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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.

FOR THE USE OF HIS PUPILS.

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PREFACE.

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, of studying it, were afforded to them.

Again, some of my contrivances, which in their employment greatly facilitated my experiments, were too complex, in their structure, to be understood without a minuteness of explanation, which, even if it were useful and agreeable to some of my class, 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. My "Minutes" were so enlarged at each successive edition, that had I not resorted to this appellation, when the work really consisted of the minutes from which I had previously lectured, it would not have been latterly retained.

Encouraged by the success of my plan, I am now preparing an edition which will be still more extensive. The first part is now completed, and comprised in this number: the remainder will appear in time for that portion of the course to which it appertains. The lectures on Galvanism, Electricity, and Electro-magnetism with the Appendix, will form two additional numbers. 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.

TO THE READER.

It may be proper to mention, that in treating of the reaction between particles, or masses of matter, as the ultimate cause, *agreeably to the laws of the Creator*, of the phenomena and operations of the physical world, and as the trunk, of which, repulsion and attraction are the branches, my plan is peculiar. I have adopted this course, because it enables me to give definitions of natural philosophy, chemistry and physiology, which appear to me brief and appropriate.

I subjoin the following definitions from some of the most eminent chemists.

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

According to Henry, "it may be defined, the science which investigates the 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, their 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."

I avail myself of this opportunity to state my reasons, for employing "*reaction*" for "*action*" and "*react*" for "*act*," contrary to general usage, in describing chemical phenomena. It appears to me, that in all cases where chemical action is said to exist, there is really a reciprocal action. Thus nitric acid is said to act upon tin, although it might with at least as much propriety, be said, that tin acts upon nitric acid; since the latter is decomposed by the former. In this case, I would say, that there is a reaction between tin, and nitric acid, or that tin reacts with nitric acid.—See note to page 1.

In order to avoid as far as possible, those errors and obscurities, from which, it is difficult to have a work upon abstruse topics exempt—especially when printed in haste—I engaged my friends, Dr. T. P. Jones and Dr. Bache, to look over the matter, before going to press, and to examine the proof sheets afterwards.

I owe to those gentlemen, especially the latter, on whom the duty mainly devolved, several useful hints, and important corrections.

NOTICE.

The preceding pages were written in October, 1827, as prefatory to the first number of this work.

Since that time the second, third, and fourth numbers, and the appendix, have been printed, and are now comprised in this volume.

The *engravings* and *descriptions of apparatus*, for the lectures on electricity, galvanism, and electro-magnetism, are not yet completed. Meanwhile, however, those lectures may be obtained in the form, in which they were printed for the last session.

November, 1828.

CONTENTS OF No. I.

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* The experimental illustrations are numbered.

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* Apparatus contrived by the Author.
† Apparatus modified by the Author.

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* Apparatus contrived by the Author.
† Apparatus modified by the Author.

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* Apparatus contrived by the Author.
† Apparatus modified by the Author.

CONTENTS OF No. II.

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* Apparatus contrived by the Author.

† Apparatus modified by the Author.

‡ An account of some mercurial sliding rod eudiometers will be given in the Appendix.

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* Apparatus contrived by the Author.
† Apparatus modified by the Author.

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* Apparatus contrived by the Author.
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* Apparatus contrived by the Author.
† Apparatus modified by the Author.

CONTENTS OF NO. III.

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† Apparatus modified by the author.

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* Apparatus contrived by the Author.
† Apparatus modified by the Author.

CONTENTS OF NO. IV.

[†] Apparatus modified by the Author

APPENDIX.

COMPENDIUM,

&c.

ON THE CAUSE OF THE PHENOMENA AND OPERATIONS OF THE PHYSICAL WORLD.

REACTION between different portions of matter, is conceived to be the fundamental cause of the phenomena and operations of the physical world; for if there were no such reaction, every particle, or mass, would be as if no other existed.

Reaction[*] is 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.

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 operations, 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 reaction between 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.

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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 reaction, therefore, I mean reciprocal action.

[†] By the word mass, I mean a congeries of particles or atoms.

OF ATTRACTION BETWEEN PARTICLES, OR CHEMICAL ATTRACTION.*

Chemical attraction is distinguished, as it takes place between homogeneous particles; and as it exists between heterogeneous particles.

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.

All matter susceptible of crystallization.

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

Regular forces acting on similar atoms, might be expected to produce regular forms.

As homogeneous atoms must be exactly of the same size and shape, it is not wonderful that the reiteration of the same force, among such atoms, should produce similar symmetrical forms.

To produce irregular forms, the particles, or the forces actuating them, should be irregular.

Like atoms produce like forms, dissimilar atoms generally dissimilar forms.

It is not only true, that all matter, in passing from the fluid, to the solid form, appears capable of crystallizing: it has been observed, that each kind of matter crystallizes under an appropriate crystalline form.

Which reasonably might be anticipated.

That there should be as many kinds of crystals, as there are atoms of a different nature, ought not to excite wonder: since, for the same reason that homogeneous atoms, of one species, actuated by like forces, produce regular forms of one kind, homogeneous atoms of another kind, similarly actuated, may aggregate into other regular forms.

Observations of Gahn, Bergmann, Romé de L'Isle, Haüy.

The theoretic view, thus founded on a supposed diversity in the atoms of different kinds of matter, and the consequent difference in the forms of their crystals, has received much practical illustration through the observations of Romé de L'Isle, Gahn, Bergmann, and Haüy.

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[*] 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, the other of particles. Moreover it was among chemists, that the investigation of the phenomena and laws of crystallization commenced, naturally, if not necessarily.

Variety of forms, occasionally assumed by the same kind of matter, derived from a crystalline nucleus, common to all.

