portion of arsenic, derived from the native sulphuret of antimony, which almost always contains this dangerous metal. Its presence in tartar emetic may be detected by exposing the salt to the action of the blowpipe, when the peculiar odour of the arsenic will be perceived. This dangerous impurity, however, is not present in well-crystallized tartar emetic, a fact which should form a strong additional motive with the apothecary, always to purchase this antimonial in crystals.

"Besides being decomposed by the mineral acids, the alkalies whether

* Oxychloride. † Sesquioxide. ‡ Chloride of barium.

pure or carbonated, sulphuretted hydrogen, and hydrosulphates,* the same effect is produced by many other substances. Thus, it is decomposed by some of the metals and their oxides, by lime-water and muriate of lime,† and by the acetate and subacetate of lead. This antimonial salt is also affected by common water when holding carbonate of lime in solution, but not when containing muriates,‡ sulphate of lime, or extractive matter. Hence it is necessary to dissolve it in distilled water, when the pure effects of the medicine are designed to be produced. Other substances which decompose tartar emetic, are the decoction of tamarinds, lemonade, whey, and generally all bitter and astringent vegetables, such as Peruvian bark, rhubarb, galls, catechu, &c. Of these different substances, some precipitate the antimonial oxide, and others produce new salts with it, either soluble or nearly insoluble; but it by no means follows that they render the tartar emetic inert. On the contrary, the ordinary effects of the medicine are produced, though by the agency of the new combinations formed. Some doubt, however, may be entertained whether this remark will apply to the effects of the bitter and astringent vegetable medicines, which owe their power of decomposing tartar emetic to the presence of tannin, which forms an insoluble compound with the oxide of antimony. Nevertheless, Laennec has remarked that, though cinchona and infusions of other vegetables precipitate tartar emetic, still the new compounds formed have the same properties as those of the tartar emetic itself. It is difficult to believe this statement without some qualification; as the evidence is very strong in proof of the influence of bark and other astringent vegetables, in mitigating the effects of an over-dose of tartar emetic. The truth probably is, that the tannate of antimony, produced by these vegetables, is not inert, though by no means so active as the undecomposed salt; and that it is capable of producing similar effects with tartar emetic, provided it be given in a sufficient dose.

"Tartar emetic enters into but three officinal preparations, contained in the British and United States Pharmacopœias. These are antimonial wine, tartar emetic ointment, and Coxe's hive syrup (Mel Scillæ Compositum. Ph. U. S.)."

Tartar emetic may be considered as consisting of

Two equivalents of tartaric acid,	$66 \times 2 =$	132
Two of sesquioxide of antimony,	$77 \times 2 =$	154
One of potash,		48
Two of water,	$9 \times 2 =$	18
		352

OF METALS PROPER OF MINOR IMPORTANCE.

OF PALLADIUM.

Besides iron, copper, and lead, four metals, palladium, rhodium, iridium and osmium, are found in union with, or accompanying, the native grains of platinum as imported from South America. Accordingly, if a portion of that assemblage of metallic particles, of which the native grains of platinum above mentioned form the principal part, be digested in aqua

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* Sulphydrates.

† Chloride of calcium.

‡ Chlorides.

regia, the platinum, together with the palladium, rhodium, copper, and lead, will be dissolved; while a black powder will be left, consisting of osmium and iridium in combination with each other.

The platinum may be precipitated from this solution, as has been already stated, by the addition of the chloride of ammonium. Next all the noble metals present are precipitated by a bright plate of zinc. They are then digested in chlorohydric acid, and subsequently redissolved in aqua regia. Any excess of acid in the resulting solution should be neutralized by carbonate of soda. Afterwards the palladium may be precipitated by the addition of the bicyanide of mercury. From the cyanide of palladium, thus precipitated, the palladium may be liberated by a red heat.

Mr. Cloud, of the United States mint, found this metal in a native alloy of gold which was brought from Brazil.

Palladium resembles platinum in colour and lustre, but is more fusible, and rather harder. Its specific gravity, also, is much less, being about 11.5. It is malleable and ductile, and insusceptible of oxidizement by heat and air.

OF RHODIUM.

After the palladium has been precipitated, the solution contains the chloracids of rhodium, mercury, and several other metals, united with the chloride (or chlorobase) of sodium, resulting from the carbonate of soda, employed as abovementioned to neutralize the excess of acid. There is likewise present a portion of the undecomposed bicyanide of mercury. Under these circumstances, chlorohydric acid must be added, in order to convert this bicyanide into a bichloride, and the solution afterwards must be evaporated to dryness. The resulting mass should then be washed with alcohol, which dissolves all the chlorosalts of sodium present, except the chlorhodiate. Rhodium is obtained from this, by heating it in a current of hydrogen which removes the acid, the chloride of sodium being removed by water.

Rhodium, according to Berzelius, cannot be fused, except by subjecting it, when in the state of a sulphide or arsenuret, to an intense heat. After fusion, it resembles platinum in appearance. Its salts are generally either red or yellow. It is named from its chloride, which is rose-red.

OF IRIDIUM.

When the black powder, consisting of the osmiuret of iridium, which remains as above stated, after we have subjected the crude grains of platinum to aqua regia, is heated with soda, an osmiate of soda is formed, which may be removed by dissolving it in water. The remaining mass is to be treated with aqua regia, in which the iridium converted into a chloride, dissolves. By repeating this process, the whole is finally converted into solutions of the chloride of iridium, and osmiate of soda.

From the former, crystals of the chloride of iridium may be obtained by evaporation, which, on exposure to a strong heat, yield metallic iridium.

Iridium resembles platinum in appearance, and is probably, according to Thomson, the heaviest of the metals. When heated in contact with air, nearly to redness, it is oxidized, but on the application of a higher temperature it is again restored to the metallic state. Thenard, however, states that iridium which has been subjected to a strong heat, is absolutely insusceptible of oxidizement by the air, at any temperature.

Iridium is said to be the most refractory of the metals, having never been fused until it was placed between the poles of Children's large galvanic battery. It was then converted into a globule possessing metallic whiteness and lustre.

OF OSMIUM.

Osmic acid may be obtained by distilling the solution of osmiate of soda, procured as above described, with nitric acid, at a gentle heat. The osmic acid passes over, and may afterwards be reduced by the addition of chlorohydric acid and mercury. It is, however, alloyed with mercury, and mingled with the chloride of the same metal. These may be sublimed by a gentle heat, leaving pure metallic osmium.

Obtained in this way, osmium is of a grayish-black colour, but if a portion of the volatilized oxide be made to pass with a current of hydrogen through a glass tube, the osmium is deposited in the form of a ring of metallic brilliancy, and of a white colour. It is so difficult to fuse in close vessels, and so liable to be volatilized, when heated in the air, that it has only been obtained in powder, or in minute friable masses. Its volatility in the air arises from its great susceptibility of oxidizement, and the volatility of its oxide, the fumes of which are pungent.

OF NICKEL.

A mineral had been known to the German miners by the name of kupfer nickel, or false copper. About the middle of the last century, Cronstedt alleged the existence, in this mineral, of a peculiar metal. Nevertheless, the metal, thus indicated, was considered by many chemists as an alloy of copper with iron. About 1775, Bergmann confirmed, by an analysis, the allegation of Cronstedt.

Kupfer nickel is principally an arsenuret of nickel, but contains, also, sulphur, iron, cobalt, and copper.

Nickel is extricated from this mineral, by a tedious and intricate process.

Of the Properties of Nickel.

This metal is of a white colour, difficult of fusion, malleable and not easily oxidized by the air. It is so susceptible of the magnetic influence that a permanent magnet may be made of it. If sufficiently abundant, nickel would be very valuable in the arts. It combines with oxygen, chlorine, iodine, cyanogen, sulphur, and the metals. Its oxides are soluble in the acids, and in their habitudes are much like those of copper. The solubility of its protoxide, in caustic ammonia, is an important mean of separating nickel from its alloys.

OF CADMIUM.

This metal has been derived only from the ores of zinc. During the reduction of calamine, a substance sublimes, which yields from 12 to 20 per cent. of cadmium.

A solution of the ore in sulphuric acid, being impregnated with sulphydric acid, the cadmium precipitates in the state of sulphide mixed with a little sulphide of zinc, and sometimes with sulphide of copper.

When these sulphides are exposed to chlorohydric acid, water is decomposed, the sulphur unites with the hydrogen and escapes, and they are converted into chlorides. Carbonate of ammonia being added to the resulting solution of cadmium and zinc, a carbonate of cadmium is alone precipitated. From this, the metal may be obtained by means of heat and charcoal.

Of the Properties of Cadmium.

This metal is almost as white as tin, is without odour or taste, very brilliant, and susceptible of a fine polish. It is crystallizable, malleable and ductile, and so soft as to yield easily to a file or knife. Its specific gravity is 8.6 nearly. It is too scarce to be usefully applied. It fuses and volatilizes at a very low temperature.

OF CHROMIUM.

This metal is found in nature only in the state of an acid and of an oxide generally united with lead or iron, though in some instances pure. It was in the native chromate of lead, found usually in crystals which rival the ruby in colour, that this metal was discovered by Vauquelin. A compound of protoxide of chromium and iron, called incorrectly chromate of iron is found plentifully in this country. The oxide of chromium, when intensely heated with charcoal, is reduced, but not without great difficulty.

The presence of chromium in a mineral, may be detected by the fusion of a minute portion before the blowpipe with borax; or preferably, with the ammoniacal phosphate of soda. In this way, a globule of a beautiful emerald green results, which preserves its colour either in the oxidizing, or reducing flame. By these characteristics it may be distinguished either from copper or uranium; since uranium communicates a green hue only in the reducing flame, copper only in the oxidizing flame.

Chromium is a hard, brittle metal, of a grayish-white colour, and very difficult to fuse. Its specific gravity is 5.9. Its equivalent is 28. It forms with oxygen a protoxide, a deutoxide, and an acid. The deutoxide, however, is considered as a compound of the protoxide and chromic acid.

The protoxide of chromium is easily obtained by exposing the chromate of mercury to heat, by which the mercurial oxide, and a portion of the oxygen of the acid, are expelled, while the protoxide remains in the form of a grass-green powder.

It may also be obtained in the state of a hydrate, by mixing solutions of the bichromate of potash, and persulphide of potassium. This oxide is of a beautiful green colour, and communicates this colour to some of its compounds, being in fact the colouring matter of the emerald. It appears to act both as an acid and a base.

In common with zirconia, and oxide of titanium, the oxide of chromium, when obtained from the hydrate by drawing off the water by a gentle heat, becomes incandescent at a certain elevation of temperature, in a way which is altogether unaccountable. At the same time it loses its property of solubility in acids which it before possessed.

Chromic acid may be procured by the following process. Let four parts of the chromate of lead be mixed with three parts of fluoride of calcium, both finely pulverized. Then let five parts of sulphuric acid, deprived of water as far as possible by boiling, be added, and let the whole be distilled in a leaden or platina alembic at a gentle heat. A red gas will be developed, producing in the air, yellow fumes. This red gas is a fluoride of chromium, which on being passed into water, is converted into fluohydric, and chromic acids. The former may be expelled by evaporation, the chromic acid remaining in a state of purity.

If instead of causing the gaseous fluoride of chromium to enter water, it be introduced into a receptacle of platinum closed with moistened paper, and having a small quantity of water at the bottom, the gas will be decomposed by the aqueous vapour, mingled with the air of the vessel, and will deposit first about the mouth of the tube, and afterwards throughout the vessel, a flocky vegetation, consisting of ruby-red crystals of chromic acid.

Chromic acid is solid, soluble in water, and reddens litmus. It is decomposed by heat, and by most substances which possess an affinity for oxygen. It possesses an acid and astringent taste, and a ruby-red colour, which it communicates to some of its compounds, as already noticed in the case of native chromate of lead. It forms striking and beautiful precipitates with various metals. That which it produces with lead, is of a splendid orange yellow, and is much used as a pigment. The colour of the streak left by the red crystals above described, when rubbed upon a hard surface, is likewise orange yellow; and the same change ensues from pulverization. The bichromate of potash is poisonous—no doubt the acid and its compounds generally, are poisons.

Chromic acid creates a stain upon the skin which cannot be removed by water, unless it contain an alkali. Where there is any abrasion of the cuticle, the presence of this acid will induce a painful ulcer. Hence the sores to which dyers are exposed who employ bichromate of potash as a dye stuff. These sores have been alleged to arise even from exposure to the vapours or fumes of this acid. When received into the stomach, chromic acid is a virulent poison. Dr. Ducatel informs us of the case of a labourer who died in five hours, after drawing into his mouth from a syphon, a solution of bichromate of potash, although he was under the impression that by spitting, he had avoided taking it into his stomach.

Dr. Ducatel suggests an alkaline solution as the best antidote, as he ascribes the poisonous property of the bichromate, mainly to the excess of acid. An instance of a criminal prosecution for poisoning by the salt in question, is mentioned, which failed from that ignorance of its deleterious properties which Dr. Ducatel's communication must tend to correct.*

OF COBALT.

This metal is found in nature, principally in union with arsenic. By the exposure of the mineral thus containing it, to heat, with the access of air, the arsenic is oxidized and expelled, and the cobalt is reduced to the state of an impure oxide, called zaffre. By fusion with alkali and sand, zaffre yields a beautiful blue glass, which, when pulverized, forms the blue vitreous powder called smalt.

Cobalt may be obtained from its oxide, by intense ignition with charcoal, or by subjecting its oxide, while ignited, in a porcelain tube, to a current of hydrogen.

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* See Journal of the Philadelphia College of Pharmacy for January, 1834, page 272, vol. 5.

Cobalt is brittle, of a grayish-white colour, and feeble lustre. Its specific gravity is 8.5 nearly. It requires a high temperature for its fusion.

OF COLUMBIUM.

A metal discovered by Hatchett, in 1801, in a mineral obtained from America, received the name of columbium. It was afterwards detected by Ekeberg in two Swedish minerals, called tantalite, and yttrotantalite; and being supposed to be a new metal, was called tantalum. Wollaston afterwards demonstrated the identity of tantalum, with columbium.

This metal is found in the state of an acid, combined either with manganese and a little iron, or with yttria. Both combinations are very rare. It may be reduced by heating the fluocolumbate of potassium (or fluoride of columbium and potassium) with potassium.

Columbium is a brittle metal, of an iron-gray colour, having the metallic lustre. It is infusible by the most intense heat of the forge fire.

OF MANGANESE.

Manganese exists in nature principally in the state of a black bioxide; rarely in that of phosphate, sometimes in the state of sulphide. The utility of this oxide, as a source of oxygen gas, as an ingredient in glass, and as one of the agents for evolving chlorine, has been noticed. The metal is obtained by heating the oxide intensely with charcoal or potassium. It is gray, brittle, hard, and scarcely fusible by the highest heat of the forge, or air furnace. In the metallic state, it has not been applied to any useful purpose.

Manganese is remarkable for the number of compounds which it forms with oxygen. Besides a protoxide, a sesquioxide, and a bioxide, it forms two acids, the manganic, and oxymanganic acids, which would be named more correctly manganous and manganic acid. The salts of the latter detonate with combustibles.

When the black oxide (bioxide) is fused with the nitrate of potash, a compound results, of which the aqueous solution becomes blue, violet, and red, and finally colourless. Hence this compound has been called chamelion mineral.

These colours appear to be produced by the conversion of the manganate of potash, into an oxymanganate.

OF MOLYBDENUM.

This metal is only found in the state of sulphide, resembling plumbago, or united with oxygen and lead in the state of molybdate of lead. From the sulphide, it is obtained by ebullition with nitric acid, which acidifies both the sulphur and metal. The sulphuric acid being expelled by heat, the molybdic acid is decomposed by intense ignition with charcoal.

As from the difficulty of fusing it, molybdenum has been only obtained in small grains; its properties are little known. It is alleged to have a high degree of metallic lustre, and a white colour.

OF TITANIUM.

Titanium, like many other metals, is only interesting as an item in the knowledge which human skill and assiduity have accumulated, with respect to the materials of the globe which we inhabit. It is obtained by separating the oxide from the substances with which it is naturally mixed, and heating it intensely with charcoal.

Titanium was first ascertained to exist in the state of oxide, by Mr. Gregor, in a mineral called menachanite. It was subsequently detected in the metallic state, in minute cubic crystals, in the slag at the bottom of a smelting furnace, by Dr. Wollaston.

These crystals were conductors of electricity, of a specific gravity of 5.3, and hard enough to scratch rock crystal. In colour and lustre, they were like burnished copper. They resisted the action of nitric acid or aqua regia, but were oxidized by being heated with nitre.

OF TUNGSTEN.

In 1781, Scheele having analysed a stone known by the name of tungsten, or heavy stone, concluded that it consisted of an acid united with lime. Bergmann suspected the radical of the acid to be metallic. Messrs. D'Elhuyart verified his conjecture, by heating tungstic acid intensely with charcoal.

Tungsten is grayish-white, brilliant, and extremely difficult to fuse. Its specific gravity is 17.6.

OF URANIUM.

Uranium is a very rare production in nature, and has scarcely been found in sufficient quantities for an adequate observation of its properties. It is stated to have the metallic lustre, a reddish-brown colour, to be crystalline in its structure, and scarcely susceptible of fusion by the heat of a forge fire.

OF CERIUM.

Cerium, according to Vauquelin, who was unable to obtain it in masses larger than the head of a common brass pin, is a white brittle metal. From some experiments made by Children, and Thomson, it appears to be susceptible of volatilization.

OF VANADIUM.

Vanadium was discovered, in 1801, by Del Rio, in a lead ore from Zimapan, in Mexico; but Collet Descotils, to whom the mineral was sent having made some new experiments upon it, pronounced it to be an ore of chromium. Del Rio himself, having acquiesced in this opinion, it was generally adopted until 1830, when Seftstrom discovered this metal again in a variety of Swedish iron, and in the scoria of the forge at which the iron had been wrought.

Vanadium resembles molybdenum in appearance; and in its properties lies between that metal and chromium.

209. EXPERIMENTAL ILLUSTRATIONS.

Exhibition of various specimens of the metals mentioned in the preceding pages. Magnetic influence of nickel demonstrated. Solutions of silver, mercury, and lead, precipitated by chromate of potash. Protoxide of chromium evolved by heating the chromate of mercury. Exhibition of the fluoride of chromium. Effects of cobalt, also of manganese, upon vitrified borax.

OF

ORGANIC CHEMISTRY.

Organic chemistry treats of the chemical properties and composition of all substances which are generated in vegetables or animals, or produced by the reaction of the substances of which they consist, either among themselves or with other bodies. It is naturally subdivided into vegetable and animal chemistry.

OF VEGETABLE CHEMISTRY.

It is, perhaps, less difficult to acquire some general ideas of vegetable and animal chemistry, than to make an equal progress in the chemistry of inorganic substances. The ultimate elements of vegetable and animal matter are fewer, and are peculiarly well known. But the light which is thrown upon inorganic compounds, by resolving them into their ultimate elements, is much more satisfactory than any which we can, by the same means, extend to organic products. Between these, ultimate analysis can demonstrate little more than a difference in the proportions of the hydrogen, oxygen, carbon, or nitrogen, of which they are constituted; although in their influence on vitality they may display the opposite properties of the most delicious food, or the most deleterious poison—of delighting or offending our senses in the extreme.

Hydrogen, oxygen, and carbon, are the principal ultimate elements of vegetable substances. In a few vegetables, nitrogen is a constituent. Potassium, sodium, and calcium, in the state of alkali, or earth, with minute portions of iron and of other matter, may also be found in them. But hydrogen, oxygen, and carbon, are, in quantity and importance, greatly predominant.

It is generally a marked distinction, between organic and inorganic products, that the latter can, in a much greater number of instances, be imitated by art.

The incompetency of chemists to regenerate the substances, analyzed by them, has caused the accuracy of their deductions to be questioned. Rousseau, having heard Rouelle lecture on farinaceous matter, said he would not confide in any analysis of it, till corroborated by its reproduction from the elements, into which it was alleged to have been resolved. I conceive that an acquaintance with facts, thoroughly demonstrable by modern chemistry, would have rendered that ingenious philosopher less sceptical. It may indeed at first view seem reasonable to consider synthesis as the only satisfactory test of the truth of analysis. But if when diamond is burned in one bell glass, and charcoal in another, in different portions of the same oxygen gas, and subsequently in each vessel in lieu of the diamond and charcoal, carbonic acid is found, from which, by potassium, carbon may be liberated, who would hesitate to admit both substances to consist of carbon, because this element cannot be recovered from the gaseous state in its crystalline form.

It does not appear that any vegetable matter is capable of existing as a permanent gas.

Of the Mode in which the Ultimate Ponderable Elements of Organic Bodies are associated.

It was originally advanced by Gay-Lussac, and has since been ingeniously sustained by Dumas, that vegetable and animal principles, containing three or more elements, should not be regarded as simple combinations, into which the elements enter singly, but as made up of binary* compounds which unite with each other in virtue of their opposite electrical states, as acids and bases.†

Thus sugar is conceived to be a compound of carburetted hydrogen, and carbonic acid, and ether, of etherine (oil of wine) and an acid, or water acting as an acid.

It has lately been ascertained by Wohler and Liebig, that there are common radicals not only in analogous substances, but in such as are quite unlike each other, as

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* In the sense in which the word binary is used by Berzelius and many other chemists, a binary compound is one which contains two heterogeneous elementary atoms. By Dalton this word has been used to signify a combination of two atoms of one kind with one of another.

† Johnson's Report for 1832, page 497.

for instance, benzule, consisting of C 14, H 5, O 2,* forms, with an atom of hydrogen, oil of bitter almonds, and with an atom of oxygen, benzoic acid. It produces also a chloride, a bromide, and an iodide, with an atom of each of the halogen bodies, to the compounds of which those names are severally appropriate.

Prout supposes that a large class of vegetable products, into which he has ascertained the hydrogen and oxygen to enter in the ratio for forming water, to consist of this liquid and carbon. They are hydrates of carbon. In fact under this head would be placed almost all vegetable principles which are neither acid, oily, nor resinous; such, for instance, as sugar, starch, gum, ligneous fibre, or lignin.

Of the Influence of Heat upon Vegetables, with, and without Access of Air.

When subjected to distillation, vegetables, in the first place, yield the water and essential oils previously existing in them. If the heat be raised to redness, they afford carbonic and pyroligneous (acetic) acid: also carbonic oxide with bituminous matter, or essential oils formed by the union of the hydrogen and carbon in various ratios, and which are more volatile in proportion as hydrogen predominates. By further ignition the oils and bitumen thus obtained are converted into some of the varieties of carburetted hydrogen; a deposition of carbon being a necessary concomitant of the change. In proportion as the hydrogen is rarefied by heat, its capacity to suspend the carbon appears to be diminished. (See page 233.)

The oxygen in the vegetable matter subjected to ignition in close vessels, by uniting with the hydrogen and carbon, gives rise to acetic and carbonic acid, carbonic oxide, and water. These results evidently originate from the superior volatility of the hydrogen and oxygen, which causes them to pass off into the aeriform state, with such portions of the carbon as they may, under these circumstances, be capable of retaining.

The experiments of Sir James Hall, show that vegetable matter simultaneously subjected to heat and pressure, is converted into a bitumen analogous to that of mineral coal. Under these circumstances caloric destroys the or-

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* See page 6.

ganic structure, but does not sever the constituents of many bodies, which would be otherwise partially dissipated. When ignited in the air, it were almost unnecessary to say that hydrogen, oxygen, and carbon, must yield water and carbonic acid only. These are the only products of hydrogen and carbon, when burned, where there is an ample supply of oxygen.

Of the Effects, upon Vegetable Matter, of Chlorine, Bromine, and Iodine, also of the Alkalifiable Metals, and some of the more powerful Acids.

Chlorine, bromine, and iodine, act upon vegetable matter, from their affinity for hydrogen only; for carbon they have little affinity, and exerting an attraction for oxygen, only under peculiar circumstances; in ordinary cases display none.

Where there is much carbon in intimate combination, as in wax and resinous substances, chlorine does not act, until, by heat, the attraction of the hydrogen for the carbon, is more or less counteracted. Where water is present, its decomposition is always slowly effected by chlorine, especially when any matter, attractive of oxygen, may be present, as in the case of vegetable colouring matter. Hence the efficacy of chlorine in bleaching.

The alkalifiable metals destroy vegetable matter containing oxygen as an essential constituent, by combining with this principle and liberating hydrogen. When potash and soda are heated to redness with organic substances, they are converted into alkaline carbonates, acquiring the carbon and oxygen requisite to form carbonic acid from the organic matter; but at a temperature of 400° or 450°, those alkalies produce oxalic acid by the decomposition of the organic matter, and are converted into oxalates.