The principal source of difficulty in accounting for crystallization, was, that the same matter did not always appear in the same forms, and that dissimilar matter did sometimes exhibit similar forms. This perplexity has been removed, by showing, that, however various the crystalline forms assumed by any one kind of matter, they may be reduced generally to one primitive form or nucleus.

Stones more susceptible of cleavage, in some directions than in others.

It had long been known to lapidaries, that, in some directions, stones could be split with much greater facility than in others. Makers of gun flints were indebted to this susceptibility, in the objects of their labour, for the facility with which they could give them the proper form.

Speculations of Bergmann, founded on the observation of Gahn, that the fragments of a calcareous rhomboid, were all rhomboidal.

Subsequently, the illustrious Bergmann, endeavouring to ascertain the mechanical structure of crystals, considered the variety in the crystalline forms, of the same substance, as resulting from the successive super-position of laminæ, sometimes equal, sometimes increasing, at other times decreasing, on a common primitive form. Application of this idea was made, by him, to a small number of crystalline specimens, and it was realized in the case of calcareous spar.

This investigation of Bergmann was induced by an observation, previously made by Gahn, that the fragments of a rhomboid of calcareous spar, carefully broken, were rhomboids.

Romé de L'Isle made assemblages of crystals, assigning to each an appropriate nucleus. Measurements of angles introduced by him.

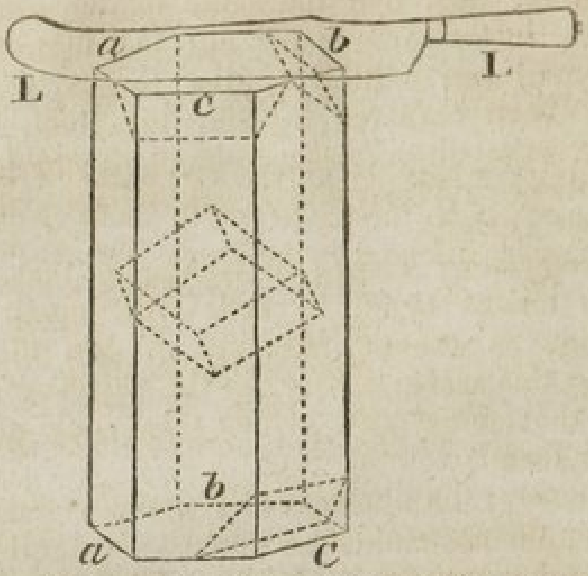
Romé de L'Isle endeavoured to make assemblages of crystals, of the same nature. Among the different forms, belonging to each species, he selected one, which, from its simplicity, appeared likely to be the primitive form, or the basis from which the others were derived. Besides describing or defining their figures, he introduced the highly important practice of measuring their angles.

Laws of crystalline arrangement traced, or computed, by Haüy.

Haüy proceeded to associate the laws of their arrangement with the form and dimensions of the integrant molecules, and to submit these laws to computation. This undertaking, most arduously, ingeniously, and profoundly prosecuted, has given rise to the science of Crystallography, in its present advanced state.

We are indebted to Haüy for the following method of illustrating the extrication of a primitive, from a secondary crystal.

Fig. 1.



Extrication of the rhomboidal nucleus from an hexagonal prism of calcareous spar.

As each of the sides of an hexagonal prism of calcareous spar, is bounded by two edges, one at each end of the prism; there are six edges at each end, and in all, twelve edges. If to every one of the twelve edges a knife be forcibly applied, in the direction indicated in figure 1, one of the edges *a b c*, *a b c*, bounding each side, will yield so as to expose a smooth natural facet, making an angle of 45° with the adjoining side. The alternate edges will not split off so as to present surfaces corresponding either in smoothness, or obliquity, with those above described, so that the six facets will be equally divided between the two ends of the prism, each having three facets alternating with three remaining edges.

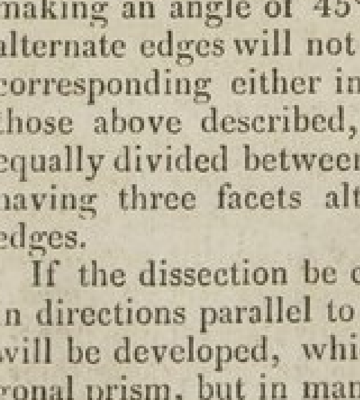
If the dissection be continued, by applying the knife in directions parallel to the facets, finally a rhomboid R will be developed, which exists not only in the hexagonal prism, but in many other crystalline forms of calcareous spar.

All these other forms are called secondary. The rhomboid, which is their common nucleus, or primitive form, is beautifully exemplified in the Iceland spar.

Developement of an octoëdral nucleus in fluor spar.

Probability of the existence, in all homogeneous crystals, of a primitive form.

Fig. 2.



The same author teaches us that a cubic crystal of fluor spar, can only be split in directions parallel to the faces of an octoëdral nucleus, whose situation, relatively to the containing cube, is represented by figure 2.

By various dissections, analogous to those which have been adduced, it is rendered highly probable that every crystallizable substance has an appropriate form, which it assumes in the first instance, and which is the basis of all its other forms.

Some primitive forms inferred by analogy.

The nuclei may sometimes be obtained by percussion, sometimes by heat; in other cases by heat followed by refrigeration.

Angles in homogeneous nuclei always the same.

Although a nucleus cannot be extracted in every instance from crystals, the existence in them of primitive forms, is usually inferred by analogy. The angles which the sides make with each other, are always the same in a nucleus, however obtained; and such crystals are always divisible in directions parallel to all their surfaces, whereas there are some surfaces of secondary forms, parallel to which, by cleavage, new facets cannot be obtained.

Primitive forms distinguishable from secondary, by being susceptible of cleavage parallel to all their faces.

Haüy enumerates six primitive crystalline forms, the parallelopiped (including the cube, rhomboid, and four-sided prism), tetraëdron, octoëdron, hexaëdral prism, rhombic dodecaëdron, and dodecaëdron with triangular faces.

Fig. 3.—Quadrangular or four-sided prism.

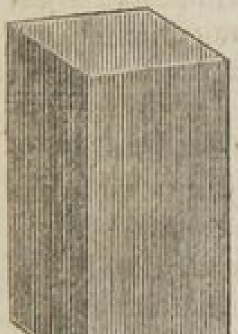


Fig. 4.—Cube.

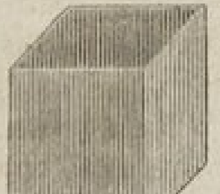


Fig. 5.—Rhomboid.

Fig. 6.—Tetraëdron.

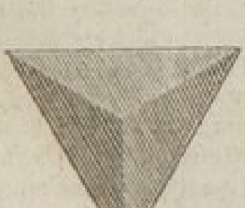


Fig. 7.—Octoëdron.

FIG. 8.—HEXANGULAR OR SIX SIDED PRISM.

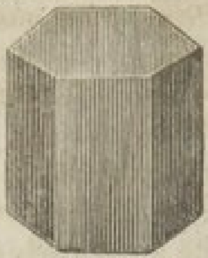


FIG. 9.—RHOMBIC DODECAËDRON.

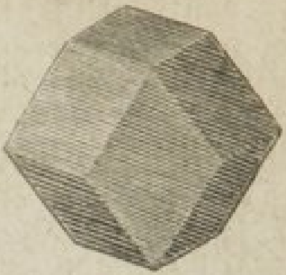


FIG. 10.—DODECAËDRON with triangular faces.

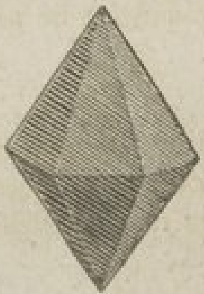
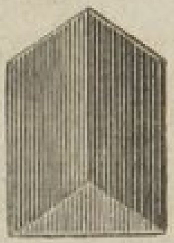


FIG. 11.—TRIANGULAR OR THREE SIDED PRISM.



By dissections, not parallel to their surfaces, primitive forms reduced to tetraëdron, triangular prism, and parallelopipeds: which are inferred to be the only forms, of integrant atoms.

The primitive forms, by a further dissection of the octoëdron, hexangular prism, and dodecaëdra, in directions, not parallel to the sides, may be reduced into three forms: the tetraëdron, or simplest solid, the triangular prism, or the most simple prism; and the parallelopiped, including the cube, rhomboid, and four sided prism. As it is in size only, that integrant atoms can be altered by cleavage; it is inferred that if the dissections were continued until the smallest integrant atom should be developed, its form would be the same as that of the parent mass. Hence also the inference has arisen, that the only forms, which belong to integrant atoms, are those above-mentioned.*

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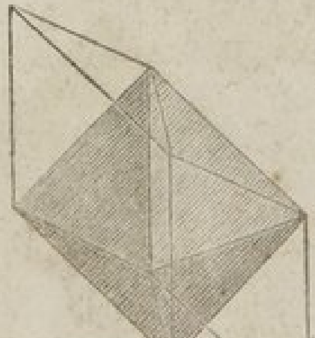
* These deductions from Haüy's hypothesis, are called in question in the following passage, quoted from Brande's Manual, 2d edition, page 208.



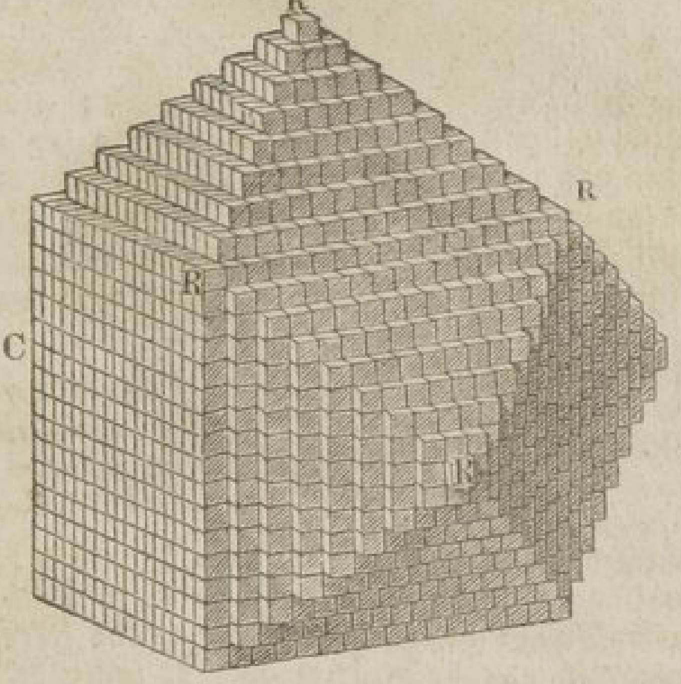
"But in crystallography we meet with appearances which Haüy's theory but imperfectly explains. A slice of fluor spar, for instance, obtained by making two successive and parallel sections, may be divided into acute rhomboids; but these are not the primitive form of the spar, because by the removal of a tetraëdron from each extremity of the rhomboid an octoëdron is obtained. Thus, as the whole mass of fluor may be divided into tetraëdra and octoëdra, it becomes a question which of these forms is to be called primitive, especially as neither of them can fill space without leaving vacuities, nor can they

We owe also to Haüy the following examples of the conversion of cubes into dodecaëdra or twelve sided solids.