Fluohydric, fluoboric, and sulphuric acid, at moderate temperatures, destroy organic matter, by their attraction for water; in which respect, they evidently do not act as acids, but have an effect analogous to that of the dry alkaline hydrates, and desiccated chlorides.

In like manner, sulphuric acid, hydrate of potash, and the chloride of calcium, absorb the elements of water from alcohol, and discolour it, by evolving a carbonaceous matter.

Chlorohydric acid acts feebly on organic substances, but so far as it does act, it appears also to operate by its affinity for water.

Nitric acid, on the other hand, has no other effect than to impart oxygen, giving rise to the same products as combustion. This result ought not to excite surprise, as this acid is, in effect, composed of the atmospheric elements, condensed into the liquid form, and containing an excess of that principle which is the most active. Owing to the volatility of nitric acid, many substances cannot be completely oxygenated by it, unless after several distillations. Repeatedly distilled from sugar, it first produces malic* acid, then oxalic acid, and finally water and carbonic acid. These ultimate results are inevitably consequent to the ignition of the nitrates with dry vegetable substances; as, in this case, the base of the nitrate detains the acid, until the heat is adequate to produce a powerful reaction.

Of the Influence of the Proportions of the Ultimate Elements upon the Qualities of the Substances which they constitute.

It is suggested by Gay-Lussac and Thenard, that the properties of vegetable substances may be inferred to a limited extent, from the proportions of their ultimate elements. He observes, that no nitrogen being present, if the oxygen be in a greater ratio to the hydrogen than in water, the compound is acid. If the ratio of the oxygen to the hydrogen be less than in water, the compound may be acid; but is, generally, also oily, resinous, alcoholic, or etherial. If the ratio of these elements to each other, be the same as in water, the product is of the nature of sugar, gum, or woody fibre. To this it may be added that alkalinity in vegetable principles, seems to require the presence of nitrogen.

OF THE ANALYSIS OF ORGANIC SUBSTANCES.

The analysis of vegetable and animal matter has been latterly accomplished by heating the substance with chlorate of potash, or preferably with oxide of copper, so as to oxidize all the carbon and hydrogen, and liberate, in the gaseous state, any nitrogen which may be present. The hydrogen has been in general estimated by the water produced; the car-

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* It has lately been alleged that a peculiar acid is produced, which has been mistaken for malic acid.

bon from the quantity of carbonic acid. Hence the products of the operation have been first passed over chloride of calcium, and afterwards subjected to hydrate of potash, lime water, or alkaline solutions. The water has been estimated from the increased weight of the chloride, and the carbonic acid by the volume absorbed.

OF THE SYMBOLS EMPLOYED BY CHEMISTS.

Before treating of organic substances, which consist nearly of the same ultimate elements, it will be advantageous to understand chemical symbols, as when expressed in these, the composition of a body can be understood almost intuitively, and of course for the same reason, the difference between two bodies can be more readily perceived. I shall translate from Berzelius an account of the symbols which he has devised, and which it would be well to understand, as they will often be met with. Objections have been made to some part of his plan, but in general I believe it will be expedient to adhere to it, since whatever Berzelius recommends, awakens the attention of chemists universally, and must cause his symbols to be generally understood throughout the chemical world.

"We select (says that distinguished chemist) as symbols the initial letters of the latin names of bodies. When the names of several bodies have the same initial, we add to each a letter which it has not in common with the rest; as, for instance, C signifies carbon, Cl chlorine, Cr chromium, Cu copper, Co Cobalt. When, however, the names of a metallic and of a non-metallic radical commence by the same letters, no additional letter is added to the latter. But when two non-metallic radicals have a common initial, it is necessary to distinguish one by means of an additional letter. Thus, to distinguish chlorine, bromine, and silicon, severally, from carbon, boron, and sulphur, the symbols of the former are Cl, Br, and Si, while those of the latter are, simply, C, B, S.

"The number of atoms is designated by cyphers. A cypher placed to the left multiplies all the symbols to the right, as far as the first cross, $+$ or the whole formula. A little cypher situated to the right of a symbol, and a little above its level, multiplies that symbol only. Thus $S^2\ O^5$ signifies one atom of hyposulphuric acid, consisting of two atoms of sulphur and five of oxygen, while $2\ S^2\ O^5$ signifies *two* atoms of the same acid. In such cases as that just cited, in which two atoms of the radical are united with one, three, or five of oxygen, the expression for the former would be abbreviated advantageously by having a specific sign for a double atom. The sign which I have adopted for this purpose, is a dash across the lower part of the symbolic letter. Thus P signifies a single atom, $\underline{P}$[*] a double atom of phosphorus. Compound atoms of the first order are expressed as in the following example of sulphate of copper—$Cu\ O + S\ O^3$. The sulphate of the sesquioxide of iron would be expressed by $Fe\ O^3 + 3\ S\ O^3$.

"It may be expedient to designate the number of atoms of oxygen, by dots placed over the letters symbolic of radicals. Thus we may designate the sulphate of copper by $\dot{Cu}\ \dddot{S}$, the sulphate of the sesquioxide of iron, by $\dddot{F}^3\ \dddot{S}^3$."

To perfect the harmony of the system of formulas, Berzelius proposes to employ analogous symbols for all basigen bodies, and to designate the

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[*] Instead of placing the dash on the lower parts of the letter, it is generally placed under it, as the former mode requires type cast for the purpose.

presence of sulphur, selenium, and tellurium, in a compound, by a comma, a dash, or cross, placed over the letter signifying the radical. "Usually (he observes) we commence formulas by the electropositive element, and terminate with that which is electronegative."

"The following are the symbols by which each simple body is to be represented.

O,	Oxygen.	B,	Boron.
H,	Hydrogen.	Si,	Silicium. Silicon.
N,	Nitrogen.	Se,	Selenium.
S,	Sulphur.	As,	Arsenic.
P,	Phosphorus.	Cr,	Chromium.
Cl,	Chlorine.	Mo,	Molybdenum.
Br,	Bromine.	W, (Tu) Wolfram,	Tungsten.
I,	Iodine.	Sb, Stibium,	Antimony.
F,	Fluorine.	Te,	Tellurium.
C,	Carbon.	Co,	Cobalt.
Col, *	Columbium.	Ni,	Nickel.
Ta,	Tantalum.	Fe, Ferrum,	Iron.
Ti,	Titanium.	M,	Manganese.
Os,	Osmium.	Ce,	Cerium.
Au, Aurum,	Gold.	V,	Vanadium.
I,	Iridium.	Al,	Aluminium.
R,	Rhodium.	Zr,	Zirconium.
Pt,	Platinum.	Th,	Thorium.
Pd,	Palladium.	Y,	Yttrium.
Hg, Hydrargyrum,	Mercury.	G,	Glucinum.
Ag, Argentum,	Silver.	Mg,	Magnesium.
Cu, Cuprum,	Copper.	Ca,	Calcium.
U,	Uranium.	Sr,	Strontium.
Bi,	Bismuth.	Ba,	Barium.
Sn, Stannum,	Tin.	L,	Lithium.
Pb, Plumbum,	Lead.	Na, (So) Natrium,	Sodium.
Cd,	Cadmium.	K (Po) Kalium,	Potassium.
Zn,	Zinc.		

In obedience to the example of the British chemists, instead of K and Na, I shall employ Po and So, as the symbols of potassium and sodium. Of the different modes which Berzelius has suggested to designate oxygen, sulphur, selenium, and tellurium, I prefer adhering to the initial letters and numbers, to the employment of the dot, dash, comma, and cross; especially as agreeably to the classification to which I have resorted, it would be necessary, pursuant to that plan, to contrive a sign for each of the basacigen bodies. Yet to indicate the presence of oxygen, I shall occasionally resort to the dot.

Some of the British chemists concur with Berzelius in employing the dash to convey the idea of two atoms of the radical; others do not. Upon the whole, I believe it will be best to employ this sign, placing it below the letter representing the radical, to avoid the necessity of peculiar type.

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* Columbium and tantalum are different names for the same metal.

OF VEGETABLE PRINCIPLES, WHICH ARE NEITHER ACID, ALKALINE, OILY, RESINOUS, NOR VOLATILE.

OF GUM AND MUCILAGE.

The obvious properties of gum must be familiar to every body, as observed in the solution of gum arabic in water. Solubility in water, with insolubility in alcohol, is an essential characteristic of gum. In ether, it is insoluble. It is neither sweet nor sour. By nitric acid it is partially converted into mucic acid.

Gum is separated from water in a thick curdy precipitate, by subacetate of lead.

It causes the oxides of antimony and bismuth to remain in solution, when otherwise they would be precipitated by water, as sub-salts.

Substances, of which gum is the generic appellation, agree in certain general properties; but there are perhaps scarcely two exactly alike. They appear to vary with the plant, or tree, to which they owe their production.

Gum and mucilage were, until latterly, supposed to be solid and liquid forms of the same matter, but are now considered as differing in their chemical properties. Gum is soluble in water, whether hot or cold, while mucilage is insoluble in cold water, and but little if at all soluble in hot water. When subjected to this liquid at a boiling heat, mucilage swells prodigiously, and so far unites with the water, as to make a thick paste, or a glutinous liquid.

Gum arabic is considered as the most perfect specimen of the principle called gum. Berzelius considers the reaction of a solution of this substance with a solution of the silicate of potash, as the most characteristic of its properties. One portion of it forms, with one part of the alkali and all the acid, a triple compound, which precipitates; while another portion of the gum, and the remainder of the potash, combine and remain in solution.

Gum arabic differs from other gums in combining with the sesquioxide of iron, and forming a compound insoluble in water, but soluble in acids. A solution of gum arabic in 1000 parts of water, being mixed with a solution of the sesquioxide of iron, yields, in 24 hours, a yellow precipitate. This species of gum also combines with, and precipitates the protoxide of mercury from the nitrate.

Of mucilage, infusions of gum tragacanth, and flaxseed, are deemed the best specimens. From the bark of the slippery elm, and the pith of sassafras, especially the latter, very superior species of mucilage are obtained.

"Guerin has published an elaborate examination of the gums. He divides them into three classes: 1°. *Arabine*, of which gum arabic is the type, soluble in cold water; 2°. *Bassorine*, which swells into a jelly, but does not dissolve in water: Bassora gum is the type of this class; 3°. *Cerasine*, from the gum of the cherry-tree (*Cerasus*) is also insoluble in cold, but soluble in boiling water, and when treated with nitric acid, gives about *one-fourth* less mucic acid than bassorine.

"*Arabine*, by his analysis, consists of carbon $= 48{\cdot}81$, hydrogen $6{\cdot}2$, oxygen $49{\cdot}85$, nitrogen $0{\cdot}14 = 6\ C + 5\ H + 5\ O$. Gum senegal and the soluble parts of gum tragacanth and bassora gum consist of arabine.

"*Bassorine* = carbon $37{\cdot}28$, hydrogen $= 6{\cdot}85$, oxygen $= 55{\cdot}87 = 10\ C + 11\ H + 11\ O$.

"*Cerasine* appears to be metamorphic arabine, for it has precisely the same composition, and is changed into it by solution in boiling water. The gums of the cherry, apricot, prune, peach, and almond-tree, are of this kind."*

OF SUGAR.

Under this head I would place two genera of substances; crystallizable sugars, and syrups incapable of crystallization. Of the former, sugar candy, and the crystals found in raisins and in honey, are specimens. The latter are exemplified by the uncrystallizable syrups of raisins and of honey; also the sweet matter of the sweet potato and molasses, called the uncrystallizable syrup of the sugar cane. I conceive sweetness to be an indispensable attribute of sugar.

The qualities, both of crystallizable and uncrystallizable sugars, vary with the plants from which they are produced. In the power of imparting sweetness to infusions, the crystallizable sugar of the cane is pre-eminent.

In manna, which is the concrete juice of a species of ash (Fraxinus ornus) there is a peculiar crystallizable

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* Johnson's Report for 1832, page 511.

sugar, called mannite. In mushrooms, also, a peculiar sugar is said to exist.

Sugar is soluble in about an equal weight of cold water. Above a boiling heat, it becomes a liquid, per se, dissolving in its water of crystallization. Alcohol dissolves one-fourth of its weight of sugar.

Berzelius observes, that judging from the experiments which have been hitherto made, sugar does not combine with any salt, but reacts with many metallic salts. Yet he alleges that its aqueous solution dissolves the carbonate and subacetate of copper, giving rise to a green liquid, from which the metal is precipitated by sulphydric acid, or cyanoferrite of potassium, but not by alkalies. When boiled with solutions of cupreous salts, it causes the reduction of the copper.

OF FECULA, OR STARCH.

A substance, of which starch is a good specimen, and of which the generic name is fecula, may be obtained from the meal or flour of grain, from the roots of the potato, and other vegetables. It is, more or less, a constituent of vegetables in general. When the farinaceous matter, procured from such sources, by rasping or grinding, is washed, the fecula is suspended, and subsequently deposited.

In the case of wheat, and other grain of a like nature, fermentation is requisite to liberate the fecula from other matter.

Fecula forms a black colour, with a great quantity of iodine—a blue with less, and a violet with still less. It does not combine with cold water, but forms a viscid solution with hot water. It is neither dissolved nor acted upon by alcohol or ether.

Boiled with diluted sulphuric acid for about thirty-six hours, fecula is converted into sugar. A similar change is alleged to have ensued, partially, in starch which was made into paste, with twelve times its weight of boiling water, and kept for two years. By the addition of gluten, and a heat between 122° and 167° F., a similar result is said to have been attained in about ten or twelve hours. It is not improbable, that in the ordinary operation of making the distiller's wash, with ground rye, and a small proportion of malt, starch may be assimilated to saccharine matter.

Fecula dissolves in cold nitric acid; but, when heated with it, yields oxalic acid. A slight torrefaction changes its nature, so that it may be used as a substitute for gum. Triturated with potash, fecula acquires the property of dissolving in cold water. The solution is clouded by acids.

Its solution in hot water is precipitated by subsalts of lead, and in cold water, by an infusion of galls.

OF AMYDINE, OR AMYLINE.

According to Mr. Caventou, by exposure to a temperature a little above 212°, dry starch acquires a slightly red tint, and emits the odour of baked bread. The modification which it sustains, under these circumstances, is analogous to that which ensues when it is gelatinized by hot water. In this state, it has been considered as a hydrate of fecula, but it is alleged by him that the jelly cannot be restored to its original state. He regards it as essentially the same substance as that which T. de Saussure has designated as amydine. The blue colour produced by iodine with starch, Mr. Caventou considers as the characteristic effect of amydine.

When starch is exposed to a temperature higher than is necessary to convert it into amydine, it becomes more soluble in cold water, and produces with iodine, a purple colour.

Amydine forms an insoluble compound, with protoxide of lead, when digested with the sub-acetate.

OF HORDEIN.

Besides gluten and fecula, barley is alleged to contain a principle, called hordein, resembling sawdust in its external characters.

Hordein is supposed to be converted, during the malting process, into sugar and starch. This conjecture is much strengthened by the discovery, that lignin, to which hordein is most analogous, may be converted into sugar.

Dr. Thomson supposes hordein to be only a variety of fecula.

Of the Composition of Gum, Sugar, and Starch.

The proportions in which hydrogen, oxygen, and carbon, exist in gum, sugar, and starch, are nearly the same. Gum and sugar may be deemed compounds of carbon with water, as, in either, the hydrogen and oxygen are in the proportion necessary for forming that liquid. Gum may also be considered as a compound of carbonic oxide with hydrogen, as it is said to contain an equal number of the atoms of each ultimate element.

In sugar, there is a small excess of carbon.

The composition of starch differs but little from that of gum or sugar.

According to Dumas, the composition of anhydrous sugar is such, that it may be represented by a compound of carbonic acid and etherine (sweet oil of wine). Hence it would correspond with the probable composition, though not with the properties of carbonic ether, supposing the existence of such an ether to be possible.

Agreeably to an analysis made by Opperman, the composition of manna sugar accords with that which is assigned to gum. He obtained four atoms carbon, nine hydrogen, four oxygen. It follows that manna, as well as gum, may be a compound of carbonic oxide and hydrogen, though it may hold the element last mentioned in a different proportion.

OF GLUTEN AND VEGETABLE ALBUMEN.

Plants contain substances which have been designated as vegeto-animal, on account of their analogy with the white of egg, and the fibrin of animal matter. Nitrogen is always an ultimate element in them, and occasionally sulphur and phosphorus. As they are to be found in all vegetables, to a greater or less extent, it appears proper to arrange them under the head of the general principles of vegetables, although in a majority of vegetables, only very minute quantities are to be detected. The glutinous mass which remains when wheat flour is kneaded in a bag under water, had received the name of gluten. Latterly this mass has been separated into two distinct principles; one of which retains the name of gluten, while to the other, the appellation of vegetable albumen has been given, on account of the coagulation of its aqueous solution by heat. By Einhof and Taddei, it was ascertained that the mass called gluten, as above mentioned, was partly soluble, and partly insoluble in boiling alcohol. The soluble portion Taddei called gliadine, the insoluble portion zimome; but Berzelius designates the former as gluten, the latter as vegetable albumen.

Vegetable albumen is found in all those products of vegetation which yield emulsions when triturated with water; as, for instance, in almonds, in which it is in a state of combination with an oil. It exists in all vegetable juices which are coagulated by heat.

It is not adhesive. By desiccation it becomes opake. Caustic alkalies dissolve it readily, having their causticity diminished. By a great excess of acid it precipitates from the solution, but not otherwise; although the acid predominate sufficiently to redden litmus. When precipitated by an excess of acid, it subsides in combination with the acid, and may be redissolved by pure water, but not by a diluted acid. From the last mentioned solution, the albumen is precipitated very readily by the cyanoferrite of potassium, or the bichloride of mercury.

It is to destroy the gluten and vegetable albumen, that fermentation is required in the manufacture of starch.

Gluten is distinguished by its approaching more to the nature of animal matter, than any other products of vegetation, excepting vegetable albumen. In consequence of the presence of nitrogen, it yields ammonia by distillation. It is to the presence of gluten in wheat, that its pre-eminence in nutritive power is attributed.

To the glutinous property of this substance, dough is supposed to owe its rising, during the process of panification, after being mixed with leaven or yeast.

The cellular part of leavened bread, is indebted for its existence to gluten, which, by confining the gaseous matter arising from an incipient fermentation, is inflated into innumerable cavities.

Gingerbread owes its cellular structure to a different process. Among its ingredients are molasses and pearlash; the latter consisting of potash and carbonic acid. By the fermentation of the flour and molasses, an acid is generated, which, combining with the potash, liberates the carbonic acid. This gas, by expanding within the dough in consequence of the heat of the oven, causes innumerable cavities, resembling those produced in the ordinary process of panification.

Probably a bicarbonate would cause the rising of gingerbread better than pearlash, as it would yield double the quantity of gas.

A bicarbonated alkali is found to act as a leaven in cakes, when old cider is mingled with the dough. No doubt lemonade would answer the same purpose.

Farinaceous matter, destitute of gluten, can only be made into heavy cakes, as exemplified by those of Indian meal.

One of the principal defects of bread, is sourness, arising from acidity in the yeast. This may be easily removed by pearlash, or a filtered infusion of clean ashes. Carbonate of ammonia is also used by bakers, and probably promotes the lightness of the bread, by its vaporization.

OF INDIGO AND INDIGOGENE.

According to Liebig, the blue colouring matter of the crude indigo of commerce, consists of a substance which he calls indigogene, and oxygen. He conceives that indigogene pre-exists in the plants, and, when pure, is white. When the indigo plant is macerated in water, the indigogene being soluble in that liquid, is dissolved, and by the oxygen of the air is converted into indigo blue, which is insoluble. This substance is deoxidized by the dyer, by means of green vitriol and lime. While thus rendered soluble, and yellow in colour, the indigogene unites with the cloth, and regaining its oxygen and its insolubility by exposure, dyes the cloth permanently blue.

Indigo is soluble in concentrated sulphuric acid, especially that of Nordhausen. Berzelius alleges the resulting combination to be productive of two acids.

Indigotic acid is produced by the reaction of nitric acid with indigo.

OF CAOUTCHOUC, OR GUM ELASTIC.

Caoutchouc, or gum elastic, is a most singular substance, on account of its peculiar elasticity, whence its popular name above mentioned. It is insoluble either in water or alcohol, but dissolves in ether or the volatile oils, especially those of turpentine, sassafras, cajeput and naphtha. When recovered from its solution in these oils by evaporation, it does not fully regain its elasticity in any case, but it is said to recover this property when precipitated from cajeput oil by alcohol.

Caoutchouc burns with a bright flame, especially in oxygen gas. It exudes, in the fluid state, from certain plants, and congeals in the form of the mould on which it may be received. After a length of time, it is acted on by alkalies and fixed oils; and merely by the mechanical compression of a tight bandage, undergoes a species of disorganization, rendering it more adhesive and less elastic.

It yields ammonia by distillation, and of course contains nitrogen. It becomes warm when suddenly extended.

It is said that when precipitated by alcohol from cajeput oil, it regains its elasticity.

It has been ascertained by Dr. Mitchell, that caoutchouc bags, after soaking in a mixture of ether and alcohol of the specific gravity of from 750° to 780°, or the usual officinal strength, may be inflated with air, and the material of which they consist consequently extended to various degrees of tenuity, according to the peculiar character of the variety subjected to trial. Hence it may be used to make balloons, gas bags, or sheet gum elastic, which is very useful for fillets, with which to make air-tight junctures or lutings. There is no better mode of joining a tube to the tubulure of a retort, or receiver, than tying about the tubulure the body of a small caoutchouc bag, while the tube is inserted into the neck, and carefully secured by a ligature. Fused caoutchouc is useful in some cases as a lute. It will not, however, resist fuming nitrosonitric acid. I have observed that it takes fire when subjected to that acid.

Dr. Mitchell has made some very interesting observations respecting the power of gases to pass through thin membranes of caoutchouc. By some inconceivable process, gases, which are all prone, in a greater or less degree, to reciprocal intermixture, will effect this result, notwithstanding the interposition of caoutchouc, and the opponent influence of great pressure.

When a vessel filled with atmospheric air, and having the mouth closed by a caoutchouc membrane, was introduced into a vessel of hydrogen, this gas made its way into the vessel, until the membrane burst outwards; but when the vessel, while similarly closed by the membrane, and replete with hydrogen, was exposed to common air, the hydrogen escaped until the membrane burst inwards. A tube, with a trumpet-shaped mouth, being bent so as to form a syphon, and the larger orifice closed by the membrane while full of atmospheric air, a suitable quantity of mercury was poured into the syphon, until it stood in both legs at the same height. Under these circumstances, when the membrane was brought into contact successively with different gases, they were found to enter with various degrees of celerity, as will appear from the following statement:—

	H.	M.
Ammoniacal gas - - -	0	1
Sulphydric acid - - - -	0	2½
Cyanogen - - - -	0	3¼
Carbonic acid - - - -	0	5½
Protoxide of nitrogen - - -	0	6½
Arsenuretted hydrogen - -	0	27½
Olefiant gas - - - -	0	28
Hydrogen - - - -	0	37½
Oxygen - - - - -	1	13
Carbonic oxide - - - -	2	40
Nitrogen - - - - -	3	15

The gases continued in some instances to enter until the mercury in the longer leg rose to the height of sixty inches.

These results appear to me wonderful, and their attainment does great honour to the sagacity and ingenuity of the author. It is quite surprising that the atoms of ammonia should pass through the membrane with greater celerity than those of hydrogen, when each of the former consists of three of the last mentioned gas, united with one atom of nitrogen. Also that two atoms of oxygen, while associated with an atom of carbon, should permeate the membrane more speedily than an isolated atom of oxygen.

It also appears from experiments made by Dr. Mitchell, and repeated by myself, that caoutchouc is probably more highly susceptible of electric excitement, than any other organized body; and probably is at least equal in excitability to any inorganic substance.

OF LIGNIN.

The insoluble, tasteless, inodorous, and tenacious fibres of wood, hemp, or flax, have been distinguished as a peculiar vegetable matter, called lignin.

From the experiments of Mr. Braconnot, it appears that lignin may be converted either into gum or sugar, by means of sulphuric acid. Some linen rags were triturated with concentrated sulphuric acid, until the fibres disappeared. The resulting mixture being diluted with water, and the acid saturated with chalk, the aqueous solution, when separated by the filter and evaporated, yielded a species of gum in weight exceeding the linen employed. When instead of saturating the acid with chalk, as above mentioned, the mixture of acid and mucilage, produced by the reaction of the acid and lignin, was diluted with water, and boiled for about ten hours, the acid then saturated, and the liquor afterwards filtered and evaporated, crystals of a sugar, resembling that of raisins, were obtained.

By reducing the fibres of wood, previously subjected to boiling water to remove every thing soluble in that liquid, to a state of minute division, and subsequently exposing them to the heat of an oven, they are converted into a flour capable of forming either a nutritious jelly or bread sufficiently good to be eaten.

The specific gravity of lignin is greater than that of water, the apparent lightness of wood being due to its pores.

OF CORK.

Cork is considered as a distinct principle, as its very peculiar mechanical qualities would indicate. It forms, by the action of nitric acid, a peculiar acid, called suberic acid.

OF FIXED OILS.

Oleaginous substances, like olive oil, castor oil, fat, lamp oil, which cannot be distilled unaltered, are called fixed oils, while those are called volatile, which, like the oil or spirit of turpentine, petroleum, cajeput, &c., may, without change, sustain the process of distillation.

Among the most remarkable of the vegetable oils, are those of the olive, of linseed, of poppy seed, and rape seed. Being procured by expression, they contain mucilage. To the presence of this, their liability to become rancid has been ascribed. Rancidity I suppose to arise from a sort of slow combustion, during which, oxygen is absorbed. It is not improbable, however, that the oxidizement of the oil may be accelerated by the decomposition of water in the mucilage.

Fixed oils owe their colour, in part, to some extraneous matter, which may be removed by charcoal. They are heavier than alcohol, and lighter than water, and are more or less soluble in ether, especially castor oil. Linseed and olive oil are soluble in alcohol, which has been deprived of water by pearlash. Castor oil may be dissolved in any proportion in alcohol, thus strengthened. The temperatures at which different oils freeze, are very various; and every oil appears to be decomposable by heat, or refrigeration, into a less fusible and more fusible oil. Hence, in cold weather, a portion of the oil of olives may be seen congealed, while the remainder is still liquid.

The soaps which the fixed oils generate with the alkalies are well known, and pre-eminently useful. I stated above, that all of them appear to be decomposable by heat, or refrigeration, into a less fusible, and a more fusible portion. It appears, from some experiments made in France, by Chevreul, that vegetable and animal oils are composed of two different matters, both soluble in hot alcohol; but one of them, much less so in cold alcohol. Hence, by the agency of this liquid, he was enabled to separate them. The less soluble substance is called stearin, and the other elain. These, in the process of saponification, give rise to two or three acids, which, combining with the alkali, constitute soap. The acids produced by stearin, are called margaric and stearic; that formed by elain, oleic. Another matter is at the same time liberated in small quantity, called the sweet principle of oils.

With soda, oils form hard soap; with potash, soft soap; but the one is made to produce the other by the addition of chloride of sodium. The chlorine unites with the potassium, and the sodium with the oxygen and acids, which the potassium abandons.

Water is said to be hard, when it curdles a solution of soap. This quality usually arises from the presence of sulphate of lime, or chloride of sodium, or both.

Sulphur and phosphorus are soluble in fixed oils. An important distinction is to be recollected, existing between what are called drying oils, and those which are devoid of the property thus indicated. Linseed oil is rendered drying, by boiling it with the oxides of lead.

It has been suggested, that the oil is deprived of mucilage, during this process; as an affinity is known to subsist between mucilage and the protoxide of lead. Without the property of drying, fixed oils could not be used in varnish or in paint.

The fixed oils, when distilled, yield a volatile oil, and carburetted hydrogen; carbon remaining in the retort. The volatile oil, thus obtained, is formed during the process. By combustion in the open air, or with oxygen, fixed oils are converted into carbonic acid and water. They consist of carbon and hydrogen, and a small proportion of oxygen. Nitric acid acts with great energy on them, and by imparting oxygen, renders them thicker. Chlorine has, indirectly, the same effect. Probably by removing hydrogen, it increases the proportion of oxygen in the compound.

The fixed oils, especially the drying oils, have the property of inflaming with nitric acid, and entering into combustion with lampblack, or other light carbonaceous matter; also with cotton, wool, and flax. Inflammation has been alleged to arise from their admixture with ashes.

OF WAX.

Wax, which is considered by modern chemists as a concrete fixed oil, is generally a product of vegetation. It covers leaves and fruits, and constitutes, principally, the pollen of flowers. Being thus extensively produced by vegetation, beeswax was supposed to be collected, not secreted by the insects, through whose instrumentality it is obtained. It has since been advanced by Huber, that bees who have access to nothing but sugar, can produce wax; and Oppermann has alleged that pure vegetable wax differs from beeswax in composition.

There are considerable differences in wax, as to fusibility, colour, &c. White wax is produced by a bleaching process, analogous to that by which linen is whitened. It is exposed in thin laminæ to chlorine or the air.

Wax is insoluble in water. Boiling alcohol dissolves about one-twentieth of its weight. It retains, on cooling, only $\frac{1}{100}$, and this precipitates on adding water. Ether, when boiling, takes up one-twentieth. The alkalies convert it into a species of soap. Acids do not act on it. Hence it is of great use to defend corks, and other substances exposed to them. It is the best material for candles, owing to its yielding a tolerably pure carburetted hydrogen, and being less fusible than tallow.

According to Dr. John, wax consists of two different principles, of which one is soluble, the other insoluble in alcohol. To the former he has given the name of cerin, to the latter that of myricin. The composition of wax is probably $C^{13}\,O\,H^{11}$.

OF THE VOLATILE, OR ESSENTIAL OILS.

The volatile oils (with the exception of those from the rinds of lemons and oranges, which are procured by expression) are separated from the vegetable substances, in which they exist, by distillation with water. In consequence of the attraction between the aqueous particles, and those of the volatile oils thus procured, the latter pass into the state of vapour, at a much lower temperature than that at which they would boil, per se.

The volatile oils have usually a penetrating smell, and an acrid taste. When pure, they may be evaporated from a pane of glass without leaving a stain.

They unite with alkalies, with great difficulty. They are soluble in alcohol, but not in water. Concentrated nitric acid inflames them. According to Henry, some of them detonate with chlorates, and take fire in chlorine.

The volatile oils dissolve sulphur, forming compounds which have been known as balsams of sulphur. Phosphorus is likewise soluble in these oils, to a small extent.

The composition of the volatile oils has been variously represented by different chemists. Berzelius divides them into two classes—those which contain, and those which do not contain oxygen. In the latter class he places only the oils of turpentine, lemon, and bergamot. Dumas excludes the oil of bergamot from the class devoid of oxygen, but includes that of roses.

The oil of turpentine is the most useful of the volatile oils, mainly on account of its cheapness. It consists, according to the recent analysis of Dumas, when perfectly pure and free from water, of ten atoms of carbon and eight of hydrogen. The oil of lemons is composed, according to the analysis of the same chemist, of five atoms of carbon and four of hydrogen; so that it is *polymeric* with the oil of turpentine.

According to Dumas, the heavy essential oils differ from the light, principally in containing more oxygen and in acting as acids; while the latter act as bases. He considers the oil of cloves, which is one of the heavy essential oils, as consisting of 20 atoms of carbon, 13 of hydrogen, and 5 of oxygen.

A substance called caryophillin has been procured from this oil, which derives some importance from being polymeric with native camphor.

The oil of mustard, another heavy essential oil, presents a very complicated composition. It is, according to the analysis of the above mentioned chemist, composed of carbon, hydrogen, nitrogen, oxygen, and sulphur, in proportions which I shall here express, for the sake of brevity, by the following formula. $C^{16}\,H^{10}\,N^{2}\,O_{\frac{5}{4}}\,S_{\frac{5}{4}}$. He is of opinion that the oxygen and sulphur perform the part towards a compound radical consisting of carbon, hydrogen, and nitrogen, which is more generally performed by oxygen alone: or in other words, that the sulphur supplies the place of a certain quantity of oxygen.

On the Inspissation of Oils, by Exposure to the Air.

The inspissation observed in oils, whether fixed or volatile, during exposure to the air, is generally ascribed to their oxygenation. It seems to me probable, that oxygen acts by converting hydrogen into water which evaporates.

It was suggested by Dr. Henry, of Manchester, that this absorption of oxygen accounts for the unhealthfulness of newly painted rooms. It appears to me that the breathing of one person would consume more oxygen, than the paint of any common room.

I think it probable that the vapour which, by its escape, causes the hardening of the paint, carries off a minute portion of the pigment. That something is volatilized, is perceptible by the smell.

OF CAMPHOR.

Camphor is usually considered as a concrete volatile oil, which, from its affinity for air, evaporates ere it becomes liquid. It is distinguished by forming an acid, instead of being inflamed by the action of heated nitric acid. To produce this result, the camphor is repeatedly distilled, with four times its weight of nitric acid. At a more moderate temperature, this acid dissolves camphor, forming what is called oil of camphor. Chlorohydric and other acids also dissolve this substance. Sulphuric acid and camphor reciprocally decompose each other.

Camphor is composed, according to the analysis of Dumas, of ten atoms of carbon, eight of hydrogen, and one of oxygen.

OF ARTIFICIAL CAMPHOR.

If 100 parts of oil of turpentine, refrigerated by snow and salt, be saturated with chlorohydric acid gas, by means of an impregnating apparatus, a quantity of the gas, equal to about one-third of the weight of the turpentine, is absorbed. Meanwhile the turpentine is changed into a soft crystalline mass, from which, allowing it to drip for some days, about twenty parts of a colourless acid liquor are obtained, charged with many crystals, and one hundred parts of a white, granular, crystalline substance, which so much resembles camphor in odour and volatility, that it has received the same appellation.

Artificial camphor is lighter than water. It does not redden litmus. It may be sublimed, but not without partial decomposition. If passed through an incandescent tube, it is resolved into its constituents. It dissolves in alcohol, and is precipitated from it, by water, unchanged. Chlorine is disengaged from it by nitric acid.

This substance has been analyzed both by Dumas and Oppermann. According to the former chemist, it is composed of a volume of chlorohydric acid, united to one volume of a compound formed of ten atoms carbon, and eight hydrogen.

When a mixture of artificial camphor and quicklime is distilled, a liquid is obtained, which has, according to Dumas, the smell and properties of oil of turpentine, and which he calls "*camphene*." If chlorohydric acid be passed through this liquid, artificial camphor is reproduced, which may therefore be considered as a chlorohydrate of *camphene*. Hence camphene would appear, like etherine (sweet oil of wine) and several other compounds of carbon with hydrogen, to act both as a radical and as a base, since the composition of native camphor, which acts as a base, is such, that it may be represented by one atom of camphene and one of oxygen, and camphoric acid may be considered as a compound of one atom of camphene and five of oxygen.

Camphene is considered by Dumas as identical with *pure* oil of turpentine in composition and properties.

When chlorohydric acid is passed through essential oil of lemons, a substance is obtained analogous to that produced by the action of the same gas on oil of turpentine. Dumas has found, on analyzing this product, that it consists of chlorohydric acid united to a compound of carbon and hydrogen, polymeric with camphene; since a volume of its vapour, though consisting of the same elements in the same proportion as camphene, contains but half as much of each.

This compound, for which Dumas proposes the name of citrene, may be isolated by distilling the artificial camphor made from the essential oil of lemons with quicklime. Citrene is a colourless limpid liquid, possessing the odour and properties of the essential oil of lemons, with which it is identical in composition. Dumas considers that it bears the same relation to the ordinary essential oil of lemons, as camphene does to oil of turpentine; that it is, in fact, the *pure anhydrous* oil of lemons.

According to Dumas, crystals may be obtained by refrigeration, from some varieties of the oil of peppermint and from the oil of anniseed, which he considers as bearing the same relation to the compounds of carbon and hydrogen existing in those bodies, as natural camphor does to the camphene of oil of turpentine. The crystals obtained from the oil of peppermint, consist of an atom of oxygen united to a compound consisting of ten of carbon and ten of hydrogen; those from the oil of anniseed, of an atom of oxygen united to another compound of carbon and hydrogen containing ten of carbon and six of hydrogen.

The analogy cannot, however, be considered as perfect, until natural camphor shall be obtained by oxidizing the oil of turpentine.

OF RESINS.

According to Dr. Henry, resins are the inspissated juices of certain plants. I should prefer to say, that resins exist in the juices of certain plants, in union with essential oils, which exuding and evaporating, the resins remain in concrete masses or tears. They are also separated from their volatile oils by distillation.

Resins cannot be distilled without decomposition. They are dry, brittle, inflammable, and insoluble in water; but are generally soluble in alcohol, ether, essential oils, alkalies, and acids. Probably with various degrees of facility, they may all be combined with fixed oils.

Copal is not soluble in alcohol, unless camphorated. At a temperature sufficient for its fusion, if copal be dropped into linseed oil, equally heated, a compound is formed, which, exposed to the air, gradually hardens, and forms an excellent varnish.

Common rosin, or resin, exudes from various pines, especially the pinus australis, in union with oil of turpentine, which is distilled from it.

It seems more proper to use the word rosin, to designate this species; since the formerly synonymous word, resin, has been applied to the genus, which rosin exemplifies in all the most prominent properties.

Strong sulphuric acid decomposes resins. Nitric acid, by long digestion on them, produces a substance analogous to tannin. They are dissolved by acetic acid, and precipitated from it by water. When dissolved in turpentine, alcohol, or drying oils, resins are of much use in varnishing.

Resins and Gum-Resins—Acid Bodies.[*]

"The resins and gum resins have been much investigated, and with great success, by Unverdorben. In a series of elaborate memoirs he has shown that many of the known resins are mixtures of several substances of the same class, which may be separated from each other generally by the action of alcohol and ether. Thus sandarak is a mixture of three gums, copal of five, benzoin of three, guiac of two, and gum lac and colophony also of several. He has shown likewise, that all these resinous bodies possess electronegative properties, forming salts with oxides in definite proportions. These compounds are decomposed by the electric current, the resins being attracted to the positive, and the oxides to the negative wire. The alcoholic solutions of these bodies also redden litmus, so that there can be no doubt of their electronegative character, though it would not only unnecessarily extend the meaning of the term *acid*, but also unnecessarily overburden the nomenclature, to apply the term to all these faintly negative substances, and to form classes of salts of their many obscure compounds. The labours of Unverdorben alone have already brought together such a mass of observations on this subject, that, as has been justly observed by Berzelius, were each of the resins to be examined with equal care, the detail would speedily occupy as much space as the whole of our present systems of chemistry."

Basic Resins.

"Buchner and Herberger have advanced one step further in the investigation of resinous bodies. Unverdorben had found the *fifth* resin of copal to be *indifferent;*[†] these chemists describe some to be possessed of weak basic properties. Thus the resin extracted from jalap and from euphorbium they find to be each a compound of two; one of which is a weak acid, and the other a weak base; and

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[*] Johnson's Report on Chemistry for 1832, to the British Association for the Advancement of Science.

[†] An "*indifferent*" substance is one neither acid nor alkaline.

they consider all the drastic gum-resins to be similar compounds. The subject, however, requires further investigation."

EXPERIMENTAL ILLUSTRATIONS.

A solution of gum precipitated by alcohol; a solution of resin by water.

OF GUM-RESINS.

This name is applied to a class of vegetable substances, which consist of a mixture of resins, gum, essential oil, and extractive matter. Opium, aloes, gum ammoniac, assafetida, euphorbium, galbanum, gamboge, myrrh, and scammony, come under this head.

As the resin and essential oil require alcohol, the gum and extractive matter, water, for solution, proof spirit is the best solvent of the gum-resins.

*Opium.**

"Few substances have undergone more repeated investigations than opium, or been subjected to more varied chemical torture. Of this some idea may be formed from the following list of immediate principles obtained from it, as given by Pelletier:

Morphine, a base discovered by Serturner.

Meconic acid, discovered by Serturner.

Narcotine, a base discovered by Derosne.

Meconine, an indifferent substance? Dublanc and Couerbe.

Narceine, an indifferent substance? Pelletier.

Brown acid and extractive matter; a peculiar resin strongly electronegative; a fatty oil; caoutchouc; gum; bassorine; lignine, and a volatile principle."

OF NAPHTHA, PETROLEUM, BITUMENS, AMBER, AND MINERAL COAL.

There is a gradation of substances, apparently arising from the wreck of a former world, from naphtha, which is highly volatile, to anthracite, which is extremely insusceptible of the aeriform state.

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* Johnson's Report for 1832, p. 513.

Bitumen is, in its qualities, intermediate between the extremes, being separable, by distillation, into carburetted hydrogen, a volatile oil, and carbon.

Petroleum is more fluid, lighter, and more inflammable than bitumen.

The decomposition of the bituminous matter, in mineral coal, by ignition, yields carburetted hydrogen, as in the gas-light process.

Naphtha is found pure in nature, and may likewise be obtained by distillation from petroleum. Pure naphtha is a volatile, inflammable, colourless, limpid liquid, with a strong and disagreeable smell. A variety of this substance is distilled from coal tar, which condenses during the evolution of carburetted hydrogen from bituminous coal. Naphtha is chiefly of use in preserving potassium. It consists of carbon and hydrogen, but the proportions in which its constituents are united, have been variously represented by different chemists.

Amber is a singular fossil, which is supposed to owe its origin to vegetable matter. It is distinguished by burning with a peculiar odour, and yielding when subjected to distillation, succinic acid, and a peculiar essential oil, called oil of amber, which much resembles naphtha in smell and other properties. The acid sublimes into the neck of the retort in crystals. Amber is insoluble both in water and in alcohol. It resembles copal in its appearance and in its properties.

It has been suggested that the diamond is a product of vegetation, or the decomposition of vegetable matter.

OF PARAFFIN AND EUPION.

Eupion and paraffin are both obtained from the tar which results from the distillation of organic substances. If animal substances be used, the eupion exceeds the paraffin in quantity, but if vegetable substances be employed, the paraffin predominates.

Paraffin is a white crystalline inflammable body, soft to the touch, and capable of being elongated and bent. It melts at 110°, and volatilizes at a higher temperature without alteration. Paraffin is composed of carbon and hydrogen, and contains of each, the same number of atoms. It appears to possess the singular property of not being affected either by acids or alkalies.

Eupion is a colourless, transparent, inflammable, insipid, and inodorous liquid. It boils at 336°, and distils without change. It is so remarkably expansible, that in passing from 66° to its boiling point, it increases in bulk one-fifth.

OF KREOSOTE.

This name has been given to an essential oil resulting from the destructive distillation of vegetable matter. It is represented as highly interesting and important, on account of its efficacy as a medicine, and in preserving meat; being in fact considered as the principle to which pyroligneous acid and wood smoke are indebted for their antiseptic powers, and tar-water for its medicinal virtues.

Kreosote is elaborated either from crude pyroligneous acid, or from wood tar, by a series of distillations, and subjection to different agents, which resemble much more the operation of the alchemists, than those of the enlighted chemist of the present time. I am confident that before long a much more simple process for its extrication will be devised.

Besides its activity in medicine, kreosote is alleged to have energetic powers as a chemical agent. It is an oleaginous, colourless, transparent, and highly refracting liquid. Its smell is that of crude pyroligneous acid or of smoked meat, and its taste is caustic and burning. To the touch it is a little greasy, and its consistency is similar to that of the oil of almonds. It is rather heavier than water, being of the specific gravity of 1.037. It boils at 365°.

The following account of its properties I quote from a pamphlet by Dr. E. Miguet, member of the Chemical and Philosophical Society of Paris, &c. &c., translated by William Wetherill, M. D., for a copy of which I am indebted to the translator.

"CHEMICAL PROPERTIES.

"Submitted to the action of caloric, it boils at 203 of Centigrade, and is not congealed even at the temperature of 27 Cent.; it burns with a smoky flame; it is not a conductor of electricity.

"It forms with water at 20 degrees, two different combinations; one is a solution of one part and a quarter of kreosote in 100 parts of water, which makes one part of kreosote to 80 of this liquid; the other, on the contrary, is a solution of 10 parts of water in 100 of kreosote.

"The aqueous solution of this substance does not change the colour either of tournsol (litmus) or curcuma, and is not neutralized either by acids or alkalies. It forms, however, a number of interesting combinations with these two classes of bodies. Nitric acid attacks kreosote actively, and a disengagement of red vapours takes place. It combines with chlorine, bromine, iodine, phosphorus, and sulphur. Potassium thrown into kreosote is dissolved; there then takes place a disengagement of gas, and potash is formed, which remains combined with thickened kreosote. This substance can be separated without any alteration by distillation. Concentrated sulphuric acid, in small quantity, colours kreosote red; a larger quantity blackens and thickens it: the sulphuric acid is decomposed and the sulphur left free.

"Of all acids, the acetic has the strongest affinity for kreosote; it seems to be its proper solvent, and combines with it in every proportion.

"This substance forms with potash two combinations: one is an anhydrous liquid, of an oily consistence; the other, a hydrate, which crystallizes in pearly white spangles. Even carbonic acid separates kreosote from these combinations without alteration; its action is the same with soda. It has a great affinity for lime and the hydrate of barytes, and gives with these bodies compounds of a dingy white colour, soluble in water, and when in a dry state, may be made into powder of a pale rose colour. Ammonia dissolves it cold; this alkali generally accompanies it, and gives some trouble in its separation. It dissolves a vast number of salts, some hot, others cold. Alcohol, ether, carbonate of sulphur,* eupion, acetic ether, combine in every proportion with kreosote.

"Of all organic substances, the resins, the resinous colouring principles, and other like bodies, are most actively attacked by kreosote. It decomposes them even cold, as well as dissolves them totally. It forms cold a solution of a yellow red colour with cochineal, a deep red with dragon's blood, yellow with madder, yellow with saffron. Placed in contact with indigo, it dissolves cold, the colouring matter which is precipitated by the addition of water and of alcohol.

"It now remains for me to mention other properties of kreosote of the highest interest, because it is on these that rest all its therapeutic importance.

"Kreosote agitated with the white of an egg, coagulates it immediately; a property on which its efficacy is rationally founded. If in a large quantity of an aqueous solution of this last substance, we put a single drop of kreosote, it is immediately filled with coagulated albuminous pellicles. When fresh meat has been placed for an hour in a solution of kreosote, after having been well dried, it may be exposed to the heat of the sun without putrefaction; it becomes hard in about eight days, and assumes an agreeable odour of good smoked meat, its colour being reddish brown. Fish may be preserved by the same process; many birds killed by kreosote were preserved for a month and a half without having any unpleasant smell. I have now one remaining which is completely dry, never having presented any indication of putrefaction. But as pyroligneous acid and tar water produce the same effects, it cannot be doubted that

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* I presume bisulphide of carbon is intended.

kreosote is the preserving antiputrid principle of these liquids, and also of smoke.

"It would be interesting to know how kreosote acts under these circumstances, and presuming it was upon the blood, what reaction takes place. M. Reichenbach has placed kreosote successively in contact with the serum, the coagulum, the colouring matter, and pure fibrin, and has concluded from his experiments: 1st. That kreosote coagulates the albumen of the blood. 2d. That this coagulation takes place immediately, when the two liquids are concentrated. 3d. That it takes place little by little, when one or the other is in quantity. 4th. That the fibrin separates itself from the other principles, and is not attacked by kreosote. But it is said that the albumen which is coagulated will not putrify, and the muscular fibre alone does not appear susceptible of entering into putrefaction.

"The foregoing shows to how many uses this substance is applicable. It would be desirable only that its preparation might be simplified, which is tedious and difficult. Two processes have been pointed out, one to extract the kreosote from pyroligneous acid: the other for extracting it from tar. I have no doubt the last process will furnish the greater quantity, and the extraction will be more easy."

OF VEGETABLE ACIDS.

I propose, before concluding organic chemistry, to introduce some tables, giving an account of all the acids which belong to this branch of the science. I shall treat particularly only of the more important.

OF ACETIC ACID.

Of all the vegetable acids, the acetic is most frequently found in nature, and is most easily produced by art. It exists in the sap of almost all plants, either free, or united with potash; likewise in a sensible extent in sweat, urine, and milk. During imperfect digestion, it is usually generated in the stomach. It is invariably a product of the destructive distillation of vegetable substances.

Of the Means of obtaining Acetic Acid.

The distilled vinegar of pharmacy is a very dilute acetic acid. It may be obtained in a more concentrated form by distilling the acetate of copper; but in this case it is partially decomposed, producing a peculiar inflammable volatile liquid, called pyro-acetic spirit.

It may be procured, also, from any of its salts, by distillation with sulphuric acid.

In whichever of these modes it may be evolved, a second distillation is necessary to render it pure.

When obtained by sulphuric acid, it is liable to be contaminated with sulphurous acid, from which it may be depurated, by adding a small quantity of black oxide of manganese, previously to the second distillation.

Of the Properties of Acetic Acid.

The purest acetic acid which has been obtained, crystallizes at the temperature of about 55°. It is colourless, inflammable, very volatile, and has a very pungent odour and taste. Its specific gravity is 1.063, at 60°, and is not altered by the addition of an equal bulk of water. When thus diluted, its freezing point is lowered many degrees below that of water. The maximum of density 1.079 is produced, by adding to the crystallizable acid one-third of its weight of water.

Acetic acid probably consists of $C^4\ O^3\ H^3$.

OF PYROLIGNEOUS ACID.