Generation of a dodecaëdron with rhombic faces, by layers of atoms, decreasing at each addition, by one row on each edge.

If a cube be increased by layers of particles, applied to all its sides, the edges of the layers being parallel to those of the cube, and each layer being made less, than that immediately preceding it, by one row of particles on each of its edges, a dodecaëdron, or twelve sided solid, with rhombic faces, will be produced.

FIG. 12.



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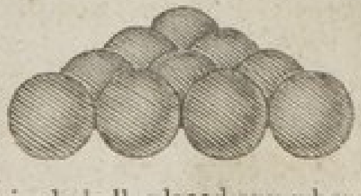
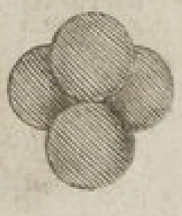
produce any arrangement sufficiently stable to form the basis of a permanent crystal.

"To obviate this incongruity, Dr. Wollaston (*Phil. Trans.* 1813,) has very ingeniously proposed to consider the primitive particles as spheres, which, by mutual attraction, have assumed that arrangement which brings them as near as possible to each other. When a number of similar balls are pressed together in the same plain, they form equilateral triangles, with each other; and if balls so placed were cemented together and afterwards broken asunder, the straight lines in which they would be disposed to separate, would form angles of 60° with each other. A single ball, placed any where on this stratum, would touch three of the lower balls, and the planes touching their surfaces would then include a regular tetraëdron. A square of four balls, with a single ball resting upon the centre of each surface, would form an octoëdron; and upon applying two other balls at opposite sides of this octoëdron, the group will represent the acute rhomboid. Thus the difficulty of the primitive form of fluor, above alluded to, is done away, by assuming a sphere as the ulti-

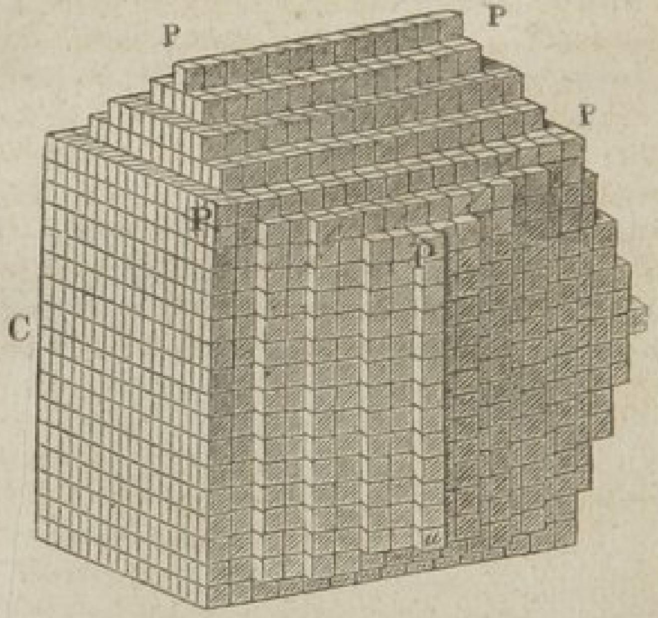




Generation of a dodecaëdron *with pentagonal faces*, by layers decreasing constantly by two rows on two parallel edges, alternately by one row, on each of the other edges.

If, in lieu of diminishing every layer one row, on every edge, they be made less, at each addition, by two rows on two parallel edges, while, upon the other two edges, each layer is made alternately the same as the preceding, alternately less by one row, a dodecaëdron, or twelve sided solid, with pentagonal or five sided faces, will be produced.

Fig. 13.



One surface (C) of the cube, in each figure, is represented as if no addition were made to it, in order that the situation of the nucleus, relatively to the pyramids raised upon it, may be understood. It must be evident that each rhombus, R R R R, in fig. 12, and pentagon, P P P P P, in fig. 13, is made up of the surfaces of two adjoining pyramids, built upon a cubic nucleus.

The decrements may proceed only on two sides, or a diminution of two, three, or more rows may take place on all the sides; yet in either case, secondary crystalline forms may be built upon the common nucleus, or primitive form.

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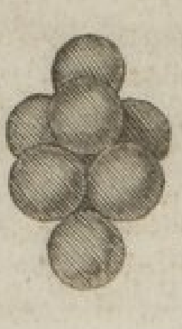
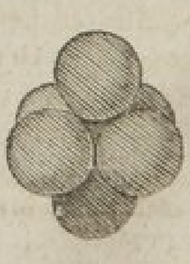
mate molecula. By oblate and oblong spheroids other forms may be obtained."