In the process by which wood is converted into charcoal, acetic acid is evolved in combination with eupion, paraffin, kreosote, and a resinous matter called pyretine, by Berzelius, forming the liquid known as pyroligneous acid.

When the process is performed with a suitable apparatus, this acid is collected. Pyroligneous acid may be considered as the matter of wood smoke in the liquid form; and when, in this form, applied to salted meat, is at least as efficacious as when employed as smoke in the usual way. The process of the smoke house is less susceptible of precision, and is liable to produce an injurious rise of temperature.

From pyroligneous acid pure acetic acid may be extricated by distillation with manganese, sulphuric acid, or with both; also by saturating it with lime, and decomposing the acetate of lime by sulphate of soda, separating the resulting acetate of soda by crystallization, and decomposing it by sulphuric acid in equivalent proportion. The sulphate of soda separating in crystals, the acetic acid may be obtained, by decantation, nearly pure. To procure it entirely free from the sulphate, it is distilled in an alembic, with a body of copper, and a head of tin or silver.

EXPERIMENTAL ILLUSTRATIONS.

Distilled vinegar, and crystallizable acetic acid, exhibited: also pyroligneous acid.

OF THE ACETATES.

The acetates, it has been already mentioned, may all be made to yield acetic acid by heat, or the affusion of sulphuric acid. They are all soluble in hot water, and generally soluble in cold water. The acetate of mercury is nearly insoluble in cold water, and but slightly soluble in hot water.

Formerly, the acetate of potash was called foliated earth of tartar; the acetate of ammonia, spirit of Mindererus.

Any of the acetates may easily be formed, by saturating the acid with the proper base. Some of them may be obtained by double decomposition, as in the case in which sulphate of zinc, and acetate of lead, yield acetate of zinc, and sulphate of lead: or in that in which acetate of ammonia is procured by heating sal ammoniac with acetate of potash, when the ammoniacal acetate sublimes in crystals. This method is recommended by Thenard, as the best for preparing the acetate of ammonia for medicinal purposes.

OF CITRIC AND MALIC ACID.

The name of citric acid discloses its origin. It exists in the lime and lemon, in union with mucilage and malic acid. Its combination with mucilage is so intimate as to render it impossible to separate the acid, without first uniting it with some other matter. Alcohol is the most ready agent for this purpose, as it combines with the acid, and precipitates the mucilage. The alcoholic solution, thus obtained, does not yield crystals, even after evaporation, re-solution in water, and evaporating the water.

The most efficient mode of obtaining this acid pure, is to saturate the juice of lemons with chalk or whiting, and afterwards to decompose the citrate of lime, thus formed, by sulphuric acid, duly diluted. The citric acid may be obtained, in crystals, from the supernatant liquid, by evaporation.

Citric acid is crystallizable. Its taste is intensely acid when concentrated, but agreeably sour when dilute. It consists of $C^4 H^2 O^4$.

Malic acid derives its name from the apple, as in this fruit it predominates, as well as in gooseberries, currants, and other similar fruits. It may be had pure, by saturating lime with apple juice, and decomposing the malate of lime by sulphuric acid.

Professor Wm. Rogers, of William and Mary College, has ascertained that this acid abounds in different species of sumach in the state of bimalate of lime.

When heated to 380°, malic acid is resolved into two acids, one of which melts at 266°, the other at 392°.

Pelouze, who has recently investigated this subject, calls the former the maleic, the latter, the paramaleic acid. It would appear from the experiments of this chemist, that these acids are isomeric with each other.

It was formerly supposed that malic acid was one of the first products of the reaction of nitric acid with sugar, and that it was subsequently converted into oxalic acid by a continuance of the action. From experiments which have lately been made, it appears probable that the acid produced, under these circumstances, differs from the malic, in composition and properties.

Malic acid is composed, according to the recent analysis of Liebig, of $C^4\ H^2\ O^4$. It appears, therefore, to be isomeric with citric acid.

OF TARTARIC ACID.

Tartaric acid is found in many vegetables. It is named from tartar, an appellation given to a deposition from wine, which contains the bitartrate of potash. This bitartrate, when freed from impurities, is sold in the shops under the name of cream of tartar. When, to twenty-four parts of this salt, thirteen of carbonate of soda are added, sal Rochelle, a tartrate of potash and soda, is produced; and, in like manner, tartar emetic, by saturating the excess of tartaric acid with protoxide of antimony. Another pharmaceutical compound, called tartarized iron, is produced by saturating the excess of acid in cream of tartar with iron, which is taken up in the state of protoxide, but becomes, by exposure, more or less sesquioxidized.

Tartaric acid is procured from cream of tartar in fine crystals, by saturating the excess of acid with chalk, and decomposing the precipitate by diluted sulphuric acid. The neutral tartrate of potash left, may be decomposed by quicklime, or chloride of calcium, and the resulting tartrate of lime will yield the acid in the same way as the analogous tartrate obtained in the first instance by the addition of chalk. Tartaric acid is extremely sour, and reddens litmus paper. The symbolic formula for tartaric acid is C^4, H^2, O^5.

A manufacturer of Thann, in Germany, in preparing tartaric acid from cream of tartar which had been deposited from the wine of that country, discovered an acid differing from that which it was his object to procure, and which he supposed to be the oxalic. Gay-Lussac subsequently proved that, while possessed of peculiar qualities, its equivalent was the same as that of tartaric acid. By Berzelius it was afterwards shown to be isomeric with this last mentioned acid, and he has consequently named it paratartaric acid. The appellation of racemic, has also been applied to it.

Paratartaric acid crystallizes in a different form from tartaric acid proper. It is likewise less soluble. The tartrates, and paratartrates, are isomeric.

When tartaric acid is exposed to heat, it swells up, melts, and is converted into a yellow transparent substance, which Braconnot supposes to be isomeric with tartaric acid.

OF TANNIC ACID, OR TANNIN.

There is a principle in vegetables which has the property of combining with the skins of animals, and converting them into leather. The process by which this change is effected, is called tanning; and hence the matter producing it, has been called tannin.

Although this appellation may be generally employed, yet as tannin forms combinations with various salifiable bases, and acts with sufficient energy to displace many of the acids; I concur with Berzelius in considering it as an acid, and consequently give it the appellation of tannic acid.

Tannic acid is found in a great number of vegetables, generally in their bark or roots, but not unfrequently in their leaves and seeds, and even in their flowers and fruits, before they have reached maturity. It is in fact the most frequent cause of astringency in vegetable products.

It may be procured, according to Mr. Pelouze, in a state of purity, by introducing powdered galls into a vessel with a body and pipe resembling that of a funnel, but contracted above into a neck like that of a bottle. The pipe of this vessel should be plugged with cotton, and must be made to descend into a tincture bottle through the mouth. The galls are then to be covered with sulphuric ether, of the officinal strength, and the mouth of the vessel covered, so as to prevent the evaporation of the ether.

The liquid which descends into the bottle will be found to separate into two portions, of which the heaviest is a solution of tannic acid. From this solution the acid may be obtained in the solid form by evaporation.

Pure tannic acid is colourless, inodorous and astringent to the taste. It is uncrystallizable. Its aqueous solution reddens litmus. It does not affect solutions of the salts of the protoxide of iron, but with those which contain the sesquioxide of this metal, it produces a precipitate of the tannate of iron. Pure tannic acid, may in a few hours be so completely removed from its solution by a piece of a raw hide, that if no gallic acid be present, the liquid will no longer affect a solution of the salts of the sesquioxide of iron; but if the last mentioned acid be present, a dark blue precipitate is formed with those salts.

According to Mr. Pelouze, the symbolic formula representing the composition of tannic acid, should be as follows: C^6, H^3, O^4.

OF ARTIFICIAL TANNIN.

A substance resembling tannic acid in many of its properties, and called generally, artificial tannin, is formed during the action of nitric or sulphuric acid on a great variety of vegetable substances. One variety of this tannin is formed by the reaction of nitric acid with charcoal.

OF GALLIC ACID.

Gallic acid has been obtained in various modes. The following appears to me preferable. A concentrated decoction of galls, previously mixed with a little acetic acid to decompose the gallate of lime, is shaken with ether for one minute. The ether being decanted and evaporated, the gallic acid is isolated in small colourless prisms.

Mr. Pelouze infers, from the experiments which he has made, that gallic acid does not exist naturally in galls, but is produced by the action of the air on the tannic acid.

Gallic acid is white and crystalline. It reddens litmus and has a feebly acid, and astringent taste. In hot water it dissolves freely, although in cold water it is but slightly soluble. With solutions containing the sesquioxide of iron, this acid gives a dark blue precipitate of gallate of iron.

The colouring matter of ink is composed of gallate and tannate of iron. The composition of gallic acid, according to Mr. Pelouze, may be expressed by the following symbolic formula, C^7, H^3, O^5.

When a retort, containing gallic acid, is plunged in a bath of oil, heated to about 400°, an acid called pyrogallic acid sublimes; but if, on the contrary, the oil be previously heated to ebullition, a new acid is produced, to which its discoverer, Mr. Pelouze, has given the name of metagallic. Pyrogallic acid was supposed, by Berzelius, to be a peculiarly pure gallic acid, but Braconnot has since shown, that it differs from this acid, both in properties and composition.

It appears that a small quantity of an acid, called the ellagic, is formed simultaneously with the gallic acid, when an infusion of galls is exposed to the air.

EXPERIMENTAL ILLUSTRATIONS.

Various metallic solutions precipitated by an infusion of galls.

OF SUCCINIC ACID.

When amber is exposed to heat in an alembic, succinic acid is sublimed in crystals, much contaminated by the essential oil of amber. By digestion in nitric acid, evaporation to dryness, washing in cold water, subsequent solution in boiling water, and finally by crystallization, the acid is obtained pure. When combined with any of the alkalies, it is useful in separating the peroxide of iron from the oxide of manganese.

Succinic acid has a sour taste, and reddens litmus paper. The symbolic formula for this acid is, C^4, H^3, O^2.

OF BENZOIC ACID.

The benzoic acid is a concrete, volatile acid, existing in gum benzoin, or benjamin, from which its appellation is derived. From this gum, the acid may be extricated, either by sublimation or by trituration with lime, digestion with water, and precipitation by chlorohydric acid.

Benzoic acid, when in union with ammonia, answers as well as succinic acid, to separate iron from manganese.

The presence of benzoic acid characterizes what are now considered by chemists as balsams. There are three balsams formed by its union with particular resins—gum benzoin, already mentioned, styrax, and the balsam of Tolu.

EXPERIMENTAL ILLUSTRATIONS.

Iron precipitated by succinic, and benzoic acid.

Crystals of benzoic acid exhibited.

OF BENZULE, THE RADICAL OF BENZOIC ACID.

In the oil of bitter almonds, and in benzoic acid, the existence of a common radical has been demonstrated by Liebig and Wohler, which is alleged to be represented by C^4, H^5, O^2; and to which the name of *benzule* has been given. With an atom of oxygen, benzule forms benzoic acid; with an atom of hydrogen, the oil of bitter almonds. Exposed to a current of chlorine, the oil above mentioned, gives up an atom of hydrogen to the chlorine, thus generating chlorohydric acid and benzule, which, uniting with an atom of chlorine, forms a chloride. The chloride of benzule thus formed, subjected to water, is converted into benzoic and chlorohydric acids. When a hydrated metallic oxide is encountered by this chloride, one portion of the metal, uniting with the chlorine, gives up its oxygen to the benzule, which being thus converted into benzoic acid, unites with an undecomposed portion of the oxide, and forms a benzoate. Distilled with cyanide of mercury, it gives a cyanide of benzule, and a chloride of mercury. Analogous results are obtained by the reaction of this substance with sulphides, iodides, bromides, &c. Benzule has not been isolated.

OF AMID, BENZAMID, OXAMETHANE, AND URETHANE.

Amid is a hypothetical compound, consisting of one atom of nitrogen and two of hydrogen, which, with carbonic oxide, is supposed to form oxamid, with benzule, benzamid. It has been suggested that the compounds formed by the reaction of potassium and sodium with ammonia may consist of those metals combined with amid.

Oxamid, is a white, crystallizable, volatile substance, insoluble in cold, and but slightly soluble in hot water. It sublimes during the decomposition of oxalate of ammonia by heat. It is equivalent to two atoms carbonic oxide, with one of amid.

Oxamethane, is the name of a compound which is produced by the reaction of ammonia and oxalic ether. It is equivalent to a compound of anhydrous oxalate of etherine (sweet oil of wine) and ammonia.

Urethane is produced by the reaction of oxychlorocarbonic ether and ammonia, and is deemed equivalent to a double anhydrous carbonate of etherine and ammonia.*

OF MECONIC ACID.

When a solution of acetate of lead is added to an infusion of opium, a precipitate is obtained, which being, while suspended in water, subjected to sulphydric acid, the lead precipitates as a sulphide. From this a clear solution, containing an acid called meconic acid, may be separated by filtration. This acid exists in opium com-

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* See Annales de Chymie, &c. &c. for November, 1833, vol. 44, p. 225.

bined with a vegetable alkali to which the efficacy of the drug is mainly ascribed.

With solutions of the sesquioxide of iron, meconic acid produces an intense red colour; with protoxide of lead an insoluble precipitate. It is to this property that we owe the process, above described, for procuring this acid.

Meconic acid produces a taste, at first sour, and subsequently bitter, and reddens litmus paper. It is composed, according to Liebig, of $C^7 H^2 O^7$.

OF A METHOD OF DETECTING THE PRESENCE OF OPIUM.

The property which meconic acid has of precipitating with lead, and of producing a red colour with iron, may enable us to detect opium, when present in a very small quantity in solution.

If ten drops of the tincture of opium, commonly called laudanum, be mingled with a half gallon of water, on adding a few drops of subacetate of lead, there will be a precipitation which, at the end of a few hours, will be perceptible in flocks. The descent of these flocks may be accelerated by detaching them gently from the sides of the recipient with a glass rod. The vessel should be conical, so as to concentrate them during their descent. After they are collected at the bottom of the vessel, about 30 drops of the red sulphate of iron and an equivalent portion of sulphuric acid should be introduced among them by means of a small glass tube. The presence of the meconic acid will be rendered evident by the redness which ensues.

When a red colour is produced by the means here described, it is probable that opium is present, as meconic acid is found only in that drug, and having no active qualities, is not used separately from it in any pharmaceutical preparation.

It may be proper to mention, that sulphocyanhydric acid produces, with the sesquioxide of iron, a colour resembling that produced by meconic acid.

EXPERIMENTAL ILLUSTRATIONS.

Into several vessels, each containing about a half gallon of water, and various quantities of laudanum, acetate of lead is first introduced. A precipitate of meconate of lead appears. At a subsequent period, when this precipitate has subsided, the presence of meconic acid is demonstrated by sulphuric acid and persulphate of iron.

OF KINIC ACID.

Kinic acid exists in Peruvian bark in union with quinia and cinchonia, the vegetable alkalies to which the active medical qualities of the bark are ascribed. It also exists in the bark in the state of kinate of lime.

As no useful application has been made of kinic acid, and no active qualities are ascribed to it, it were useless to occupy attention with any details respecting the means by which it may be isolated.

OF THE VEGETABLE ALKALIES.

The discovery of this class of substances is of the highest importance to mankind. It has enabled the physician to avail himself of the active principles of some of the most powerful remedies, with a certainty which was before unattainable. The patient, in lieu of being nauseated and even injured, by doses, of which the greater part, perhaps the whole, may be inert, if not injurious, has to swallow nothing which can be inefficacious, when judiciously prescribed.

In the Report on Chemistry for 1832, to the British Association for the Advancement of Science, by Mr. J. F. W. Johnston, to which I have already alluded, there is a table of all the vegetable principles which the author considered as alkalies at the period of publication. Of the names in this table, as quoted on the opposite page, Berzelius, at the period of the publication of the fifth volume of his treatise, 1831, only admitted the thirteen marked * as alkalies, and those marked † as not being, in his opinion, sufficiently known to be arranged with confidence among alkalies.

I consider the alkalinity of the principles mentioned in this table, which have not been recognised as alkalies by Berzelius, as resting on doubtful or inadequate evidence.

LIST OF VEGETABLE ALKALIES.

Names.	*Whence obtained.*
† Atropin.§	Atropa belladona.
* Brucia, $C^{32} + H^{36} + N^{2} + O^{6}$.	Brucia antidysenterica.
† Buxin.	Box tree.
* Cinchonia $C^{20} + H^{22} + N^{2} + O$.	Pale cinchona bark.
Conin, $C^{12} + H^{20} + N^{2} + O$.	
* Curaria.	Curara, a vegetable extract employed for rendering arrows poisonous.
† Crotonin.	Croton tiglium.
† Cynapin.	Æthusa cynapium.
* Corydalia.	Root of the corydalis tuberosa.
Crystallin.	Distillation of indigo.
* Delphinia.	Delphinium staphisagria.
† Daphinin.	Daphne mezerium.
Digitalin.	Digitalis purpurea.
† Eupatorin.	Eupatorium.
* Emetia, $C^{37} + H^{54} + N^{2} + O^{10}$.	Ipecacuanha.
† Esenbeckin.	Esenbeckia febrifuga.
Fumarin.	Fumaria officinalis.
† Guaranin.	Paulina sorblis, Guarana of commerce.
Hyssopin.	Hyssop.
Hyoscyamin.	Hyocyamus niger.
* Morphia, $C^{34} + H^{36} + N^{2} + O^{6}$.	Opium.
Meconine, $C^{9} + H^{9} + O^{4}$.	
* Narcotia, $C^{17} + H^{17} + N^{4} + O^{5}$.	
* Nicotia.	Tobacco.
Nicotianin.	
† Pariljin.	Smilax sarsaparilla.
Picrotoxin, $C^{5} + H^{6} + O^{2}$.	Menispermum cocculus.
* Quinia, $C^{20} + H^{24} + N^{2} + O^{2}$.	Yellow cinchona bark.
* Strychnia, $C^{30} + H^{32} + N^{2} + O^{3}$.	Various species of strychnos; nux vomica, among others.
* Solania.	Solanum.
† Smilacin.	Smilax sarsaparilla.
† Sanguinarin.	Sanguinaria cannadensis.
* Veratria.	Veratrum album.
Violin.	Viola odorata.

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§ By some of the British chemists the practice has been devised of distinguishing alkalies by the generic termination of *a*. Hence morphine has been called morphia, quinine, quinia, &c. But I have no reason to believe that this course has been even partially adopted by the chemists on the continent of Europe, nor by the chemists of Great Britain generally, as must be evident from its not being employed in the report made to the British Association, from which the preceding list is taken. I am therefore doubtful as to the right course; yet as I employed the termination in *a*, in the first edition of the Compendium, as it has been adopted in the U. S. Dispensatory, and as it is still generally adhered to, by Dr. Turner, whose work has had a great circulation in this country, I have concluded to continue to employ the termination in question in this work.

Crotonin and pariljin, though mentioned by Berzelius, are not in Johnston's table. Nicotia and narcotia are not universally admitted to be alkalies, and generally called nicotin and narcotin.

The Vegetable Alkalies

Appear in almost every instance to exist in the vegetables to which they belong, in union with an acid. Thus, morphia is united with meconic acid—cinchonia aud quinia with kinic acid—delphia with malic acid—veratria with gallic acid. In some instances, the acids have not been specified; but the method requisite for the analysis, shows that they are present. The salt thus formed, is entangled sometimes with resinous matter, sometimes with colouring matter, and at others with fatty matter; and in a few instances by caoutchouc. In some cases several, in others, all of these impurities may be present. Very sparing solubility in water, and comparatively copious solubility in alcohol, are among the most striking attributes of these alkalies. The characteristics which I have mentioned, must, of necessity, prescribe the methods to be used, in the development of the principles to which they belong. Potash, soda, ammonia, lime, or magnesia, is used to displace the alkali from the acid, naturally in union with it. The alkali thus displaced, from its insolubility in water, precipitates; sometimes with the precipitant, sometimes without it. Strong alcohol is employed to dissolve the alkali, after precipitation. Previously to this step in the process, to remove resinous, colouring, or fatty matter, water, weak alcohol, or ether, is occasionally used. And in the case of morphia, when ammonia is added to separate, and acetic acid to dissolve it, animal charcoal is employed to deprive it of colour. A decomposition of the native salts, in which these alkalies are found, is also effected, in some instances, by acetate of lead. The acetic acid unites with the alkali, and the oxide of lead with the acid which the alkali relinquishes. Sulphydric acid is afterwards used to remove any excess of the metal. Generally the alkalies are susceptible of crystallization, and of forming neutral crystallizable salts, with the mineral and vegetable acids.

OF MORPHIA, OR MORPHINE.

This alkali is one of the active principles of opium, in which it exists, in union with meconic acid, and entangled with a great quantity of colouring matter. From the acid it may be separated by magnesia or ammonia. The colouring matter is removed by washing with cold water, and digestion with weak alcohol. After this, the morphia is dissolved in boiling hot alcohol, from which it crystallizes on cooling.

By Dr. Thomson, the morphia, after having been precipitated by ammonia, in the first instance, is dissolved in acetic acid, and is afterwards deprived of its colouring matter, by animal charcoal.

Agreeably to the observations of Dr. Staples, a graduate of our school, this alkali may be precipitated from common laudanum, by a mixture of equal parts of aqua ammoniæ and alcohol, the alcohol being added to prevent the precipitation of matter insoluble in water. In about twelve hours the whole of the interior surface of the vessel will be studded with crystals intermingled with colouring matter, the crystals themselves being of the colour of brown sugar. By decanting the liquid, dissolving the crystals in acetic acid, and precipitating again by ammonia, the morphia may be obtained of a cream colour.

By adding chloride of calcium to a filtered aqueous infusion of opium, by complex affinity, chlorohydrate of morphia and meconate of lime are formed. The latter, being insoluble, precipitates; the former remains in solution, and by straining through cloth, evaporation, re-solution, filtration, digestion with animal charcoal—filtration, evaporation, straining, and crystallization, may be isolated in a state of purity.

Morphia is not soluble in cold, and but slightly soluble in boiling water. In alcohol, especially when boiling, it is very soluble. It is white and bitter; and crystallizes in slender, four-sided, obliquely truncated, prisms. In small doses, it promotes sleep; in larger doses, produces death.

OF NARCOTIN.

In order to obtain narcotia, opium may be shaved upon the surface of a jack plane, and digested with as much ether as will cover it at a temperature near the boiling point of the ether, for three or four days. The ether being decanted and allowed to evaporate, the narcotia will appear in slender prismatic crystals. To remove all the narcotia, opium must be subjected to successive portions of ether.

OF STRYCHNIA, OR STRYCHNINE.

The poisonous principle of the strychnos nux vomica, and strychnos ignatia, proves to be an alkali, which is called strychnia. It may be developed by a process similar to that used for morphia. It was originally obtained by Pelletier and Caventou, by subjecting the bean of the strychnos ignatia, duly rasped, to nitric ether, in a Papin's digester, to remove fatty matter; and subsequent exposure of the residue to alcohol, in which the strychnia, in union with an acid, dissolves. The alcohol having been evaporated, and the residuum dissolved in water, the addition of potash caused the alkali to precipitate. It was afterwards washed in cold water, and redissolved in alcohol, from which it crystallized by evaporation.

The colour of strychnia is white. Its taste is intolerably bitter, leaving a metallic impression in the mouth. It is nearly insoluble in water, or ether, but is very soluble in alcohol. It is a terrible poison, very small quantities producing tetanus to a fatal extent.

OF BRUCIA.

This alkali exists in the bark of the brucia antidysenterica. This bark was first subjected to sulphuric ether, and afterwards to alcohol. The alcohol being evaporated, afforded a dry residuum, which was dissolved in water. The solution in water was saturated with oxalic acid, and evaporated to dryness. The residue was the oxalate of brucia, disguised by colouring matter, which was removed by alcohol. The oxalate of brucia was decomposed by lime or magnesia, either of which forms an insoluble salt with oxalic acid; while the brucia is soluble in 500 times its weight of boiling water, or in 850 parts of cold. Hence it was separated from the insoluble oxalate by water.

Brucia crystallizes in oblique prisms, with parallelograms for their bases. It is less bitter than strychnia, but its taste is more acrid and durable. It melts when heated a little above 212°, and congeals on cooling into a mass resembling wax. It neutralizes acids, affording a distinct class of salts. On animals, its effects are analogous to those of strychnia, but less violent.

OF EMETIA, OR EMETINE.

This alkali is obtained from ipecacuanha. The roots, well pulverized, are digested in ether. They are then subjected to alcohol, the resulting solution is evaporated, and the residuum dissolved in water and macerated upon magnesia, which causes the emetia to precipitate. This precipitate is washed in cold water to remove colouring matter, and afterwards subjected to alcohol, which takes up the emetia. The emetia again separated from its solvent by evaporation, being dissolved by diluted acid, and blanched by animal charcoal, may be precipitated pure, by any of the alkaline oxides.