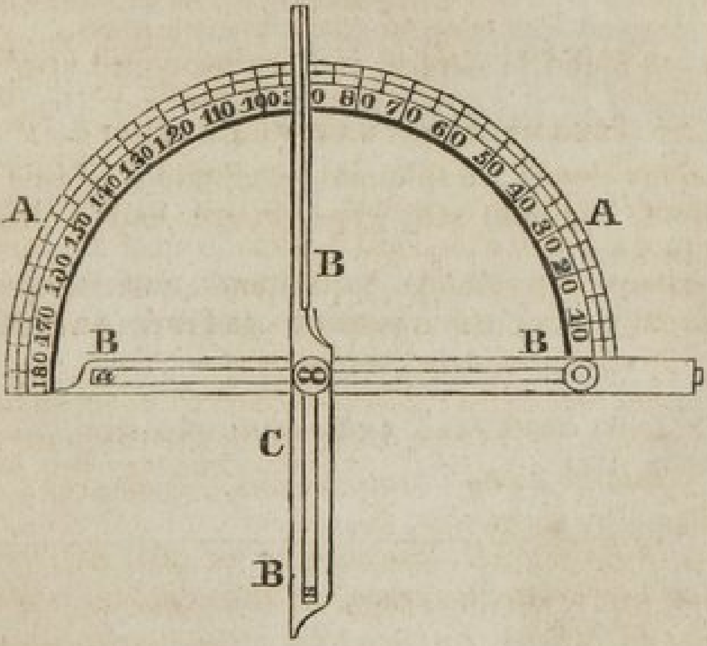
It is presumed that enough has now been said, to convey a general idea of the mode in which particles, in passing from the fluid to the solid state, may in the first instance generate primary forms, by layers which increase as the crystals grow larger, and in the next place, produce a variety of secondary forms, by layers decreasing in various ways, accordingly as the crystallizable matter may be more or less abundant, as the temperature may vary, or the solvent (in cases where there may be a solvent) may evaporate faster or slower.

Crystalline varieties may arise from variations in temperature, quantity of matter, or rate of evaporation.

In the preceding figures, the atoms composing the crystals are supposed to be prodigiously magnified in order to render them visible. Hence, the figures appear rough, but the natural crystal being formed of atoms which are too small to be distinguished by vision, cannot create palpable asperities. Yet the exposure of the edges of the decreasing layers, is not without a sensible influence; since there is a greater brilliancy of surface in primitive, than in secondary crystals.

In preceding figures, atoms supposed to be magnified: really too small to create sensible inequalities.

FIG. 14.—OF THE GONIOMETER, OR INSTRUMENT FOR MEASURING THE ANGLES OF CRYSTALS.



The goniometer 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, fig. 14, 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 the most suitable length, on the side on which the crystal is applied.

OF DECRYSTALLIZATION.

It has lately been ascertained by Mr. Daniell, that crystals may be partially developed by a process, the inverse of that which has been described. When alum is slowly dissolved, its crystalline structure becomes very evident.

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.

Crystals are found in nature, and are produced artificially.

EXAMPLES OF NATIVE CRYSTALS.

The precious stones are splendid productions of this kind. 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: Pearl ash 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.

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.

1.—EXPERIMENTAL ILLUSTRATION

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.

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 condensed into, or combined with, liquids.

To sever elements, united by chemical affinity, the finest edge which human art can produce, were utterly incompetent. Thus,

Chalk consists of lime and carbonic acid; Vermilion, 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.

2.—DIFFERENT CASES OF AFFINITY.

1st case—Simple Combination.

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

Instances :—

Copper and zinc	form	Brass.
Oil and alkali	,,	Soap.
Acids and alkalies	,,	Salts.
Chlorine and metals	,,	Chlorides, as for instance calomel or corrosive sublimate.
Sulphur and metals	,,	Sulphurets.

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 A B, and to have a greater affinity for A than for B.

Instances of simple elective affinity :—

Nitrate of	Silver	decomposed by	Mercury.
	Mercury	,,	Copper.
	Copper	,,	Iron.
Muriate of Lime		,,	Sulphuric Acid.
Sulphate of	Alumina Magnesia	,,	Potash.

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.

Instance of double elective affinity :—

A B		A D
Sulphate of Zinc being mixed with Acetate of Lead,	forms	Sulphate of Lead and Acetate of Zinc.
C D		C B

4th Case of Affinity.

A, B, C, being in union, D, on being added, combines with B, which it would not do were not C present. A and C remain united.

Instance:—Ammoniacal nitrate of copper, or silver, decomposed by arsenious acid, so that nitrate of ammonia, and a metallic arsenite result. The arsenious solution will not, per se, decompose the nitrates.

This case differs from the last, because although two compounds are formed, only one is decomposed.

5th Case of Affinity.

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

Instance:—Ammonia added to solutions of copper, silver, gold, &c., in any acid, unites both with the acid and the metal.

This is a case of double elective attraction, in which but three substances are concerned, one acting in a double capacity.

ON COHESION AS AN OPPONENT TO CHEMICAL COMBINATION.

3.—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.

4.—INFLUENCE OF SOLUTION EXPERIMENTALLY ILLUSTRATED.

Tartaric acid, and a carbonate, although pulverized, and intimately intermingled, are observed not to react until moistened, when a lively effervescence ensues.

5.—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 almost always divide the numbers representing the greater proportions, without a fraction.

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 multiplied, 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: consequently, equivalents, formed upon either basis, may be converted into those corresponding with the other, either by multiplying or dividing by 8.

In the most ample, and accurate works on the subject, those of

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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 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.

Thomson and Berzelius, oxygen is made unity.—But there are as respectable authorities in favour of hydrogen, as the standard unit.

TABLES OF CHEMICAL EQUIVALENTS,

Are very useful; for as the equivalent number of any compound, is to any weight of the compound, so is the equivalent of either of its ingredients, to the quantity of such ingredient in the said weight of the compound.

And as the equivalent of any compound, is to that of any substance, whether simple or compound, capable of decomposing it; so is the weight of the compound to be decomposed, to such a weight of said substance, as will prove just adequate to effect the decomposition.

Moreover, when the proportions, afforded by analysis, do not harmonize exactly with the equivalents, the discordancy is ascribed to the imperfection of our means or powers.

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.

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 dissections, as the space which contains it. 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 what has been said respecting the small number of definite proportions, to which substances, in combining, are restricted. Hence elementary atoms are not considered as liable to an unlimited subdivision, either by chemical, or mechanical agency.