Thus obtained, emetia is white, pulverulent, and unalterable by the air —scarcely soluble in water, but very soluble in ether or alcohol. Its taste is slightly bitter. It restores the colour of litmus, when reddened by an acid; and is capable of forming crystallizable salts, like other alkalies. It appears to possess all the emetic properties of the root from which it is procured.

OF CINCHONIA, OR CINCHONINE, AND QUINIA, OR QUININE.

These appellations have been employed to distinguish the alkalies, lately found in Peruvian bark.

The following are the processes by which they were obtained by the discoverers, Pelletier and Caventou.

Two parts, by weight, of pale bark, ("cinchona gris," or "cinchona condamenea,") were subjected, four times, to six parts of hot alcohol. The alcoholic tinctures were united and distilled to separate the alcohol; two parts of water being added, towards the close of the distillation, to secure the residuum from injury by the fire. This residuum received on a filter, employed to separate it from the water, had a red colour, and a resinous appearance. In this state it was washed with water, weakly alkaline. After many days washing with alkaline water, this passed the filter, limpid and without colour. The matter on the filter was next washed with pure water, and afterwards appeared of a greenish-white, very fusible, soluble in alcohol, and gave crystals which were in the state of the cinchonia, as discovered by Dr. Gomez, of Lisbon, having some characteristics of a resinous substance. By solution in chlorohydric acid, very much diluted, a quantity of green fatty matter was separated. This separation is imperfectly accomplished if the acid be strong.

The solution thus obtained was of a golden-yellow colour, and when evaporated it gave crystals, soluble in alcohol and in water. Its taste was very bitter, and it was precipitated abundantly by alkaline solutions; and being slightly heated, and mixed with magnesia, it yielded a precipitate. This, after washing it with water, was dissolved in alcohol, producing a very bitter solution, whence crystals of cinchonia were obtained by evaporation. By subsequent solution, in the same menstruum, and evaporation, cinchonia was obtained in very white, delicate, brilliant, prismatic, needle-shaped crystals.

Cinchonia, though nearly insoluble in water, when cold, is soluble in it when boiling. A thousand parts, by weight, are requisite; and the solution becomes opake, or opalescent, on cooling.

It is very bitter, though from its insolubility, this property is not immediately perceptible. Its sulphate, and other soluble salts, are excessively bitter; but the effect on the taste differs from that of a strong decoction of the bark, in not being associated with an astringency due to another principle.

Treating the yellow Peruvian bark, "quinquina jaune", (cinchona cordifolia) by the process used in developing cinchonia, Messrs. Pelletier and Caventou were surprised to find a yellowish substance, apparently insusceptible of crystallization. This substance they were at first led to consider as cinchonia, disguised by foreign matter. It was, however, finally ascertained to be a vegetable alkali, analogous to cinchonia, but not identical with it.

The alkali, thus discovered, has been denominated quinine, or quinia.

Quinia is so difficult to crystallize, that it was supposed to be uncrystallizable. It has since been obtained from its solution, in very highly concentrated alcohol, in crystalline needles, or fine crystalline tufts. When entirely deprived of water, by drying, it appears a porous mass, of a dirty white. It is almost insoluble in water, but readily dissolves in alcohol or ether. It is extremely bitter.

Of the Means of obtaining Sulphate of Quinia.

It appears to me that the most eligible process for obtaining sulphate of quinia, is as follows.

Boil a pound of the bruised bark with three fluid drachms of sulphuric acid, in a gallon of water. Make a similar decoction of the same bark, with half the quantity of acid, and again, with a lesser quantity of acid, until all the soluble matter appears to be extracted. Add pulverized hydrate of lime, until the acid is saturated. By these means, sulphate of lime, mingled with quinia, will be precipitated. In the next place, the precipitate, being collected and dried, is to be boiled in alcohol, which will take up the quinia. The alcohol being removed by distillation, the quinia is to be saturated with sulphuric acid very much diluted with water; animal charcoal added, and the liquid concentrated by ebullition. Afterwards, by refrigeration, crystals of the sulphate will appear.

OF DELPHIA, DELPHINIA, OR DELPHINE.

It was in the seeds of the delphinium staphisagria or stavesacre, (in which it exists as a malate) that this alkali was detected. A decoction of the seeds, which had been cleansed and reduced to a pulp, was filtered. The fluid, which passed the filter, was boiled with magnesia, which liberated the delphia. It was then separated from the magnesia, by alcohol, and from this solvent, by evaporation.

Delphia is white, pulverulent, and very soluble in alcohol or ether. It is inodorous, but its taste is extremely acrid and bitter. Water derives from it an acrid taste, though it does not dissolve any appreciable quantity. By combination with acids, it forms neutral salts, which are soluble in water, and very acrid and bitter.

OF VERATRIA, OR VERATRINE.

This alkali is obtained from the seeds of the veratrum sabadilla; also from the root of the veratrum album, or that of the colchicum autumnale.

The seeds, partially depurated by digestion with ether, yielded a coloured tincture with heated alcohol. This tincture deposited some waxy matter, on cooling, and by evaporation afforded a residuum, soluble in water, excepting a small portion of extraneous matter. The watery solution being slowly and partially evaporated, until an orange-coloured precipitate ceased to appear, acetate of lead was added to it. A copious yellow precipitate ensued, and the liquor, being separated from it by a filter, became almost colourless. This fluid was subjected to sulphydric acid, to precipitate any lead which it might contain. The solution, then, with magnesia, gave a precipitate, from which alcohol took up veratria, which was afterwards isolated by evaporation.

Veratria is white, pulverulent, and inodorous, but, nevertheless, poisonous, when inhaled, producing violent and dangerous sneezing. Its taste is not bitter, but excessively acrid. It is very soluble in alcohol and ether. Minute quantities, taken into the stomach, produce intolerable vomiting and sickness. Larger doses would certainly be fatal.

OF CORYDALIA, OR CORYDALIN.

"This alkali, discovered by Dr. Wackenroder, is contained in the root of the fumitory, not the common fumitory, (*fumaria officinalis*,) but *fumaria cava*, and *corydalis tuberosa* of Decandolle. It exists in the plant as a soluble malate, is precipitated from its aqueous solution by magnesia, and is purified by alcohol."*

OF CURARIA, OR CURARINE.

This organic base was discovered by Boussingault and Roulin, in a matter employed by the savages of South America to poison arrows.

OF NICOTIA, OR NICOTIN.

Tobacco is alleged to owe its acridity and narcotic powers to a principle called nicotia, which exists in it as a base, combined with acetic acid.

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* Turner's Chemistry, 4th English edition, page 779.

OF SOLANIA, OR SOLANINE.

Solania is the name which has been given to a substance considered as an alkali, which exists in a species of the nightshade, (solanum nigrum,) and in the bittersweet (solanum dulcamara).

The filtrated juice of the berries of the nightshade is digested in ammonia; a precipitate which results, is washed on the filter, and digested in boiling alcohol. After the evaporation of this fluid, solania is obtained in sufficient purity. It is a white, opake, pearly powder, which is inodorous, slightly bitter, and nauseous. Its acid solutions are more bitter. Its salts are uncrystallizable. In cold water it is insoluble—and in hot, dissolves only to a small extent. It is very soluble in alcohol, but is not dissolved by ether. It restores the colour of litmus, reddened by an acid. It causes vomiting at first, afterwards sleep.

OF SUBSTANCES ALLEGED, BUT NOT PROVED TO BE ALKALIES.

Of the principles which come under this head, I shall notice a few.

OF PICROTOXIA, OR PICROTOXINE.

From a strong infusion of the cocculus indicus, a white crystalline powder was precipitated by the addition of ammonia in excess. This powder, washed with cold water, and subjected to alcohol, yielded a solution, which, on being evaporated, deposited beautiful silky needles. A similar result was obtained from an alcoholic infusion of the seeds, by magnesia, which caused a grayish precipitate, from which alcohol dissolved a matter crystallizable by evaporation.

In either way obtained, the crystalline precipitate is picrotoxia; a substance supposed to be alkaline, and which constitutes the poisonous principle of the seeds from which it is procured.

Picrotoxia is white. Its taste is disgustingly bitter. One hundred parts of boiling water dissolve only four of picrotoxia, and one-half of this precipitates on cooling. Alcohol of about 810 s. g. dissolves one-third of its weight of this principle. Picrotoxia is a virulent poison.

OF ACONITA, OR ACONOTINE.

From the aconitum napellus, or wolfsbane, the active principle has been extracted. It is supposed to be an alkali.

OF PARILJIN AND SMILACIN.

The principles called by the abovementioned names, are said to exist in the smilax sarsaparilla; but as they are not admitted to be the active principles of the plant, I do not treat of them particularly. Some interesting observations respecting them, may be seen in the U. S. Dispensatory, page 589, 2d edition.

OF ATROPIA, OR ATROPINE.

Atropia is procured from a decoction of the leaves of the atropa belladonna, or deadly nightshade. Two pounds of the leaves were boiled in successive portions of water, which being united, and sulphuric acid added to the whole, the resulting liquid was filtered, and yielded a crystalline precipitate with potash. This precipitate repeatedly dissolved in acids, and precipitated by alkalies, gave pure atropia. Thus obtained, it is snow-white, and quite tasteless. When recently precipitated, it is slightly soluble in water. After being dried, it is insoluble in water, ether, or oil of turpentine. In cold alcohol, it is sparingly soluble; but copiously, in the same menstruum, when boiling hot.

Atropia forms compounds with acids, which cannot, however, be rendered so neutral, as not to indicate acidity.

OF DATURIA, OR DATURINE.

This appellation was given by Brandes, to an alkaline principle, which, he alleges, he has extracted from the seeds of the datura stramonium.

OF HYOSCYAMA, OR HYOSCYMINE.

To a principle to which this appellation is given, the active qualities of the hyoscyamus niger, or henbane, are attributed.

It is alleged to be susceptible of crystallization, and capable of forming salts with acids.

Atropia, hyoscyama, and aconita, are so poisonous, that their discoverer, Brandes, found it impracticable to prosecute his inquiries respecting them, as far as desirable, from their injurious influence on his health.

Chemical Characters of the Vegetable Alkalies.

They are all solid, white, inodorous, heavier than water, and either bitter, or acrid. All of them render the syrup of violets green.

Veratria, delphia, and emetia, can be obtained only in powder. The others are susceptible of crystallization.

They all yield ammonia by destructive distillation, which demonstrates that nitrogen is invariably one of their constituents.

They are all soluble in alcohol, and nearly, if not quite, insoluble in cold water.

When their salts are subjected to the Voltaic poles, the alkali is always attracted to the negative pole.

Their affinity for acids is generally greater than that of the oxides of the metals proper, but is less than that of the alkalies and alkaline earths.

In solutions of their neutral salts, an infusion of galls causes a precipitate, which alcohol dissolves.

These characters are intended for the alkalies, whose existence is well established.

Of the Means of discriminating between certain Vegetable Alkalies.

Morphia and *brucia* produce with nitric acid, a fine red colour, while the other alkalies, under the same circumstances, are either rendered yellow, or are scarcely altered.

In a solution of morphia, reddened by nitric acid, protochloride of tin causes a dull brown precipitate; while, in a solution of brucia, similarly reddened, it causes a violet precipitate. Of the acetates of these alkalies, only that of morphia is crystallizable.

When a nitrate either of *quinia*, or of *cinchonia* is evaporated, at a certain degree of concentration, globules of an oleaginous appearance are deposited, which congeal at a low temperature assuming the aspect of wax. These globules, when covered by water, neither dissolve nor sustain any change of volume; but in a few days, are converted into a group of shining prismatic crystals. By these characteristics, quinia and cinchonia may be distinguished from the other alkalies. They may be distinguished from each other, because quinia is fusible, uncrystallizable, and susceptible of a total decomposition by heat, while cinchonia is partially susceptible of volatilization, infusible, and crystallizes with facility. Besides, of their acetates, only that of quinia is crystallizable.

Strychnia is the only alkali which is both infusible and insusceptible of volatilization. When it contains brucia, it reddens with nitric acid, and yields a precipitate similar to that afforded by morphia. Hence, unless pure, it cannot be distinguished by these tests. The neutral nitrate of strychnia may be separated from that of brucia, since it crystallizes, while the latter remains dissolved.

Emetia is pulverulent, very fusible, sensibly soluble in boiling water, insoluble in ether, and neither neutralizes acids, nor forms with them crystallizable salts.

Veratria may be detected, by its extraordinary acridity, and the violent sneezing which it excites. Besides, it is uncrystallizable, pulverulent, very fusible, soluble in ether, is rendered yellow by nitric acid, and resembles emetia in its habitudes with acids.

Delphia is distinguished from veratria, by the difference of their physiological properties. Delphia is alleged to be inodorous, and is not said to excite sneezing. It produces a taste, which is at first bitter, but which afterwards becomes acrid.

Of the Composition of the Vegetable Alkalies.

According to Thenard, all the vegetable alkalies are constituted of hydrogen, oxygen, carbon, and nitrogen. This last mentioned principle enters into their composition in a quantity which varies from 4.30 to 9.02 in 100. It is remarked, that in strychnia, which contains the most carbon, there are 78.22 parts in 100, while in emetia, which contains the least carbon, this element exists in the ratio of 64.57 parts in 100. It follows, that it is the most abundant ingredient in this class of substances. In quinia, cinchonia, and strychnia, the nitrogen exceeds the oxygen in quantity; but the opposite is true, in the instances of veratria, brucia, emetia, and morphia.

It has recently been alleged by Mr. Brande, that cinchonia is destitute of oxygen.

"*Does the azote in vegetable alkalies constitute ammonia?* It has been found that the vegetable alkalies, so far as they have been examined with care, contain, as an essential constituent, a considerable quantity of nitrogen; and the question early suggested itself—Does the nitrogen in these salt bases exist in the form of ammonia? If so, it would be easy to understand why they exhibit alkaline properties. The experiments of Pelletier and Dumas appeared to supply a negative answer to the question, as well as the later ones of Liebig, who found that though brucine and strychnine are completely decomposed by nitric acid, yet ammonia is not one of the products. But there are other circumstances which are considerably in favour of the opposite opinion. Thus, in the six vegetable alkalies, morphine, narcotine, strychnine, brucine, quinine, and cinchonine, Liebig found that each atom contained one atom of nitrogen; and that thus the saturating power of each was in proportion to the amount of that element which it contained. The sulphates he found also to contain two atoms of water,* corresponding exactly to the quantity of water found by Mitscherlich to exist in the crystallizable salts of ammonia with the oxacids. These coincidences are extremely curious; and though they prove nothing, yet they show that we are not yet in a state to answer the question, definitively, whether the vegetable alkalies do really contain ammonia or not."†

Matteucci conceives, that the following result which he has lately attained, is favourable to the opinion that alkalinity in the vegetable alkalies, is due to the presence of ammonia. Sulphate of copper, and pure morphia finely pulverized and intimately mingled, were placed upon paper moistened with alcohol, and brought into contact with the copper plate terminating a galvanic pile of ten pairs. Under these circumstances, the evolution of ammonia is rendered evident by the production of a blue colour with the copper.

OF THE VINOUS FERMENTATION.

When certain vegetable infusions, or mixtures of saccharine and farinaceous matter, or the juices of fruits, as those of the apple or grape, are kept at a temperature neither above 120°, nor below 50°, a chemical reaction ensues, during which, carbon and oxygen unite, and escape in the form of carbonic acid gas; while the proportion of the hydrogen, being increased in the residue, a new liquid is composed, in which hydrogen predominates. This liquid is alcohol, or spirit of wine, in which the intoxicating power of fermented liquors resides, and the process by which it is produced, is called the vinous fermentation.

Of Yeast, or Ferment.

The vinous fermentation is wonderfully and mysteriously promoted by the presence of a ferment. This is a peculiar species of matter, usually called yeast, which is extricated, or formed, during fermentation; and which, from its viscidity, so envelopes the carbonic acid, generated at the same time, as to be elevated by it, to the surface of the liquid. The part which yeast performs as an exciting cause of fermentation, seems to be somewhat analogous to that of a virus, in inducing disease, similar to that from which it originates.

It has always appeared to me possible that the vinous and acetous fermentations were severally due to appro-

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* The sulphate of strychnine he has since found may be obtained in an anhydrous state.—*Pogg.* p. 487.

† Johnson's Report, page 499.

priate animalcules, of which yeast might be the eggs, or in the case of the acetous fermentation, that the mother of vinegar might be similarly constituted. It is remarkable that the temperature requisite for fermentation, has nearly the same limits as that requisite for life.

The proportion of yeast required to induce fermentation, is very small, not being more than one part in one thousand, when judiciously managed.

The juice of the apple, and that of the grape, ferment spontaneously, in consequence of the presence of some matter, naturally existing in the fruit, which operates like yeast. A pure solution of sugar is not susceptible of the vinous fermentation.

Whatever may be the nature of the septic principle in vegetables, a temporary exposure to the air is indispensable to give it activity. Vegetable juices may be prevented from entering into fermentation, by heating them to the boiling point, and sealing them up, in bottles, so as to exclude the air completely; yet, after fermentation has been induced, it cannot be arrested by excluding the air.

OF ALCOHOL.

By the distillation of fermented liquors, the alcohol in them is separated, as it boils at a lower temperature than water. It still contains, however, more or less of this liquid; and though depurated from it, to a considerable degree, by repeated distillations, the chemical affinity of pearlash, or some other substance attractive of moisture, is requisite to produce the highest possible degree of purity, at which the specific gravity of alcohol is, to that of water, nearly, as 800 to 1000, at 60° F.

Of the Properties of Alcohol.

The union between alcohol and water is so energetic, as to cause a rise of temperature, and a diminution of volume, when they are mixed.

Alcohol, by combustion, yields only water and carbonic acid. It is more expansible than water, and boils at 176° F. Its capacity for heat, whether in the liquid or aeriform state, is much less than that of water. It is a powerful solvent, and a most useful agent in pharmacy, and in the delicate analysis of vegetable and animal matter. It is alleged that it has been frozen at —90° by Bussy.

I have ascertained, that the addition of one-seventh of oil of turpentine, will render the flame of alcohol so luminous, as to be a competent substitute for a candle flame.

When alcohol is passed through a red-hot porcelain or copper tube, it is decomposed into equal volumes of water and olefiant gas. Yet it will appear from the next article, that carbon and hydrogen are now conceived to exist in alcohol not as olefiant gas, but as etherine or sweet oil of wine.

OF ETHERIFICATION.

By the reaction between alcohol and acids, a variety of volatile, inflammable liquids are produced, which are called ethers. These ethers are named after the acids by which they are generated, and of which, in a majority of instances, they are partially composed.

The generic appellation ether, has likewise been extended to some analogous liquids formed by the reaction of the halogen bodies with alcohol.

In the former edition of this text book, I quoted Thenard's classification of ethers, agreeably to which he divides them into those which are generated like sulphuric ether, merely by the abstraction of half the quantity of water which exists in alcohol; those which are formed by the substitution of a volume of an acid, for a volume of water, and those which are formed by a union of alcohol with certain acids.

Dr. Thomson, in his Organic Chemistry, divides ethers into those which contain acids, and those which do not, and designates the former as acid ethers, although admitted to be devoid of the acidity which the name implies. He conceives the oxacid ethers to consist each of an appropriate acid after which it is named, united to an equivalent volume of the liquid called sulphuric ether, instead of alcohol as suggested by Thenard. He concurs with Thenard respecting the composition of the hydracid ethers, but does not treat of them as a separate class.

It may be proper to observe that the ethers of Thenard's third class are in general obtained by the aid of sulphuric acid, which being made to act upon alcohol, mingled with an acid, or to act upon a salt containing an acid while the alcohol is present, in lieu of sulphuric ether, an etherial liquid containing the liberated acid is evolved.

OF SULPHURIC OR HYDRIC ETHER.

When equal weights of alcohol and sulphuric acid are mixed and distilled, a liquid known by the name of sulphuric ether is produced. If the distillation be continued long enough, fumes of sulphurous acid, an oleaginous liquid, and alcohol containing this liquid, together with water and acid, pass over. Finally the residue rises in a foam, so as to render it necessary to terminate the process.

The ether may be washed with water, into which a small quantity of red lead, or manganese, has been introduced, to remove the sulphurous acid. Liquid ammonia, diluted with water, neutralizes this acid instantly. The whole should be subjected to distillation, by means of a water bath, heated to 120°, to separate the ether—and afterwards raised to a boiling heat, to obtain the alcohol and sweet oil of wine, or Hoffman's anodyne liquor.

Thus obtained, ether is pure enough for medicinal purposes, and generally for those of the laboratory; but is not free from water. In order to depurate it of this liquid, it must be mixed with chloride of calcium, and distilled with a gentle heat.

Of the Properties of Sulphuric Ether.

Sulphuric ether is very volatile and light, being, in weight, to water, when pure, as 700 to 1000. The cold produced by the evaporation of this liquid in the air, and by its ebullition in vacuo, was adduced among the phenomena of caloric, page 66, 39. It boils at 98°, under the pressure of the atmosphere, and in vacuo, below the freezing point of water. This ether combines with water to a limited extent, but unites with alcohol in any proportion. It freezes at — 46°. It has peculiar and useful powers as a solvent.

OF ETHERINE OR SWEET OIL OF WINE, AND HOFFMAN'S ANODYNE LIQUOR.

The oleaginous liquid, called sweet oil of wine, which towards the termination of the process in making sulphuric ether, comes over separately, or in union with alcohol forming Hoffman's anodyne liquor, is alleged, by

Faraday and Hennel, to be a compound of carbon and hydrogen with sulphuric acid. During the process, an acid is generated, which has been called the sulphovinic acid, consisting of two atoms of sulphuric acid, one of carbohydrogen, and either one or two atoms of water.* This acid is at first decomposed into ether, and lastly, more or less, into a compound of sulphuric acid and carbohydrogen, containing only one atom of the acid, which the above mentioned chemists considered as oil *of wine*. In fact it appears that there are two liquids which have been called oil of wine, one of which contains sulphuric acid, while the other consists solely of carbon and hydrogen united in the ratio of their equivalents. This latter, which is, as I conceive, the true sweet oil of wine, is now called etherine. I have been in the practice of obtaining etherine for many years, by depriving the oleaginous compound consisting of this substance and sulphuric acid, of the latter ingredient, by liquid ammonia. By means of this alkali, the sulphate of etherine is decomposed, and half its volume of pure etherine swims on the surface of the alkaline solution. The oil thus extricated, is the efficient principle of Hoffman's anodyne, which appears medicinally to be an important preparation, although not duly appreciated, in this respect, in England and France.

Brande alleges that it "is of no use in medicine." According to Thenard, sulphuric ether, united to alcohol, forms Hoffman's liquor.

I have the authority of my colleagues, Drs. Physick and Dewees, for asserting, that a solution of etherine in alcohol, (Hoffman's anodyne) is highly "*useful in some disturbed states of the system in tranquillizing it, and disposing to sleep*," being, in such cases, far preferable to, and very different in its effects from, a mixture of ether and alcohol.

Alcohol, containing etherine, produces a milky appearance with water, in consequence of the precipitation of the etherine, which is insoluble in water. This Dr. Physick had long remarked as an essential attribute of the genuine Hoffman's anodyne liquor. At one period, there was scarcely any to be found in the shops in this city, which possessed this essential characteristic; but the de-

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* That is, carbohydrogen in the state of tetarto carbohydrogen or etherine. See page 235.

fect having been pointed out, has been corrected by many of our druggists.

In the old way of making sulphuric ether, a certain quantity of Hoffman's anodyne had always been obtained towards the close of the process; but a new process was introduced, agreeably to which, an additional quantity of alcohol being added, before the materials could reach the state of concentration requisite for producing etherine, the anodyne liquor ceased to be a concomitant product of the ether. Hence a mixture of ether and alcohol was used as a substitute for it, both in this country and in France.

Agreeably to the formula for Hoffman's anodyne, given in the London Pharmacopœia, two "fluidrachms" of etherine are to be added to a pint of "spirit of sulphuric ether" consisting of two parts of alcohol, and one of ether. This process is preferable as respects precision, but has this objection, that the oil is more difficult to procure than the solution of it in alcohol, which may always be generated towards the close of the old process of etherification. I question if the presence of ether be advantageous in all cases. I have long been accustomed to make, with etherine and alcohol without ether, an anodyne which has been highly approved by those who have tried it.

I regret that no adequate efforts have been made to ascertain the medical virtues of etherine, and how the admixture of ether may tend to improve or impair its efficacy.

It has been mentioned cursorily, that the compound of etherine and sulphuric acid, as it is first obtained, on admixture with ammonia, is reduced to half its volume. The reaction is energetic, and accompanied by a rise of temperature. I believe the habitudes of the sulphate of etherine with ammonia, are not noticed by Hennel.