The ratio of the equivalent numbers, is supposed to be dependent on, and identical with, that of the integrant atoms of the substances to which they appertain. Thus the fact that 4 parts by weight, of soda, will saturate as much of any acid, as 6 parts, of potash, is explained by supposing the weights of the smallest atoms, of those alkalies, which can exist, are to each other, as 4 to 6.

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 3.5 to 6: 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 6, as the other contains atoms of lime, weighing 3.5.

It has been stated that the number, representing the least proportion in which a substance is known to combine, will usually divide the number representing a greater proportion without a fraction, almost the only exception being where the quotient is 1.5. This result is ascribed to the indivisibility of atoms, which renders it impossible that they should unite otherwise than as 1 to 1, 1 to 2, 1 to 3, 1 to 4, 1 to 5, or as 2 to 3, &c.

On account of this 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.

OF BINARY, TERNARY, AND QUATERNARY COMPOUNDS.

A compound, consisting of two ingredients, both reduced to the smallest possible proportions, is considered as having as many atoms of the one, as of the other; and each integrant atom of the compound, as consisting of an atom of each ingredient. Such combinations are called binary, because they contain but two constituent atoms.

When in any compound, the quantity, of either ingredient, is the double of that which its least combining proportion would afford, the other ingredient being in its least proportion, it is inferred, that for every atom of the one, there must be two atoms of the other. Hence each integrant atom of the compound, consisting necessarily of three constituent atoms, is called ternary.

When in any compound consisting of two ingredients, the proportion of either is three times greater than its least combining proportion, it is inferred that three atoms of one kind, are united with one of the other, and there being necessarily four constituent atoms, in each integrant atom, the compound is called quaternary.

ON CALORIFIC REPULSION.

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

The existence of repulsion and attraction between the particles of matter, is as evident as the existence of matter. Opposite qualities, cannot belong to the same particles. There must therefore be particles, in which repulsion is inherent, as well as others in which attraction is inherent.

6.—EXPERIMENTAL PROOFS, OF THE EXISTENCE OF A MATERIAL CAUSE, OF CALORIFIC REPULSION.

If ice, at 32°, be subjected to 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°. Water exposed to a fire, does not grow hotter after it boils, but steams more or less, according to the activity of the fire. The steam appears to carry off the principle which the fire communicates. Steam, only heated to the boiling point, or 212°, will raise the temperature of nearly ten times its weight of water, 100 degrees.

The heat, which would raise ten parts of water to 100 degrees, if it were concentrated into one of those parts, would probably raise it nearly to 1000 degrees, 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 aëriform 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, it imparts a repulsive property which counteracts cohesion, so as to cause, successively, expansion, fusion, and the aëriform state.*

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 in 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.

ORDER PURSUED IN TREATING OF CALORIC.

Of Expansion. On the modification of the effects of Caloric by atmospheric pressure. Means of producing heat, or rendering Caloric sensible. On the communication of heat. Slow

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* See Appendix for essay on the question, whether heat can be motion.

communication: Quick communication. Means of producing cold, or rendering Caloric latent. On the various states, wherein Caloric exists in nature.

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

7.—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.

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.

W W 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, of which an engraving and description will be given in due time.

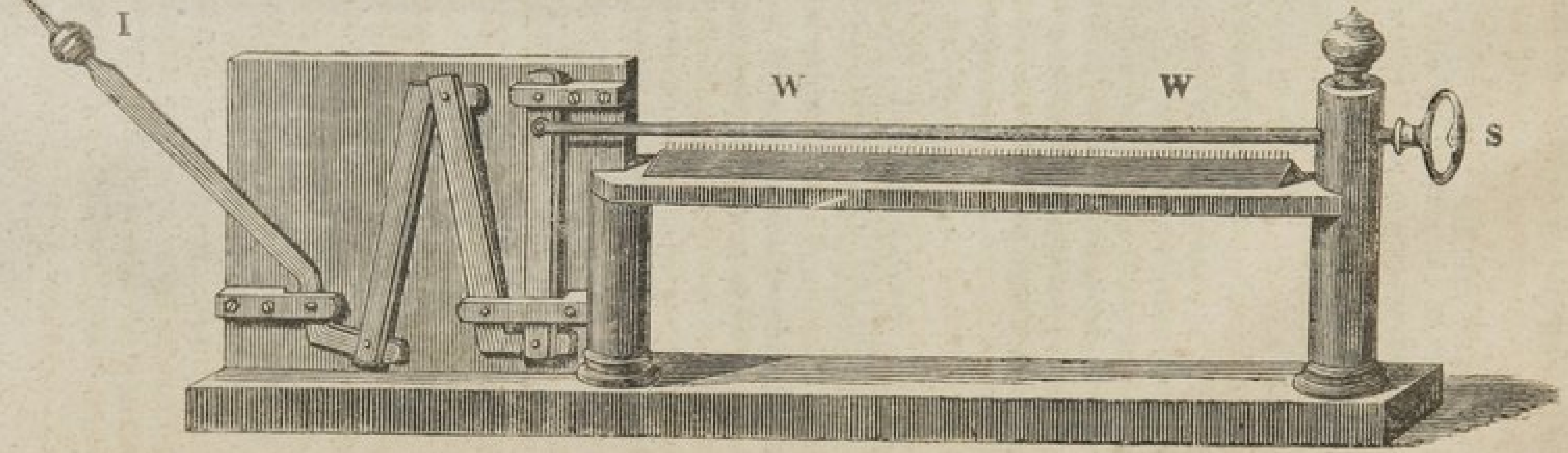
If while the index is depressed, by the expansion, ice or cold water be applied to the wire, a contraction immediately follows, so as to raise the index to its original position.