EXPERIMENTAL ILLUSTRATIONS.

A mixture of two parts of alcohol with one of sulphuric acid, by measure, being mixed and distilled, sulphuric ether is obtained: also Hoffman's anodyne liquor, and etherine.

Milky appearance arising from the mixture of Hoffman's anodyne, with water, exhibited.

SURPRISING INFLAMMABILITY OF SULPHURIC ETHER ILLUSTRATED.

The inflammability of sulphuric ether may be illustrated by applying the flame of a taper to a jet of it, while passing through the air, as represented in the preceding figure. Under these circumstances, the ether is converted into a continuous arch of flame.

The jet may be produced by compressing the bag with the hand, or by heating the bulb containing the ether, so that the pressure of the vapour generated by ebullition, may propel the liquid in a stream from the capillary orifice. If the latter method be adopted, the bag may be dispensed with.

OF CHLOROHYDRIC OR MURIATIC ETHER.

Chlorohydric ether may be obtained by distilling alcohol with concentrated chlorohydric acid. The distillation is performed by means of a glass retort, communicating by a tube with some water at the temperature of about 90° F. in a bottle, with three orifices. Through one orifice, the tube proceeding from the retort enters, and is luted air-tight; into another orifice, a tube of safety is inserted; from the third orifice proceeds another tube, bent twice at right angles, so as to reach the bottom of a long narrow phial surrounded with a freezing mixture, the orifice being nearly, but not quite closed. The water in the intermediate vessel detains any alcohol or acid evolved with the ether, which, in consequence of its greater volatility, reaches and is condensed in the phial. See page 155.

Chlorohydric ether is very volatile, being a permanently aëriform fluid above the temperature of 70°. When poured upon the hand, it boils, and produces a sensation of cold. In smell, it resembles sulphuric ether. It has a sweet taste. Its specific gravity is, to that of water, as 874 to 1000. When passed through an ignited tube, it is resolved into equal volumes of olefiant and chlorohydric acid gas.

OF IODOHYDRIC AND BROMOHYDRIC ETHER.

Iodohydric ether was generated by Gay-Lussac, by distilling iodohydric acid with alcohol. It is much heavier than water, being of a specific gravity of 1.9206 at 72° F. It boils at 148°. Its smell is analogous to that of the other ethers. By keeping, it disengages iodine, and acquires a rose-red colour.

With bromohydric acid, an ether may be formed analogous to those produced with iodohydric and chlorohydric acid.

OF THE ETHERIAL COMPOUNDS OF CARBON AND HYDROGEN WITH THE HALOGEN BODIES.

Under the name of chlorine ether, the compound formed by the union of olefiant gas and chlorine, is mentioned in page 239. I have since met with some additional information, by which it appears that there are other compounds of chlorine with carbon and hydrogen, of which an account is subjoined. In what form the carbohydrogen exists in them, is still doubtful. See carbohydrogen, page 235, Compendium.

Of these compounds, one has been known heretofore as chloric and "heavy muriatic ether," being obtained by the reaction of chlorine with alcohol. It may be called protochlorine ether.

This ether is a liquid of an oleaginous consistency, an agreeable odour, and a sharp taste. It consists of one atom of etherine, and one of chlorine.

Bichlorine ether, generally called chloric ether, is alluded to, page 239,* under the name of chlorine ether, as formed by the reaction of chlorine with olefiant gas. It is a colourless, oily looking liquid, with a peculiar odour, and a sweet aromatic taste.

Perchlorine ether was obtained by distilling alcohol from chloride of lime, by Mr. Guthrie, of Sackett's Harbour, New York, who however supposed it to be identical with the ether last described. Not long afterwards, without any knowledge of the experiments of Guthrie, it was procured by Soubeiran in Europe, and ascertained to be a compound of one atom of etherine, and four of chlorine.

Perchlorine ether is a volatile liquid, of an agreeable odour, and a sweetish aromatic taste. Both this and bichlorine ether have been advantageously employed in medicine.

Bromine and iodine also combine with carbohydrogen, probably in the state of etherine. The resulting compounds have qualities in some respects analogous to the chlorine ethers, but that formed by iodine is a pulverulent solid. Both bromine and iodine ether are produced by the reaction of their halogen elements with olefiant gas. That formed with iodine is generated by the aid of the solar rays.

OF NITRIC ETHER.

This ether may be obtained in a diluted state, by distilling alcohol with diluted nitric acid, or with nitre and sulphuric acid. When sulphuric acid is used, the product is liable to consist, in part, of sulphuric ether.

Thenard informs us, that, to obtain pure nitric ether, equal parts of alcohol, and of the nitric acid of commerce, may be mixed and distilled with great caution, the product being passed into a series of Woulfe's bottles, the first empty, the others half filled with brine, and surrounded by a freezing mixture. As soon as the reaction commences, it increases rapidly, so that it is necessary to check it, by cooling the retort.

I subjoin an engraving and description of a method which I have contrived for generating nitric ether.

I am of opinion that it would be advantageous if the prescriptions of our physicians were made with a reference to ingredients of a high degree of purity. The physician should know how much real nitric, or sulphuric ether is contained in the diluted article which he directs

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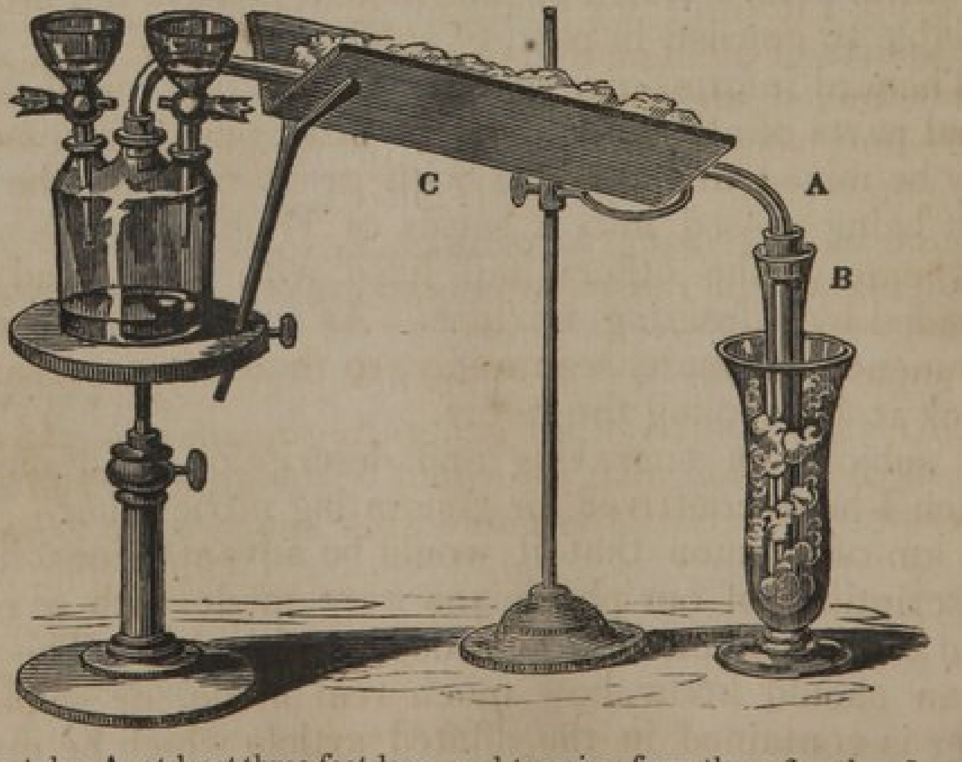
* Compendium.

his patient to use. Hence pure nitric or sulphuric ether should be prescribed, adding as much alcohol or water as he may deem necessary. Agreeably to the present practice, it is in the power of manufacturing chemists to impoverish etherial preparations, with little danger of detection.

Pursuant to the London Pharmacopœia, three ounces of nitric acid, by distillation with a quart of alcohol, are allowed to produce 24 ounces of sweet spirit of nitre. According to Thenard, the quantity of ether, when the materials are in the ratio of equality, amounts to two-thirds of the weight of the acid. Hence it is probable that the quantity of ether in the 24 ounces of sweet spirit, obtained as above mentioned, is not more than two ounces.

I infer that sweet spirits of nitre of a more uniform strength, would be obtained by the addition of alcohol to pure nitric ether, to an extent no more than adequate to render it soluble in water, and then adding water to the alcoholic solution, until the ether should form only a twelfth of the aggregate. In a preparation thus made, the properties of the ether would not be unnecessarily associated with those of alcohol, as in the usual officinal preparation.

APPARATUS FOR THE GENERATION OF NITRIC ETHER.



Let a tube, A, at least three feet long, and tapering from three-fourths of an inch to a half an inch in diameter, be so bent at each end, that the larger may fasten air-tight into the middle orifice of a three-necked bottle, the smaller end entering another tube, B, standing nearly upright in a freezing mixture, in any convenient vessel. The tube, A, must be so inclined, that any liquid condensing in it, must run into the tube, B, and must be surrounded by a freezing mixture, supported about it by the wooden trough, C. It has been mentioned, that, into one of the orifices of the bottle, one end of the tube is to be inserted. Let each of the two other orifices be furnished with a glass funnel, with a glass cock. Having made these arrangements, pour through one of the funnels about as much strong alcohol as will cover the bottom of the bottle nearly a half inch in depth. Next, by means of the other funnel, cautiously add as much concentrated nitric acid, as will cause an active ebullition. When the boiling relaxes, add more acid, and repeat the addition, till it ceases to renovate the ebullition. In like manner, add more alcohol, till the evolution of vapour can no longer be excited in this way. Afterwards, resort may again be had to the acid. Meanwhile, the ether, generated by the process, will be condensed by the artificial cold in both tubes, and in consequence of their relative situation, will be deposited in the liquid form, in the vertical tube only.

For several years past, I have, in place of the funnels, employed tubes with trumpet-shaped mouths above, and terminating under the surface of the liquid within the bottle in capillary perforations. The bore of that by which the nitric acid is introduced, ought not to be larger than the sixteenth of an inch.

If in addition to the apparatus above described, there were a contrivance for drawing off the residual liquor, as often as the quantity accumulated should be so great as to interfere with the process, the operation might continue for an unlimited time. The most convenient mean of removing the residuum, would be a glass cock; but this would be objectionable, on account of the expense, and the danger of its being fractured by the heat generated by the reaction of the acid with the alcohol. If the vessel were furnished with four necks instead of three, through one of them, one of the legs of a syphon might be introduced, so as to descend to the bottom of the bottle; the other leg of the syphon, entering another two-necked bottle through one of its orifices. Exhausting this last mentioned bottle, by a tube leading from the other orifice to a suction pump, any liquid in the four-necked bottle might be removed from it, through the syphon, into the other.

OF THE THEORY OF ETHERIFICATION.

It would not comport with the limits prescribed to this work, to treat particularly of each species of ether. I shall therefore here take leave of the subject of ethers, with some general observations on etherification.

It has already been stated that carbon and hydrogen combine in the ratio of their equivalents to form several polymeric compounds, and among others, one which has been designated lately as etherine. This was considered as the genuine oleum vini dulce, by Thenard, Dumas, Boullay, and many other chemists, but was by Hennel treated only as an ingredient in that oil, under the appellation of "hydrocarbon."

Prior to the researches of the last mentioned chemist, alcohol was generally, if not universally, considered by chemists as a compound of olefiant gas and aqueous vapour. Ether was conceived to consist of the same volume of the gas, with half the volume of aqueous vapour.

Etherification, when effected by means of sulphuric acid, was ascribed principally to the abstraction of water, by the sulphuric acid. An analogous explanation was given with respect to the formation of ethers, by phosphoric, arsenic, and fluoboric acid.

Other ethers were conceived to consist of a volume of acid united either to a volume of olefiant gas, or to a volume of alcoholic vapour.

But Hennel has demonstrated that while one portion of sulphuric acid, when heated with alcohol, abstracts water, another combines with "hydrocarbon" acting as a radical, and thus a compound containing two atoms of the acid, and one of "hydrocarbon," is formed, constituting an acid called sulphovinic, having a double radical of sulphur and hydrocarbon, or etherine. By the continuance of heat, as in the usual distillatory process, the sulphovinic acid is partially decomposed, and its "hydrocarbon" being evolved and uniting with water in quantity sufficient to form sulphuric ether, this liquid is conceived to be elaborated. But as the operation proceeds, water being rendered more scarce, and the temperature rising, the "hydrocarbon," in separating from sulphovinic acid, retains one atom of sulphuric acid, and thus forms the liquid which he designates as oil of wine. These views of Hennel were confirmed by the distillation of sulphovinate of potash and sulphuric acid successively, with and without the addition of water. In the former case, the "hydrocarbon," (etherine) by uniting with a double quantity of water, was productive of alcohol; in the latter, by being supplied with less water, gave rise to ether.

It has been latterly inferred by Berzelius, Dumas, and others, that the common base of alcohol, and of all ethers, is not olefiant gas, but a substance with which that gas is polymeric.* I mean the principle above alluded to, called hydrocarbon by Hennel, and by Berzelius, etherine.

It appears that etherine has a basic affinity for acids, and for water acting as an acid. Berzelius conceives that an atom of etherine combined with two atoms of water, forms alcohol; while with one atom of water, it forms sulphuric ether.

When the resulting compound of an acid with etherine is more volatile than any other combination which can be generated by the materials subjected to the process of etherification, the acid and etherine combine, constituting an ether which may be separated by distillation. In those cases in which the compound of the acid with the etherine, in alcohol, is not volatile, as in the instance of sulphovinic acid, when the mixture is subjected to heat, the compound is decomposed, the etherine passes over in the first instance, in combination with so much water as will enable it to form the volatile liquid called sulphuric ether. This takes place with sulphuric, phosphoric, arsenic, and fluoboric acid, or probably any other acid, for the distillation of which, a high temperature is requisite. Hence the liquid called sulphuric ether, consisting of two atoms of etherine, and one of water, is generated, not only by the acid after which it is named, but likewise by others having a strong affinity for water. But when during the ordinary process for sulphuric ether, in consequence of the proportion of water being diminished, the temperature of the mixture reaches a certain point, the acid, if sufficiently vaporizable, may begin to come over in combination with etherine, forming, in the case of sulphuric acid, an oleaginous liquid called oil of wine by Hennel.

If with alcohol and sulphuric acid, a more volatile acid be distilled, it passes over usually in union with the etherine, constituting a peculiar ether.

Each of the other liquids to which the name of ether is applied in conjunction with that of an acid, consists of etherine and the acid whose name it bears. Hennel's oil of wine, consisting of etherine and sulphuric acid, agrees with the other "*acid*" ethers in composition and in properties, being at least as etherial as benzoic, oxalic, or tartaric ether, or other compounds which bear the name. It is therefore, as I conceive, both in qualities and in composition, entitled to be considered as sulphuric ether, while the liquid heretofore called by this name, should, as already stated, be designated as hydric ether.

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* See page 234, Compendium.

OF THIALIC ETHER, AND OF MERCAPTAN AND MERCAPTUM.

By the reaction of the sulphovinates with the bisulphide or the sulphydrate of barium, Zeisse has obtained two volatile liquids, one of which he calls thialic ether, the other mercaptan (from corpus mercurium captans) on account of its singularly energetic reaction with the bioxide and bichloride of mercury. Mercaptan appears to consist of one atom of etherine, and two atoms of sulphydric acid. In reacting with the bioxide or bichloride of mercury, yielding an atom of hydrogen, and receiving an atom of metal, it is converted into a compound called by Zeisse a mercaptide, and which is considered by him as consisting of mercaptum, a principle which has never been isolated, and the metal. Mercaptum is capable of combining with other metals, gold and platina for instance. The resulting combinations are called by their discoverer mercaptides.

Mercaptan consists of $C^4\ H^6\ S^2$, and is consequently equivalent to $C^4\ H^4 + 2\ H\ S$.

It appears to me that there is this analogy between mercaptan, alcohol, and sulphovinic acid, that each consists of etherine united to two atoms of an appropriate acid. Alcohol is a bihydrate, sulphovinic acid a bisulphate, and mercaptan a bisulphydrate of etherine. When mercaptan reacts with a metallic oxide, one atom of its hydrogen forms water with the oxygen, while an atom of its sulphur converts the metal into a sulphobase. Consequently the formula of the mercaptide of mercury should be $Hg\ S + C^4\ H^4 + H\ S$, which would make it equivalent to a sulphydrate of etherine and mercury.

This explanation is consistent with that given by Zeisse, but it appears to me that in reacting with a bioxide or bichloride, two atoms of mercaptan must be decomposed, and a compound formed, represented in composition by the following formula: $Hg\ S^2 + 2\ E + 2\ H\ S$.

Mercaptan is a colourless etherial liquid, with a peculiarly penetrating odour, and a sweet etherial taste. Its specific gravity is 0.842, and its boiling point is about 144°.

By its properties and composition, independently of its reaction with metals, it seems entitled to be classed with the other etherial compounds of etherine, as bisulphydric ether.

OF THE ACID COMPOUNDS OF ETHERINE.

It has been already stated that etherine forms two compounds with sulphuric acid, the oil of wine of Hennel, and sulphovinic acid. Magnus alleges that he has formed two acids which differ in composition from sulphovinic acid, in containing an atom less of water, but are isomeric with each other. One of the acids in question was formed by the addition of anhydrous sulphuric acid to alcohol.

The production of a liquid identical in properties with sulphuric ether, by the reaction of phosphoric acid with alcohol, has been mentioned. Pelouze has ascertained that during this process an acid analogous to the sulphovinic is produced, which he calls phosphovinic.

Dumas and Boullay have ascertained that by passing a current of ammoniacal gas through oxalic ether, an acid is produced, which unites with the ammonia. To this acid they have given the name of oxalovinic.

LIST OF THE NAMES AND COMPOSITION OF THE COMPOUNDS OF ETHERINE.

	Etherine (oil of wine)	$= 4\,C + 4\,H = E.$
	Sulphuric ether	$= E + \dot{H}.$*
	Alcohol	$= E + 2\,\dot{H}.$
	Sulphate of etherine, (oil of wine containing sulphuric acid)	$= 2\,E + 2\,\dddot{S} + \dot{H}.$
Sulpho-vinic acid,	According to Berzelius	$= E + 2\,\dddot{S} + \dot{H}.$
	According to Magnus	$= E + 2\,\dddot{S} + 2\,\dot{H}.$
	The two isomeric acids discovered by Magnus	$= E + 2\,\ddot{S} + \dot{H}.$
Phospho-vinic acid,	According to Pelouze	$= E + \overset{.....}{\underline{P}} + 2\,\dot{H}.$
	According to Liebig	$= E + \overset{.....}{\underline{P}} + \dot{H}.$
	Oxalovinic acid, probably	$= E + 2\,\dddot{\underline{C}}.$†
	Nitric ether‡	$= E + \dddot{N} + \dot{H}.$
	Oxychlorocarbonic ether	$= E + \underline{C}\,Cl\,O^3 + \dot{H}.$
	Oxalic ether	$= E + \dddot{\underline{C}} + \dot{H}.$
	Benzoic ether	$= E + \dot{Bz} + \dot{H}.$§
	Acetic ether	$= E + \overline{A} + \dot{H}.$‖
	Formic ether	$= E + \overline{F} + \dot{H}.$
	Tartaric ether	$= E + \overline{T} + \dot{H}.$
	Citric ether	$= E + \overline{C} + \dot{H}.$

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* The student is reminded that each dot over a symbol signifies an atom of oxygen. Hence $\dot{H}$ stands for water, $\dddot{S}$ for sulphuric acid, $\dddot{N}$ for hyponitrous acid, $\overset{.....}{\underline{P}}$ for phosphoric acid; the dash under the letter, representing a double atom of phosphorus, the five dots over it, five atoms of oxygen.

† Dumas and Boullay, the discoverers of this acid, do not seem to have ascertained the quantity of water which it contains.

‡ More properly hyponitrous.

§ Bz has been assumed as the symbol for benzule, the radical of benzoic acid.

‖ It will be seen, that following the plan of Berzelius, I have adopted the initial letter with a dash *over* it, as the symbol for each of the vegetable acids.

Malic ether $= E + \overline{M} + \dot{H}$.

Chlorine ether $= E + Cl$.

Bichlorine ether $= E + 2\,Cl$.

Perchlorine ether $= E + 4\,Cl$.

Sulphocyanic ether, probably $= E + S^2 C^2 N$.

Chlorohydric ether $= E + H\,Cl$.

Iodohydric ether $= E + H\,I$.

Bromohydric ether $= E + H\,Br$.

Mercaptan $= E + 2\,H\,S$.

OF PYROACETIC AND PYROXYLIC SPIRIT.

During the distillation of acetic acid from the acetates, they are partially resolved into a carbonate which remains in the retort, and a limpid, volatile, inflammable liquid, called pyroacetic spirit.

The formula of acetic acid being $C^4 H^3 O^3$
deducting that of carbonic acid $C \; O^2$
we get the liquid in question, of
which the formula is $C^3 H^3 O$.

Pyroxylic spirit is alleged to be a product of the distillation of wood. It is a transparent, colourless, inflammable, volatile liquid, with a pungent etherial smell. It consists of the same elements as the last mentioned compound, but in what proportion is unknown.

OF THE ACETOUS FERMENTATION.

It is well known that liquors produced by the vinous fermentation, are liable to acidity. The term vinegar, and especially the French word "vinaigre," from which it is derived, sufficiently implies the origin of this useful and well known acid, and of its appellation. The process during which this acid is produced, in vinous liquors, is called the acetous fermentation.

Alcohol, per se, is not liable to be acidified; but with the addition of water and fermentable matter, may be converted into vinegar.

It is alleged, that the strongest liquors make the strongest vinegars; yet it is certain that the acetous fermentation may be antecedent to the vinous, at least to a limited extent. When distillers are not careful to preserve their mashing vessels free from sour matter, left from previous operations, it is well known that their wash becomes sour, and that the product in alcohol is proportionably lessened. Vegetable infusions often become sour, when there has been no intervening indication of the vinous fermentation.

OF ANIMAL CHEMISTRY.

Ultimate analysis, in the case of animal, as well as in that of vegetable matter, has a tendency to confound substances extremely different in their nature. Hydrogen, oxygen, carbon, and nitrogen, are the elements of the most nutritive and the most poisonous animal principles; of the milk of the cow, and the venom of the viper. Our wonder, on observing this similitude in the composition of substances, in their nature so discordant, is however, increased, when we learn that the carbonization of our own blood, in contact with an alkali, is productive of a principle, which, united to one of the elements of water, forms the deadly prussic acid.

When on the subject of acidity, I suggested, that the occult causes of galvanic polarities, might give rise to a corresponding variety in the quantity, and proportions, of caloric, light, and electricity, in combination with ponderable matter; and thus create the astonishing diversity, observed in the properties of substances, whose ponderable elements are nearly, if not exactly, the same, and in like proportion.

It may be conjectured, that there are a great many modes in which the particles of caloric, light and electricity, may unite with each other; and in which, by subsequent combination with ponderable matter, they may vary its properties. If the light, emitted by a few atoms of tallow, burning in a candle flame, be competent to produce vision in many hundred millions of eyes, may we not suppose, that this subtile fluid, and the kindred principles of caloric and electricity, may have other means of affecting the animal nerves?

Whatever may be the cause, there is an analogy between the effects of an animal gland, and the Voltaic circuit. Within the influence of either, the affinities which prevail, under ordinary circumstances, give place to others, which are productive of new combinations. This demonstrates, that, although all matter may invariably exercise attraction of gravitation, yet the elective affinity, which gives rise to changes, both within and without the precincts of vitality, may be adventitious, and dependent on occult and complicated contingencies.

By the digits, by the eight notes in music, or by a few beads in the kaleidoscope, an almost infinite variety of combinations may be produced, each affecting the senses differently. It cannot, then, be surprising, that consequences, no less various, should, in the case of the vegetable and animal creation, arise, from a limited number of elementary principles.

Effects of Ignition on Animal Matter.

The only difference between the results of the destructive ignition of animal and vegetable matter, is, that the prevalence of nitrogen, in the former, renders this substance, or its combinations in ammonia or prussic acid, the frequent products of the decomposition of animal substances; and that the charry residuum, of this decomposition, is much more difficult to incinerate.

Peculiarities in the Composition of Animal Matter.

In the state of subphosphate of lime, bones contain a larger proportion of calcium and phosphorus, than exists in any vegetable product; and sulphur is evolved, far more copiously, during the spontaneous decomposition of flesh, than from vegetable matter under the same circumstances. Hence the smell of sulphydric acid attendant on animal putrefaction.

OF ANIMAL SUBSTANCES, WHICH ARE NEITHER OILY, ACID, NOR RESINOUS.

OF FIBRIN.