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

The following numbers given in Brande's excellent Manual of Chemistry, represent the degree of expansion produced by a rise of temperature from the freezing to the boiling point, in 12000 parts of the following metals. Platina 104, Iron 151, Copper 204, Brass 230, Tin 290, Lead 345, Zinc 360.

8.—EXPERIMENTAL ILLUSTRATION OF THE DIFFERENT EXPANSIBILITY OF METALS.

The difference of expansibility in two different kinds of metal, may be rendered apparent by soldering together, at the ends, two thin strips, one iron, the other brass. The compound strip, thus constituted, on exposure to heat, assumes the shape of an arch. The brass which is the more


I
W
W
S

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 page). Under each vessel, place equal quantities of charcoal, burning with a similar degree of intensity. The liquids in both vessels will be expanded, so as to rise into the necks; but the alcohol will rise higher than the water.

EXCEPTION TO THE LAW, THAT LIQUIDS EXPAND BY HEAT.

The bulk of water lessens, with the temperature, until it reaches 39°. 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.

EXPANSION OF AERIFORM FLUIDS.

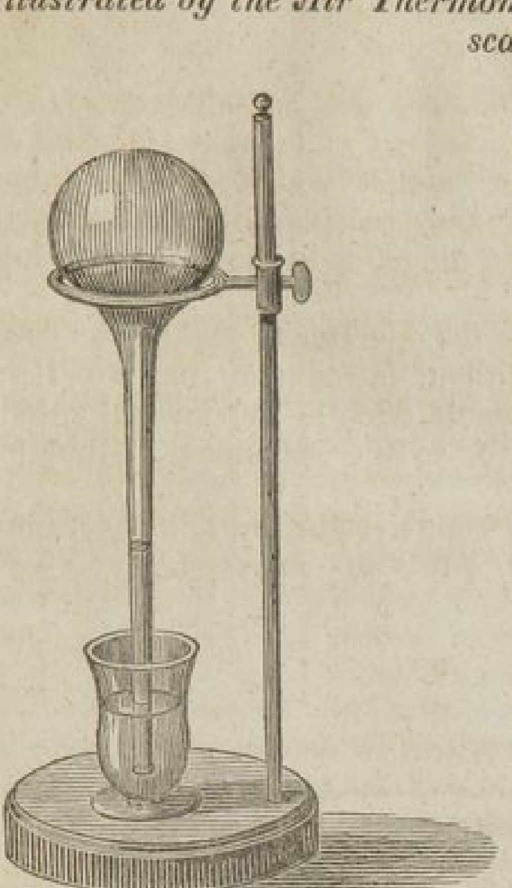
Aëriform fluids are much more expansible than liquids. In order however to appreciate the changes of bulk, which they may be observed to sustain, it is necessary to understand the influence which the pressure of the atmosphere has upon their density, independently of temperature. The simple influence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

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.

11.—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 10, (pages 19, 20).

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.[*]

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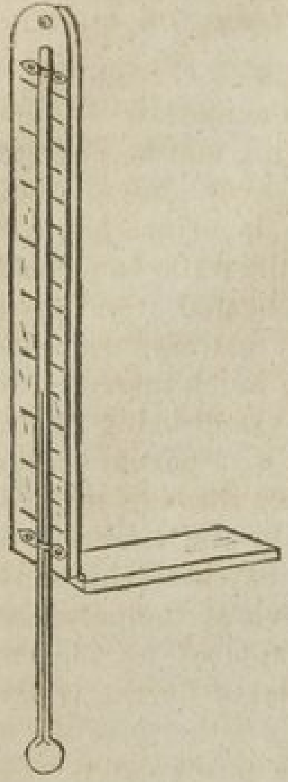
[*] The tubes used in constructing thermometers are made at almost all the glass houses, having usually a capillary perforation. They are made by rapidly drawing out a hollow glass globe, while red hot, by which means it is changed into a

12.—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.

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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.

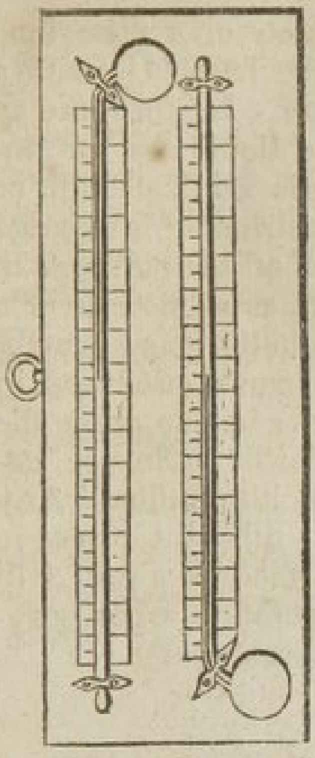
In the next place, the bulb is to be exposed to freezing water, and the point to which the liquid reaches in the capillary perforation marked. In like manner the boiling point is marked, by subjecting the bulb to boiling water. The distance between the freezing and boiling points, thus ascertained, is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

13.—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.

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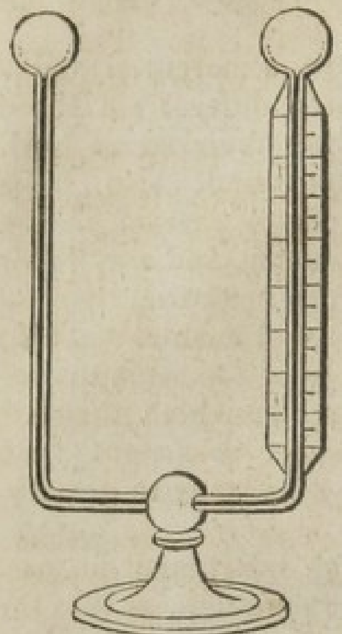
we must only consider the result as indicating the distance above, or below, 32 on his scale.