Fibrin exists in chyle and in blood, and forms the principal part of muscular flesh. It is, therefore, the most abundant animal substance.

To obtain fibrin, Thenard advises, that blood, as it flows from a vein, should be beaten with a handful of birch twigs. Each of these will become loaded with a number of long red filaments, which, by washing in cold water, are whitened and purified.

Fibrin is solid, white, insipid, inodorous, heavier than water, neither acid nor alkaline; while wet, elastic, when dry, hard and brittle, becoming of a yellowish hue. In its natural state, it contains four-fifths of its weight of water. By distillation, it yields much carbonate of ammonia, and a very bulky shining charcoal, which it is difficult to burn; but which, being burnt, leaves a residuum of the phosphates of lime and magnesia, and of the carbonates of lime and soda. Exposed in an open vessel to the action of water, occasionally renewed, fibrin putrefies, leaving more or less residue, accordingly as it may have been more or less interlarded with fat.

With respect to the action of the acids and alkalies, upon fibrin, it may be sufficient to mention, that in general, it is decomposed by them, when they are concentrated; and dissolved by them, when dilute. Nitric acid, however, even when dilute, decomposes fibrin, causing it to yield nitrogen gas.

The action of concentrated sulphuric acid, upon fibrin, deserves particular notice. When fibrin is subjected to its own weight of this acid, a perfect solution ensues, unaccompanied by any extrication of sulphurous acid. The solution, thus obtained, being diluted with water, boiled nine hours, and the acid saturated with chalk, the resulting liquid, by filtration and evaporation, yields a peculiar white matter, which the discoverer, Mr. Braconnot, has named *leucin*, from λευκος, white.

The symbolic formula for fibrin, is $C^{13} H^{14} O^5 N^3$.

OF ALBUMEN.

Albumen, though not entering so largely, as fibrin, into the animal organization, is more extensively distributed throughout it. United in various proportions with water, and minute portions of saline matter, it constitutes the whites of eggs, whence its name; the serum of the blood; the liquor of the pericardium; or that evolved in dropsy, or by blisters. It is also an ingredient in chyle, and probably, more or less, in all the animal fluids.

According to Berzelius, however, there is a difference between the properties of albumen as existing in the serum of the blood, and in the white of eggs.

Albumen is capable of existing both as a solid and as a liquid, being convertible from the latter, into the former state by heat. The habitudes of solid albumen, with acids or fire are very similar to those of fibrin.

Solid albumen is not soluble in water; hence, to procure it liquid, recourse must be had to it in its natural state of liquidity. In this form, it is sufficiently alkaline to affect tests. Its obvious properties are universally known, as seen in the white of eggs. Exposed in the Voltaic circuit, it coagulates about the wire proceeding from the positive pole.

The phenomenon of the coagulation of albumen by heat, is not well explained. As the addition of an alkali causes it to redissolve, Dr. Thomson suspects its pristine fluidity to be due to the presence of soda. Were his conjecture correct, cold water ought to coagulate it, and heat could not, unless the alkali were volatile.

Albumen forms insoluble compounds, with most of the acids. Hence a very minute quantity of it disseminated in water, may be detected by nitric acid. Neither acetic nor phosphoric acid have this effect, but paraphosphoric acid immediately coagulates albumen. Hence this substance is an excellent test to discriminate between the two last mentioned acids. Albumen is precipitated from blood by acids, and the precipitate redissolves on adding ammonia.

By uniting with the oxides, chlorides, or iodides of the metals proper, albumen precipitates nearly all of them from their solutions. As these precipitates are almost destitute of action on the animal system, albumen has been suggested as an antidote for metallic poisons.

Albumen is an excellent test, and likewise the best antidote for corrosive sublimate. It appears that this bichloride is, by reaction with the albumen, converted into protochloride, or calomel.

Albumen is coagulated by alcohol, and precipitated by tannin. It is of great use in clarifying syrups. By mixing with them, while viscid, it envelops any feculent matter with which it may come in contact; and the union continues until coagulation ensues, and renders it easy to effect a removal of the coagulum. It clarifies wine, in like manner, excepting that the coagulation results, in this case, from the presence of alcohol.

As obtained from blood, or eggs, albumen forms a very tenacious lute, by admixture with hydrate of lime.

The formula representing the composition of albumen, is according to the analysis of Gay-Lussac, and Thenard, $C^{17} H^{13} O^{6} N^{2}$, while that of Prout would make it $C^{15} H^{14} O^{6} N^{2}$.

EXPERIMENTAL ILLUSTRATIONS.

In different vessels, corrosive sublimate and albumen are dissolved in water. The contents of the vessels being mingled, a precipitate appears.

OF GELATIN.

Gelatin, agreeably to Thenard, never makes a part of the animal humours, though solid gelatin is to be found in muscles, skins, cartilages, tendons, and aponeuroses. The membranes yield a great quantity, the bones about one-third of their weight.

According to Berzelius, gelatin never exists ready formed in the bodies of animals, but is produced during the exposure to heat and water which is generally employed to obtain it. He states that this conversion takes place without any perceptible escape of gas, and may be effected in close, as well as in open vessels. The nature of the reaction does not appear to be understood.

It is alleged by the same author, that when a solution of gelatin is kept for some time, at a little below the boiling point, it gradually loses the property of forming a jelly, by refrigeration.

Gelatin displays no acidity, nor does it, like albumen, show any trace of an alkali. It is heavier than water, tasteless, colourless, and inodorous; and its ultimate elements, resulting from fiery analysis, are the same as those of albumen and fibrin. In its habitudes with water, it differs from albumen, being very soluble in boiling water, and difficult to dissolve in cold water. One part, dissolved in one hundred of boiling water, stiffens completely on cooling, and one part, with one hundred and fifty of boiling water, becomes, as it cools, gelatinous.

Several of the salts and acids have the property of precipitating gelatin, but not so unequivocally, as to be good tests of its presence. It is much more soluble in acetic acid, than in water. It is partially precipitated by alcohol, and totally by tannic acid. Alcohol precipitates it by taking away water; tannic acid, by forming an insoluble substance analogous to leather.

Chlorine also produces, with gelatin, a flocky precipitate.

Gelatin is not acted on by alcohol, oils, or ether.

By a process similar to that in which leucin was evolved from fibrin, Braconnot obtained, from gelatin, a peculiar crystallizable sugar, which resembles grape sugar, and yet is not susceptible of the vinous fermentation. It differs from common grape sugar also, in affording ammonia by destructive distillation, which demonstrates that nitrogen is among its constituents.

Gelatin, in the form of joiner's glue, is manufactured for the purposes of the arts, from the clippings of skins, and the ears of animals butchered for the market. These substances being freed from hair and oil, and boiled for a long time, yield a solution of glue; which, when sufficiently concentrated by ebullition, hardens as it cools.

The gelatin of bones may be obtained by the solvent power of water when exalted by heat and pressure, as in the celebrated digester of Papin. Or the phosphate of lime, being removed by chlorohydric acid, the gelatin becomes soluble in boiling water.

Ichthyocolla, or isinglass, is obtained from the air bladder of a species of sturgeon; and inferior kinds, from other parts of the same, or of other fishes. It is the finest specimen of glue or gelatin. The glue from bones, is alleged, by Thenard, to be the next best in quality, and is now obtained extensively in France.

Gelatin is the principal ingredient in soup. Hence, by evaporation, soup may be reduced to the consistence of a glue, which comprises, within a very small space, the materials for regenerating, with the aid of hot water, the soup from which it was obtained. In the indurated state to which I have alluded, gelatin has been sold under the name of portable soup. Calf's foot jelly consists principally of gelatin.

Agreeably to the analysis of Gay-Lussac, and Thenard, the composition of gelatin differs from that of albumen, in containing about five per cent. less carbon, and between three and four per cent. more oxygen.

EXPERIMENTAL ILLUSTRATION.

A solution of tannic acid being poured into a solution of glue, or ichthyocolla, a precipitation ensues.

OF CASEUM.

This appellation has been given by Braconnot, to the curd obtained from milk by the rennet, which appears distinct in its properties from any other animal substance.

Agreeably to the observations of Proust, caseum is capable of undergoing a species of fermentation, by which it is partially converted into two substances, which he designates as caseous oxide, and caseous acid, and to which he ascribes the agreeable flavour of cheese, when sufficiently old.

Caseous oxide, and caseous acid, were also supposed to be produced by the fermentation of gluten.

According to Braconnot, the insolubility of caseum in the state in which it is generally known, is dependent on the presence of some foreign body, generally an acid or earthy salt. As it exists in cheese, it is combined with acetic and lactic acid. From these acids it may be separated by boiling the cheese in water, and adding a solution of bicarbonate of potash to the coagulated mass, which is not taken up by the water. An effervescence occasioned by the escape of carbonic acid gas takes place, and a solution of the percaseate of potash is obtained. This solution by evaporation yields a substance resembling fish glue, which may be kept for a great length of time without undergoing any change. Mr. Braconnot, conceives that this percaseate would prove very valuable for food, especially during long voyages, since by dissolving it in water, with the addition of a little sugar and butter, or even without this latter substance, it would be a tolerable substitute for milk.

By adding diluted sulphuric acid to the solution of caseate of potash, an insoluble sulphate of caseum is precipitated.

A solution of caseum may be obtained from this, by the addition of an aqueous solution of carbonate of potash, just sufficient to saturate the sulphuric acid which liberates the caseum, and enables it to combine with water. By pouring into this solution about its own weight of alcohol, a small portion of the caseum, together with the sulphate of potash, and other impurities, precipitate, while the remainder of the caseum continues dissolved in a state approaching nearly to purity, though still retaining a small portion of potash.

According to Braconnot, pure caseum, when dry, resembles gum arabic in appearance, and in its solubility in water. It acts both as an acid and a base, since it reddens litmus paper, and forms combinations with the alkalies which are soluble in water, while its compounds with acids are insoluble in that liquid.

Braconnot has alleged that caseous oxide, for which he has proposed the name of aposepidine, may be produced by the putrefaction of any animal substance. The same chemist has denied that the substance called caseous acid, is deserving of this name. He conceives it to be a mixture of caseous oxide with various substances, and an oil, to which he attributes the pungency of old cheese.

Aposepidine, according to Braconnot, is inodorous, nearly insipid, crystallizable, and soluble in water, especially when hot.

OF MUCUS.

The term mucus, in an enlarged sense, is applied to a fluid which lubricates the mouth, œsophagus, stomach, intestines, and other passages of the body. It differs from albumen, in not being liable to coagulation: nor does it gelatinize by concentration. Neither tannic acid nor corrosive sublimate affect it. Subacetate of lead renders its solution opake, and afterwards causes a precipitation.

Agreeably to the opinion of Berzelius, mucus should be considered as a generic appellation, designating several species, of which the chemical qualities vary with the animal functions in which they are employed.

OF UREA, OR THE CRYSTALLIZABLE MATTER OF URINE.

A substance exists in the urine of animals, to which the appellation of urea has been given.

Urine is evaporated to the consistence of syrup, by a very delicate management of fire. When quite cold, nitric acid is to be added by little and little. The mixture is to be agitated, and placed in an ice bath to congeal; when a crystalline combination is formed by the acid and the urea. The crystals thus procured, are to be washed with ice-cold water, and cleansed by allowing them to drip, and pressing them between the folds of blotting paper. The nitrate of urea thus obtained, is afterwards redissolved, mingled with charcoal, strained from the charcoal, and decomposed by subcarbonate of potash. The resulting solution, being evaporated to dryness, is treated with very pure alcohol, which takes up nothing but urea, and, by concentration, affords it in pure crystals.

It is to the presence of this substance, that urine owes the power of yielding carbonate of ammonia, by distillation.

Urea is nearly inodorous, but when tasted, causes a sensation of coolness similar to that produced by nitre. It is very soluble in water, and crystallizes in transparent colourless prisms. It appears in some cases to act as a base, since it combines both with nitric and oxalic acid.

It has been mentioned, page 242, that urea consists of $C^2 N^2 O^2 H^4$. Its elements are therefore, in the proportion requisite to form an atom of cyanic acid, an atom of ammonia, and an atom of water.

When the vapour of hydrous cyanic acid is brought into contact with gaseous ammonia, the acid and alkali unite, forming a cyanate of ammonia, which contains probably an atom of water. When a solution of this cyanate is evaporated, or when the cyanate itself is exposed to the air, ammonia is evolved, and urea remains. It is, therefore, probable, the cyanate of ammonia, obtained as abovementioned, is a dicyanate, consisting, as this name implies, of one atom of acid, and two of ammonia. By parting with one atom of ammonia, it is therefore reduced to the state of a neutral cyanate, identical in composition and properties with urea.

Urea may also be obtained by decomposing the cyanate of lead by ammonia. In this case it is probable that the cyanate of ammonia is at first formed, and immediately afterwards resolved into urea.

The following formulæ show the identity of the composition of urea, and cyanate of ammonia when containing an atom of water.

Urea, $C^2 N^2 O^2 H^4$.

Cyanate of ammonia, $N C^2 O + N H^3 + H O$.

OF ANIMAL SUGAR.

Sugar is an animal, as well as a vegetable, product. Milk whey, evaporated to dryness, and subjected afterwards to water, the resulting solution being clarified by albumen, and concentrated by evaporation, yields a species of saccharine matter, in crystals, called sugar of milk. It differs from common sugar, in being much less soluble in boiling water, and in not being fermentable.

The Tartars are said to ferment the milk of their mares, and thus to convert it into an intoxicating liquor; yet, in this process, the sugar of milk is alleged to have no participation. The fermentation of milk is not found to lessen the quantity of the sugar.

Diabetic sugar, according to Dr. Henry, is crystallizable, and more analogous to that of vegetables, than to the sugar of milk.

OF ANIMAL RESINS.

Under this head, the resin of bile, ear-wax, ambergris, and castor, are placed.

OF THE RESIN OF BILE.

By adding one part of chlorohydric acid to thirty-two parts of ox bile, a resinous matter is dissolved, and by subsequent filtration and evaporation may be isolated. It melts at about the same heat as spermaceti. It is soluble in water, as well as in alcohol, and is of course deficient in a very essential characteristic of resinous substances.

It is alleged, that this resin is to be considered as the cause of the smell; and, in great measure, of the colour and taste of the bile.

OF CERUMEN, OR EAR-WAX.

According to Henry, it melts at a gentle heat, sinks into paper like oil, is very combustible, burns with a white smoke, emitting an ammoniacal odour, and leaving little charcoal. With water, it forms a sort of emulsion. Alcohol dissolves five-eighths of it, and the remainder has the properties of albumen. The residue of the solution in alcohol, after the evaporation of this solvent, resembles the resin of bile.

OF AMBERGRIS.

This substance is found, floating on the sea, within the tropics. Its origin is not well known, though it is supposed to be produced by the whale. It is not strictly a resin. Alcohol extracts from it a peculiar substance, called ambrein, which is analogous to cholesterin, a substance obtained from biliary calculi.

OF CASTOR.

Castor is found (in two small bags) in the inguinal regions of the beaver. It contains a substance analogous to the resin of bile.

OF ANIMAL OILS, OR FAT.

Fat differs from oil only in consistency. Tallow, lard, and all the other varieties of fat, may be considered as concrete oils.

Chemically, there is little difference between vegetable and animal oils. In neither is nitrogen a constituent, and in both, hydrogen and carbon are the predominant elements, oxygen being an ingredient only in a small proportion.

Animal oils are generally less disposed to fluidity than vegetable oils; yet, like these, they consist of a less fusible oil, called stearin, and of a more fusible oil, called elain, into which they are liable to be separated by means of alcohol or cold.

From the cranium of the spermaceti whale, three oleaginous substances are obtained; one harder than tallow, and called spermaceti; the others known in commerce as winter and summer strained oils. As, in very cold weather, the latter becomes concrete, the former is, under such circumstances, strained from it. Winter strained oil is the elain of the fat of the whale.

OF BUTYRIN, PHOCENIN, AND HIRCIN.

These appellations have been given to three peculiar oils; the first discovered in butter, the second in the oil of the porpoise, the third in the fat of sheep or goats.

Butyrin fuses at 70°.

It has already been mentioned, that during the process of saponification, oils are acidified; the resulting acids uniting with alkalies, and forming soap. In the case of animal oils, margaric, stearic, and oleic acids, are usually produced; but that other acids are produced in particular instances, will appear from the list I shall give of acids generated from animal substances.

Composition of Whale Oils.

Train oil, according to Dr. Thomson, consists of carbon 12 atoms, oxygen 2 atoms, hydrogen 17 atoms. Agreeably to the same author, spermaceti oil consists of carbon 10 atoms, oxygen 1 atom, hydrogen 9 atoms.

OF GLYCERIN, OR THE SWEET PRINCIPLE OF OILS.

This is a transparent, colourless, inodorous, tasteless, inflammable liquid, soluble in water, which is evolved from vegetable and animal oils, during saponification.

By nitric acid, it may be converted into oxalic acid. By sulphuric acid, it may be made to yield sugar, as fecula does under the same circumstances.

OF ADIPOCIRE.

On opening a grave at Paris, in which a large number of human bodies had been buried for many years, they were found to consist of a substance resembling spermaceti, to which the name of adipocire was given. It was afterwards found, that by exposing muscular flesh to running water, or nitric acid, adipocire might be produced; and it was generally supposed to arise from a transmutation of fibrin. Gay-Lussac subsequently expressed the opinion, that adipocire is derived entirely from fatty matter, previously existing in the flesh, the fibrin being removed by putrefaction.

Chevreul has since alleged, that the substance in question, is a soap consisting of ammonia, potash, and lime, united with margaric acid in excess.

The quantity of adipocire stated to have been found in the grave at Paris, appears to me to have been much greater, than can reasonably be ascribed to the fat of bodies, a majority of which must have been emaciated by disease.

Besides, a case was noticed by Dr. Thomson, in which the flesh of a woman, buried in "a moss" in Scotland, for more than 130 years, was chiefly converted into adipocire.

Synthesis of Oil.

It is well known, that when oils are subjected to the temperature of ignition, they are resolved into certain aeriform substances. The converse of the change thus effected, was accomplished by Berard. One volume of carbonic acid, ten volumes of carburetted hydrogen, and twenty volumes of hydrogen, being mixed and passed through a red hot porcelain tube, a deposition of white crystals took place, which were lighter than water, soluble in alcohol, and fusible, by heat, into a liquid resembling a fixed oil.

By Dobereiner, a similar result is said to have been obtained, by subjecting coal gas, and aqueous vapour, to the temperature of ignition.

OF ANIMAL ACIDS.

Johnson, in his Report for 1832 to the British Association, gives a list of twenty animal acids. Some others are mentioned, under this head, by distinguished authors, to which he does not allude. Also there are several acids, which, although existing in animal substances, or produced from them, are classed with the vegetable or inorganic acids, as having been originally detected in vegetables or inorganic bodies. Yet notwithstanding this formidable list of acids, there are very few treated of under the head of animal chemistry, to which I should deem it expedient to require the attention of the student.

The most interesting among the acids which are found in animals, are the sulphuric, chlorohydric, phosphoric, and acetic acids.

These have been sufficiently noticed under the head of inorganic or vegetable chemistry. Uric acid, which is an excrementitious animal product, is an object of interest as the most frequent constituent of urinary concretions. The rosacic and purpuric acids derive some importance from their association with uric acid.

Butyric acid has pretensions to notice as existing in a small proportion in butter.

It has been mentioned that the margaric and oleic acids are produced during saponification. They exist also in adipocire.

Sulphocyanhydric acid, though not mentioned among animal acids by Thenard, is said to exist in saliva.

The *amniotic* acid is found only in the liquor of the amnios of the cow. Benzoic acid has been detected in some kinds of urine. The formic acid exists in ants. Almost all the other acids are produced either by heat, by the action of nitric acid, or that of the fixed alkalies upon animal matter, and have been applied to no useful purpose, if we except the acids formed with cyanogen. These have been sufficiently dwelt upon, in another part of the Compendium. See pages 242 and 244.

I subjoin a list of the animal acids, the substances from which they are produced, and the agents in their production.

Names.		*Sources.*	
Uric	acid	from certain urinary calculi.	
Delphinic	,,	from the fat of the dolphin.	
Ceric	,,	by distilling a wax soap with sulphuric acid.	
Cetic	,,	by saponifying spermaceti.	
Ambreic	,,	by treating ambreine with	Nitric acid.
Castoric	,,	by treating castorine with	
Purpuric	,,	from uric by the action of	
Saccholactic Saclactic or Mucic	,,	from sugar of milk by	
Cholesteric	,,	from cholesterin by	
Hippuric	,,	from the urine of graminivous animals.	
Lactic	,,	from sour milk, or the fermented juice of beets.	
Formic	,,	from ants, or alcohol sulphuric acid and manganese, by distillation.	
Allantoic	,,	from the liquor of the allantois of the cow.	
Margaric and Stearic	,,	from stearin by	the action of potash.
Oleic	,,	from elain by	
Phocinic	,,	from an oil of the dolphin by	
Butyric, Caproic, and Capric	,,	from butter by	
Hircic	,,	from fat of the sheep or goat by	
Sebacic	,,	from suet or lard by heat.	

OF URIC ACID.

Uric acid constitutes the deposition from certain urines under the form of a yellow powder, which attaches itself so firmly to the recipient, as to be removed with difficulty, even by friction: and all those calculi, or those layers in calculi, which are yellowish, and of which the powder resembles sawdust, are formed of it. The white, in the excrement of birds, consists likewise of the acid in question. It has been found in cantharides, in the excrement of the silk worm, and, in large quantities, in that of the eagle and boa constrictor, united to ammonia. Combined with soda, it forms arthritic concretions.

It is procured by treating the sediment of urine, the yellow urinary calculi, or the excrements containing it, with a solution of potash in excess, and adding chlorohydric acid to the resulting liquid. This acid neutralizing the alkali, the uric acid dissolved in it, is precipitated in flocks which, after a time, are changed into brilliant plates. This precipitate is to be washed upon a filter with water, till the washings are not rendered turbid by nitrate of silver, and afterwards gently dried.

Of the Properties of Uric Acid.

Obtained by the process above mentioned, uric acid is a tasteless, inodorous, yellowish-white powder, insoluble in alcohol, slightly soluble in hot water, and requiring, of this last mentioned liquid, at 60°, ten thousand times its weight for solution.

The compounds which it forms with the earths and alkalies, may be decomposed by almost all the acids, even by carbonic acid. It has scarcely any effect upon litmus.

Uric acid dissolves in nitric acid, and yields, by evaporation to dryness, a residuum of a purple colour.

The composition of uric acid, according to the recent analysis of Liebig, is $C^5 N^2 H^2 O^3$. Thomson, however, supposes that the hydrogen, and two atoms of the oxygen, are due to the presence of water, and that uric acid, when *anhydrous*, is destitute of hydrogen, and contains but one atom of oxygen.

Wohler has shown that the acid obtained from uric acid by heat, and heretofore designated by the name pyro-uric, is, in fact, cyanuric acid. See page 242.

OF PURPURIC ACID.

An acid is produced by the reaction of nitric with uric acid, which was called purpuric, as it was supposed to give rise to the purple colour which has been mentioned as a mean of detecting uric acid.

OF ROSACIC ACID.

The lateritious sediment obtained from the urine in certain cases of disease, has been alleged to contain an acid called rosacic, from its rosy colour.

It appears, however, to be now generally admitted, that the acid called rosacic, consists of uric acid modified by the presence of some foreign body.

OF LACTIC ACID.

To the acid of sour milk, the appellation at the head of this article has been given, from *lac*, the latin for milk. This acid is generated by the fermentation of rice water, beet juice, or an infusion of nux vomica. It acts upon iron and zinc, causing the evolution of hydrogen. I believe this acid was first distinguished as peculiar by Berzelius. Subsequently, it was by many chemists considered as acetic acid disguised by the presence of some foreign matter; but Gay-Lussac, and Pelouze, have recently shown by an elaborate examination, that it is a peculiar acid.

It presents the singular phenomenon of an organic acid, not only capable of existing in the anhydrous state, but also of crystallizing in that state, while when combined with water, it does not crystallize.

The formula of the uncrystallizable hydrous acid, is $C^6 H^4 O^4 + 2 HO$; that of the crystallizable anhydrous acid, $C^6 H^4 O^4$.

OF FORMIC ACID.

Formic acid was originally obtained from ants. It appears to exist in them naturally.

Formic acid has been resolved into carbonic oxide and water, by Dobereiner. The synthesis of this acid has been effected by this chemist, by distilling crystallized tartaric acid, with sulphuric acid and black oxide of manganese.

Formic acid may be obtained by adding to one part of sugar in an alembic, three parts well pulverized peroxide of manganese, and three parts of sulphuric acid diluted with its weight of water. The acid should be added in three successive portions. At first, the effervescence is so great as to require the vessel to have fifteen times the capacity which would be necessary to contain the materials when quiescent. The formic acid associated with formic ether, is brought over by distillation. It may be saturated with chalk or an alkali, and the resulting formiate decomposed and isolated by distillation with ten parts by weight of sulphuric acid, diluted with four of water.

Dobereiner alleges that formic acid, and formic ether, highly merit the attention of physicians and chemists. He represents this acid as an excellent reagent for separating the noble metals from solutions in which they are intermingled with other metals proper. If a solution, containing one or more noble metals, be elevated nearly to the temperature of ebullition, on adding an alkaline formiate, the noble metals will be immediately and entirely precipitated in a very minute state of division. At the same time, by ascertaining the weight of the gas simultaneously evolved, that of the metal thrown down may be determined.

From its solution in water, the bichloride of mercury is converted into calomel with so much facility, and in a state of division so perfect, by formic acid, or formiate of soda, that Dobereiner recommends their employment in the preparation of that protochloride.

If the same quantity of sulphuric acid and manganese be mingled with six parts of alcohol, the process being in other respects the same as that for formic acid above described, formic ether becomes the predominant product. It is freed from formic acid by magnesia, from alcohol by a small quantity of water, and from water by chloride of calcium. By a more extensive contact with water, formic ether is decomposed, and alcohol and formic acid are generated.

Formic acid has a pungent taste, and a peculiar sharp odour. It is composed of $C^2 H O^3$.

OF THE BLOOD.

From the proximate elements of animal matter, we proceed to treat of the more complex substances into which such elements enter as ingredients. Among these, blood is pre-eminently important. The properties of blood are well known. Within the sphere of vitality it is always fluid. Its colour is bright red in the arteries, and dark red in the veins. Its taste is saltish, and its smell faint.

The specific gravity of human blood is 1.0527; that of ox blood 1.056.

In the state in which it exists in the veins and arteries, blood consists of albumen, fibrin, and small portions of various salts, of a multitude of minute red globules, and a liquid nearly colourless, in which the other ingredients are dissolved or suspended. Although too minute to be distinguished by the naked eye, the globules have been ascertained, by the aid of the microscope, to be constituted of a nucleus of fibrin surrounded by a colouring matter, to which the name of hematosin has been given. In order to obtain hematosin, Berzelius recommends that the crassamentum previously cut into thin slices, and subjected to pressure between the folds of blotting paper to free it from serum, should be agitated in water. By these means a solution of the hematosin is obtained, from which it may be separated in the solid state by evaporation.

Hematosin appears almost black when in mass, but becomes red by pulverization. In properties and chemical composition it agrees nearly with albumen, being coagulated and rendered insoluble by heat, and consequently precipitated from its solutions. Nevertheless it differs from the last mentioned principle in containing a minute quantity of iron.

The colour of the blood was, at one time, ascribed to subphosphate of iron dissolved in the serum by means of an alkali. Subsequently this explanation was found to be erroneous, and Brande adduced some striking facts in favour of the opinion that the matter in question, like vegetable dyes, owes its colour to unknown causes. It was afterwards discovered by Englehart, that although iron exists neither in the fibrin nor serum of the blood, it is associated with the red globules. This he proved, not only by demonstrating its existence in the products of their incineration, but by passing chlorine through a solution of them, by which means a modification ensued, which rendered the iron susceptible of detection by the usual tests. Englehart also ascertained that from a liquid containing albumen and other soluble animal substances, oxide of iron cannot be precipitated by the alkalies, sulphydrate of ammonium, or an infusion of galls.

It was suggested by Dr. Turner, that the colouring matter of the blood might be sulphocyanide of iron; but in the last edition of his chemistry, he appears to have abandoned that idea, and to lean to the opinion of Brande, above mentioned, principally upon the ground that the iron forming only $\frac{1}{200}$ of the weight of the hematosin, must be inadequate to produce the striking red colour of the liquid in question. Considering the wonderful influence of minute portions of matter, and especially of sulphocyanide of iron in affecting the colour of bodies, I am not convinced of the insufficiency of the iron in the globules to produce their hue.

It has been stated that the colour of the blood is of much brighter red in the arteries than in the veins. This difference has been ascribed to its exposure to oxygen in the lungs, and consequent decarbonization. Lately Dr. Stevens has alleged that the colour of hematosin is naturally dark, but is rendered darker by acids; while by salts it is reddened; that the florid hue of arterial blood is due to saline matter dissolved in the serum; and that the dark colour acquired in the veins arises from carbonic acid. The observations of Dr. Stevens have been so far confirmed by those of Dr. Turner, as that a portion of a coagulum of arterial blood, deprived of its serum, and the saline matter associated with it, acquired the appearance of venous blood; but recovered its florid colour when restored to its serum, or when immersed in a solution of bicarbonate of soda. These facts, if confirmed, must awaken much attention, but unfortunately do not diminish our theoretic ignorance, since the influence of the saline matter and acids on hematosin, is anomalous and inexplicable.

Blood, after its removal from the animal, is gradually resolved into two portions, one of which, called the serum, is a transparent fluid of a pale yellow colour, while the other is solid, and retains the red colour of the blood, being called the crassamentum or clot. Of this phenomenon no satisfactory explanation has been given.

The crassamentum is composed chiefly of fibrin mixed with hematosin to which it owes its colour.

The serum consists of water, holding albumen and small portions of various salts in solution, and like other fluids containing that principle may be coagulated by heat, and then yields a liquor called the serosity, which, according to Berzelius, consists of water, holding in solution, albumen, soda, the chlorides of sodium, and potassium, lactate of soda, and a peculiar animal matter with a trace of phosphoric acid.

Potash and soda diminish the tendency of the blood to coagulate, while acids hasten it. The alkalies act, by rendering the fibrin more soluble, the acids, by coagulating the albumen.

Almost all metallic salts, excepting those of the alkalies and earths, produce a precipitation in blood, in consequence of an affinity which exists between albumen and oxides, chlorides, and acids. Alcohol, by taking hold of the water, precipitates all the other matter.

OF CHYLE.

Chyle resembles blood in resolving itself into a coagulum, and a liquid like serum, but which, according to Dr. Prout, consists partly of albumen, and principally of "*incipient albumen*." The coagulum, according to Vauquelin, is an imperfect fibrin; but Brande considers it as more allied to caseous matter.

The opinions of Prout and Vauquelin derive support from the consideration that, as chyle is destined to become blood, it may be reasonably expected to contain the principal constituents of that liquid, in a state advancing towards maturity.

OF RESPIRATION.

Respiration, so far as it is dependent upon mechanical principles, was sufficiently explained under the head of atmospheric pressure. Chemistry informs us, that, during this process, a portion of oxygen gas disappears, and is replaced by carbonic acid, varying in quantity with the season, or time of day, in which the observation may be made, and with the nature of the animals whose breath may be analyzed. In the case of the human species, the quantity is nearly adequate to compensate the diminution of oxygen; while in that of some animals, it is stated to be little more than half as much.

The observations which have been made respecting nitrogen, have shown that the influence of respiration on the quantity of that gas, in the breath, is variable. In air respired by different animals, and even by the same animal at different periods, the proportion of nitrogen has sometimes been found unaltered, sometimes greater, at other times less, than before respiration.

It has been generally supposed that the oxygen of the air drawn into the lungs, is converted into carbonic acid, by uniting with carbon presented to it by the blood, and that, if the nitrogen be increased or diminished, it is in consequence of a corresponding exhalation, or absorption of this gas, by the same liquid. Yet experimental evidence, and plausible arguments, have been adduced by Dr. Edwards, in favour of the opinion, that an absorption of oxygen and nitrogen, and an evolution of carbonic acid and nitrogen, are simultaneously effected in the lungs. He supposes, that the oxygen, being absorbed by the arterial blood, passes into the circulation, and is gradually carbonized; and that returning with the venous blood into the lungs, it is evolved in the state of carbonic acid. Nitrogen is conceived to be in like manner absorbed, carried into the circulation, and evolved again; the quantity evolved, being sometimes greater, sometimes less, than that absorbed; and at other times, just equal to it.

It has been ascertained that, during the union of carbon and oxygen, as much heat is evolved, as will thaw ninety-six times the weight of the carbon, in ice. During 24 hours, a man has been estimated to emit as much carbonic acid, as would require for its formation nearly 11 ounces of carbon, and consequently the emission of as much heat as would thaw 66 pounds of ice.

Considerations similar to these, led Black, Lavoisier, Crawford, and others, to view the carbonization of oxygen gas in the air, breathed by animals, as the only source of animal heat. This opinion appeared afterwards to be invalidated by the allegations of Mr. Brodie, that in animals recently killed, refrigeration could not be retarded by sustaining their respiration artificially.

The observations of other physiologists have not confirmed those of Brodie. Besides, it has generally been considered incredible that the carbonization of oxygen should not cause the extrication of heat within, as well as without the precincts of vitality. Nevertheless, a series of very accurate experiments, made by Dulong, demonstrates that more heat is evolved by animals, than would be afforded by the combustion of the carbon imparted by them to the air. The animals subjected to observation by this philosopher, were placed in a vessel surrounded by water, so that the whole of the heat generated by them, could be known; while by means of an appropriate apparatus, the supply of air afforded to them was regulated and measured. The quantity of carbonic acid generated, and of oxygen gas consumed, were likewise ascertained. The difference between these quantities, was ascribed to the union of a portion of the oxygen with hydrogen, presented to it in the blood.

The heat yielded by the oxygen thus converted into water, and that converted into carbonic acid, was considered as comprising the whole which could be derived from respiration. This was found by Mr. Dulong never to be less than 69 per cent., nor more than 80 per cent., of the whole heat emitted by the animal. The heat which could be ascribed to that portion of the oxygen which was converted into carbonic acid, was, in the case of carnivorous animals, never less than 49, nor more than 65 per cent. of the whole heat generated; but in the case of frugivorous animals, it was never less than 65, nor more than 75 per cent. of the whole.

The conclusions of Mr. Dulong are founded on the estimate of the heat produced by the combustion of carbon and hydrogen, made by Lavoisier and Laplace. Mr. Despretz repeated the investigations of Mr. Dulong, founding his estimate of the heat produced by the combustion of oxygen gas, with carbon and hydrogen, on a new series of experiments.

I subjoin a summary statement of the deductions of Mr. Despretz.

He infers, that there is an exhalation of nitrogen in all cases during respiration, the quantity being greater from frugivorous, than carnivorous animals.

That the volume of the carbonic acid disengaged, never equals that of the oxygen which disappears; and that the disparity in this respect is greater in young animals than in adults.

That the quantity of heat which can be ascribed to the union of oxygen with carbon and hydrogen, is never less than $\frac{72}{100}$, nor greater than $\frac{90}{100}$, of the heat produced by the animal.

Upon the whole, it appears from the experiments of Dulong and Despretz, that the heat arising from respiration, is from 10 to 30 per cent. less than the whole of the heat generated by animal life. If these results are to be relied upon, the remainder must be ascribed to the fixation of the fluid matter of the blood; and that change of capacity, so often observed to be attendant upon combination or decomposition. If the temperature of substances undergoing the vinous fermentation, can be augmented by these causes, it is reasonable to suppose that they may contribute to the heat of animals.

In page 15, I mentioned the facts ascertained by Dr. Mitchell, of the Medical Institute, respecting the permeability of caoutchouc by gases.

Agreeably to one doctrine, carbon is supposed to be abstracted from the blood within the lungs; agreeably to another hypothesis, oxygen passes into it, and carbonic acid, previously formed, is emitted. To both views, the impermeability of the membrane was an alleged obstacle, but Dr. Mitchell has annihilated all difficulty arising from this source, by his experiments with caoutchouc membranes.

Dr. Turner, in his chemistry, page 912, 4th edition, makes the following remarks. "The difficulty which formerly stood in the way of both theories of respiration, arising from the supposed impermeability of animal membranes by gases, has been entirely removed by the researches of Drs. Faust and Mitchell. It fully appears from their experiments, and of the accuracy of their principal results, I am satisfied from personal observation, that animal membranes, both in the living and in the dead subject, are freely penetrable by gaseous matter."*

OF LIQUIDS SECRETED by ANIMALS.

Several liquids are described, in treatises of chemistry, which are secreted by animal organization; as, for instance, lymph, synovia, saliva, the humours of the eye, tears, the gastric and pancreatic juices, bile, sweat, urine, and milk. An account of these substances, so far as it can be afforded without chemical principles or illustrations, belongs to the chair of the Institutes.

It is my duty to explain their chemical properties and composition, as far as it may be practicable or expedient.

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* Page 913, Dr. Turner observes, alluding to the above mentioned chemists, "the American philosophers are entitled to the merit of advancing from the detached facts of others, to the establishment of a principle."

But, unfortunately, the analyses which have been made of the substances under consideration, by eminent chemists, are contradictory, and the opinions entertained of them, fluctuating: and were it otherwise, I should deem it injudicious to occupy the attention of students with details, which experienced chemists cannot recollect, unless in cases in which their attention has been particularly excited. I shall therefore conclude this part of animal chemistry, with an account of the gastric juice, milk, urine, bile, and sweat.

OF THE GASTRIC JUICE.

The gastric juice is a transparent liquid, having a somewhat bitter taste. As obtained from the stomach of an animal killed while fasting, it is neither acid nor alkaline; but it has been alleged, that it owes its solvent powers to the presence of chlorohydric and acetic acid secreted during digestion. This opinion has received support from the detection of chlorohydric and acetic acid in the stomach of animals killed during digestion; and it has been shown by Teidemann and Gmelin, that, at the temperature of the body, those acids are capable of dissolving all digestible substances employed as food.

OF MILK.

Milk needs no description. Its density and qualities vary, not only in different animals, but at different times in the same animal, according to health or food. It spontaneously separates into cream, curd, and whey.

Milk is composed of caseum, butter, sugar of milk, different salts, especially phosphates, and a little acid. The butter and a portion of the caseum are only suspended in the milk in a state of minute division, whence its opacity; but another portion of the caseum appears to be dissolved. When evaporated, a pellicle is formed on its surface. By distillation it yields water slightly contaminated with milk. If heated daily, it does not spoil for a long time. It is extremely coagulable by acids and alcohol, and likewise by the coating of the calf's stomach, to which the name of rennet has been applied. It is probable that this coagulation, when produced by acids, is due to the insolubility of the compounds formed by those bodies with caseum. The effect produced by rennet has been attributed to the acids of a portion of the gastric juice, which it is supposed it may retain. But it must be evident that only a minute proportion of acid could be thus held; and Berzelius has shown that of rennet, previously macerated in water, to remove every thing soluble in that liquid, one part will coagulate 1800 of milk, though losing only $\frac{1}{35}$ of its weight. It is, therefore, inferred by him, that caseum, like fibrin and albumen, is susceptible of two different states; in one of which it is soluble, in the other, insoluble.

Whey, as I have stated, contains sugar of milk; and besides this, some other animal matter, with phosphates and chlorides.

The milk of women contains less caseous matter, and more sugar, than cow's milk. It yields more cream, but not of a kind convertible into butter.

OF URINE.

Urine is a very complicated fluid, being apparently secreted for the purpose of carrying off impurities, received into or formed in the blood.

Agreeably to an analysis made by Berzelius, the composition of urine is as follows:—

Water	933.00
Urea	30.10
Uric acid	1.00
Free lactic acid, lactate of ammonia, and animal matter not separable from them	17.14
Mucus of the bladder	0.32
Sulphate of potassa	3.71
Sulphate of soda	3.16
Phosphate of soda	2.94
Phosphate of ammonia	1.65
Chloride of sodium	4.45
Chloride of ammonium	1.50
Earthy matters with a trace of fluoride of calcium	1.00
Silicic acid	0.03
	1000.00

OF THE BILE.

According to the analysis of Gmelin, the bile of the ox contains water; a substance having the odour of musk; cholesterine; biliary resin; a crystalline substance which he calls taurin; biliary sugar (the picromel of Thenard); colouring matter; a substance analogous to gluten; caseous and salivary matter; albumen; mucus; osmazome; an extractive matter insoluble in alcohol; margaric and oleic acid; a new acid, to which the appellation of cholic has been given; bicarbonates, acetates, oleates, margarates, cholates, sulphates, and phosphates of potash and soda; phosphate of lime; chloride of sodium; and a minute quantity of carbonate of ammonia.

Berzelius considers the composition of the bile as much more simple than would be inferred from the analysis above given. He conceives that a great portion of the substances abovementioned, may be produced by the agents employed for their evolution, and that it is probable that the bile contains the albuminous substances of the blood so modified as to be readily convertible into a great variety of compounds.

OF SWEAT.

According to Thenard, sweat contains much water, a little acetic acid, chloride of sodium, perhaps also chloride of potassium, a very little phosphate of lime, a trace of iron, and a quantity of animal matter almost too small to be appreciated. Berzelius regards sweat as water holding in solution the chlorides of sodium and potassium, lactic acid, lactate of soda, and a little animal matter.

OF URINARY CALCULI.

These may be divided, according to Henry, into six species.

I. Calculi, which are chiefly composed of uric acid, or urate of ammonia:

II. Calculi, principally composed of the ammoniaco magnesian phosphate (phosphate of ammonia and magnesia):

III. Calculi, consisting, for the most part, of phosphate of lime:

IV. Calculi, containing principally carbonate of lime:

V. Calculi which derive their characteristic property from oxalate of lime; and

VI. Calculi, composed of the substance discovered by Dr. Wollaston, and called by him *cystic oxide.*

To these may be added, calculi, containing two or more of the above mentioned ingredients, in a state of admixture; and those in which they form distinct layers, or concentric strata.

Dr. Marcet informs us, that when uric acid predominates in a calculus, a fragment, no larger than a pin's head, being held in the blowpipe flame, by a slender pair of platina tongs, blackens, emits a smoke, having a strong and characteristic odour, is gradually consumed, and leaves a minute quantity of white ashes, which are usually alkaline.

Another mode of recognising this calculus, is, to subject a small portion, in a watch glass, to a few drops of caustic potash, over a lamp. The uric acid is immediately dissolved, leaving the other ingredients untouched. From the solution thus formed, almost any acid will cause a white precipitate of pure uric acid.

Lastly. If a minute portion of calculus, consisting of uric acid in the smallest proportion, be exposed to a drop of nitric acid, and heated to dryness, the residuum will display a beautiful purple, or carmine colour.

When phosphate of lime predominates in a fragment of calculus, it first blackens, but soon after becomes perfectly white, and is very difficult of fusion before the blowpipe. Calculi of this kind, are readily dissolved by dilute muriatic acid; and, when the acid is not in great excess, may be precipitated by oxalate of ammonia.

If a calculus, consisting principally of ammoniaco-magnesian phosphate, be subjected to a gentle heat, or moistened with caustic potash, an ammoniacal odour will be perceptible.

There is a species of calculus, which, when exposed to the blowpipe flame, bubbles up and melts easily into globules, usually pearly but sometimes transparent. This species is called the fusible calculus. It is, principally, a mixture of phosphate of lime, and the phosphate of ammonia and magnesia. It is readily soluble in dilute chlorohydric acid, from which the lime may be precipitated by the addition of oxalic acid; and by adding ammonia, a precipitation ensues, of the phosphate of ammonia and magnesia.

The calculus, in which oxalate of lime predominates, is sometimes called the mulberry calculus, from its resemblance to a mulberry. The heat of a spirit lamp is generally adequate to destroy the acid in this calculus, and to develop quicklime, which may of course be detected by turmeric.

Cystic oxide is recognised, *chemically*, by its great solubility in acids and alkalies.

The calculus composed of carbonate of lime is seldom found.

Besides these calculi there are the zanthic oxide and fibrinous calculus.

The former derives its name from its yellow colour, the latter from the resemblance of its properties to fibrin. Both are extremely rare.

OF ARTHRITIC CONCRETIONS.

Arthritic concretions were shown by Wollaston to contain uric acid and soda. Urate of lime, and chloride of sodium, have since been demonstrated to exist in them by Vogel.

OF ANIMAL SOLIDS.

For reasons already specified, in the case of the liquid secretions, I do not deem it expedient to enter into a detail of the chemical properties and composition of all the substances which might come under this head. I will only state a few facts respecting some of them.

OF SKIN.

Besides the intermediate tissue called the rete mucosum, the human skin consists of the epidermis, and true skin. The former resembles coagulated albumen in its chemical properties. Of the latter, the greater part, by boiling in water, may be converted into gelatin. Hence its utility in the manufacture of glue.

OF BONES.

Besides oil, of which the marrow is mainly constituted, bones consist of cartilage, indurated by phosphate and carbonate of lime. The two last mentioned constituents may be removed by diluted nitric, or chlorohydric, acid.

The cartilage retains the shape of the bone, after the removal of the other constituents. Besides the substances already mentioned, bones contain minute portions of other matter, as will appear from the following analysis of Berzelius.

Cartilage completely soluble in water, and convertible into gelatin by boiling - -	32.17
Vessels - - - - - -	1.13
Subphosphate of lime with a little fluoride of calcium - - - - - -	53.04
Carbonate of lime - - - - -	11.30
Magnesia, either as phosphate or as carbonate	1.16
Soda with a little chloride of sodium -	1.20
	100.00

Beef bones differ from those of man in containing only a third of the quantity of carbonate of lime, and in abounding in calcareous and magnesian phosphate to a proportionably greater extent.

In addition to the ingredients in the above mentioned list, traces of sulphate of lime, alumine, silica, and oxide of iron, were discovered by Hachett, Fourcroy, and Vauquelin.

OF THE BRAIN.

The brain is said to contain in 10,000 parts,

Water - - - - -	8000
White fatty matter - - -	453
Red fatty matter - - -	70
Albumen - - - - -	700
Osmazome, a substance to which meat gravy is supposed to owe its savour	112
Phosphorus - - - - -	150
Acids, salts, and sulphur - -	515
	10,000

Such is the best account which it has pleased God to enable the brain of man to give of its own chemical constitution.

It is to be regretted, that of all studies, to which the human mind has been directed, self-analysis, whether moral or physical, seems the most beyond its powers.

OF THE PUTREFACTIVE FERMENTATION.

To that species of spontaneous decomposition which is called putrefactive, animal substances, in general, are much more disposed than vegetable; and the effluvia which they emit, during the change, are much more offensive. The presence of phosphorus and sulphur contributes greatly to the fetor of animal putrefaction. On the other hand, few animal substances are susceptible of the vinous or acetous fermentation.

The presence of water, or of its elements, seems indispensable to the spontaneous decomposition of organic substances. In no instance is either the vinous, acetous, or putrefactive fermentation induced, in substances which are perfectly dry. The effect of desiccation in preserving meat and fruits, sufficiently proves the correctness of this allegation. It is, probably, by paralyzing the activity of the water in meat, that salt favours its preservation; and the beneficial influence of sugar upon preserves, may in like manner be explained.

When, in addition to water, nitrogen is a constituent, the tendency to putrefaction is increased. Gluten and yeast, which contain nitrogen, are very liable to an extremely offensive putrefaction. To their deficiency in this principle, Dr. Turner ascribes the indisposition of oils to putrescency; but I conceive their freedom from water, and incapacity to unite with it, to be the true cause.

The insusceptibility of the vegetable alkalies of decomposition, while containing both hydrogen, oxygen, and nitrogen, may arise partly from their insolubility in water, and partly from the predominance of carbon in their composition.

Although heat to a certain extent is necessary to putrefaction, it may be arrested by a high temperature, as well as by frost. In the one case, water being vaporized, is removed; in the other, being congealed, becomes inert. We are unable to explain the peculiar efficiency of this liquid in promoting the spontaneous decomposition of organic products, in all its forms. It seems as if certain affinities which exist between the ultimate elements of many vegetable and animal substances, although suspended by the inexplicable powers of vitality, resume their operation, as soon as those powers cease, with greater or less activity, according to the nature of the substance, and the softening influence of heat and moisture.

Thenard alleges that water is not decomposed, during putrefaction, but on the contrary generated.

Besides water, we may enumerate ammonia, with carbonic, acetic, and sulphydric acid; also carburetted, and in some cases phosphuretted hydrogen, among the products of putrefaction.

CONCLUSION.

Of vegetable and animal chemistry, I must here take leave. Intrinsically, it consists of little more than a detail of facts. It is only from the splendid discoveries, which have been made in the chemistry of inorganic matter, that we can hope for any theoretic elucidation of the properties of organic products, or of the means by which vitality creates, from sources so limited, such an infinite variety of interesting productions.

From the multiplicity of analyses, of which the results are so nearly alike, as to baffle the efforts of the adept to remember them, it were utterly impracticable to impart a knowledge of the minutiæ of organic chemistry, during a course of instruction limited to four months. I am however consoled in recollecting, that it is that branch of chemical science, in which it is most easy for gentlemen of the medical profession to become their own instructors, as the subjects are within their reach, and the implements and agents for investigation are very simple, and may be obtained, comparatively, with little exertion and expense.