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 scale.

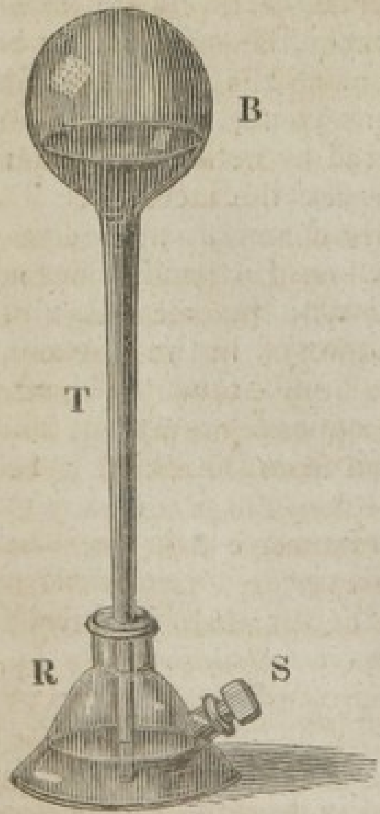
Alcohol boils at 176, but has not been frozen by any cold, natural or artificial. It is likewise more expansible than mercury, and of course it must be more competent to detect slight changes.

14.—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, both bulbs being equally affected, there is no movement produced in the fluid; but the opposite is true, when the slightest imaginable calorific influence 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.

15.—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.

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 the perfection of its recoil.

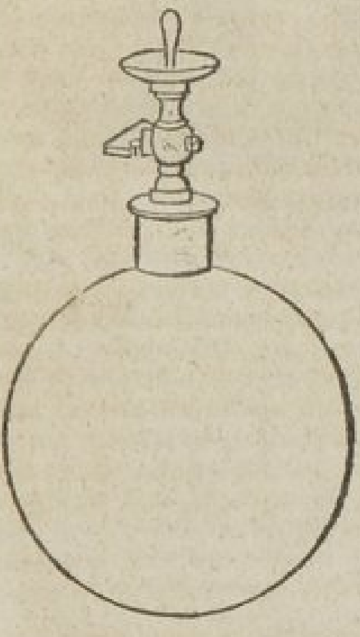
A coach spring is far more powerful, but is not more elastic, than a watch spring. Elasticity is erroneously spoken of as a varying property in the air. In common with aëriform fluids, in general, it appears to be always perfectly elastic.

MODIFICATION OF THE EFFECTS OF CALORIC BY ATMOSPHERIC PRESSURE.

DIGRESSION TO DEMONSTRATE THE NATURE AND EXTENT OF ATMOSPHERIC PRESSURE.

16.—EXPERIMENTAL PROOF THAT AIR HAS WEIGHT.

The air being allowed to re-enter an exhausted globe, while accurately counterpoised upon a scale beam, 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. The addition of the water is easily made by the chyometer, an instrument hereafter to be described.

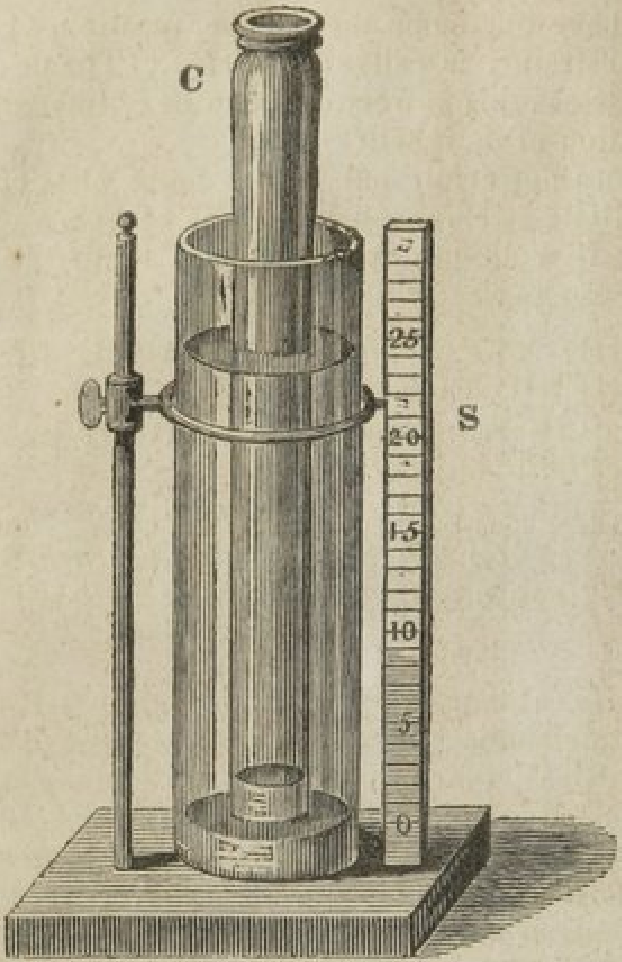
If, instead of allowing the globe to replenish itself with air, it be screwed upon a graduated receiver, so as to draw in a certain number of cubic inches of any other gaseous fluid, the ratio of its weight to that of atmospheric air may be ascertained. Consequently by successive experiments, the respective weights of equal bulks of different gases, or in other words, their specific gravities may be determined.

A NEW METHOD OF DEMONSTRATING THE EXISTENCE AND EXTENT OF THE PRESSURE OF THE ATMOSPHERE.

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.

17—*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 tube, 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.

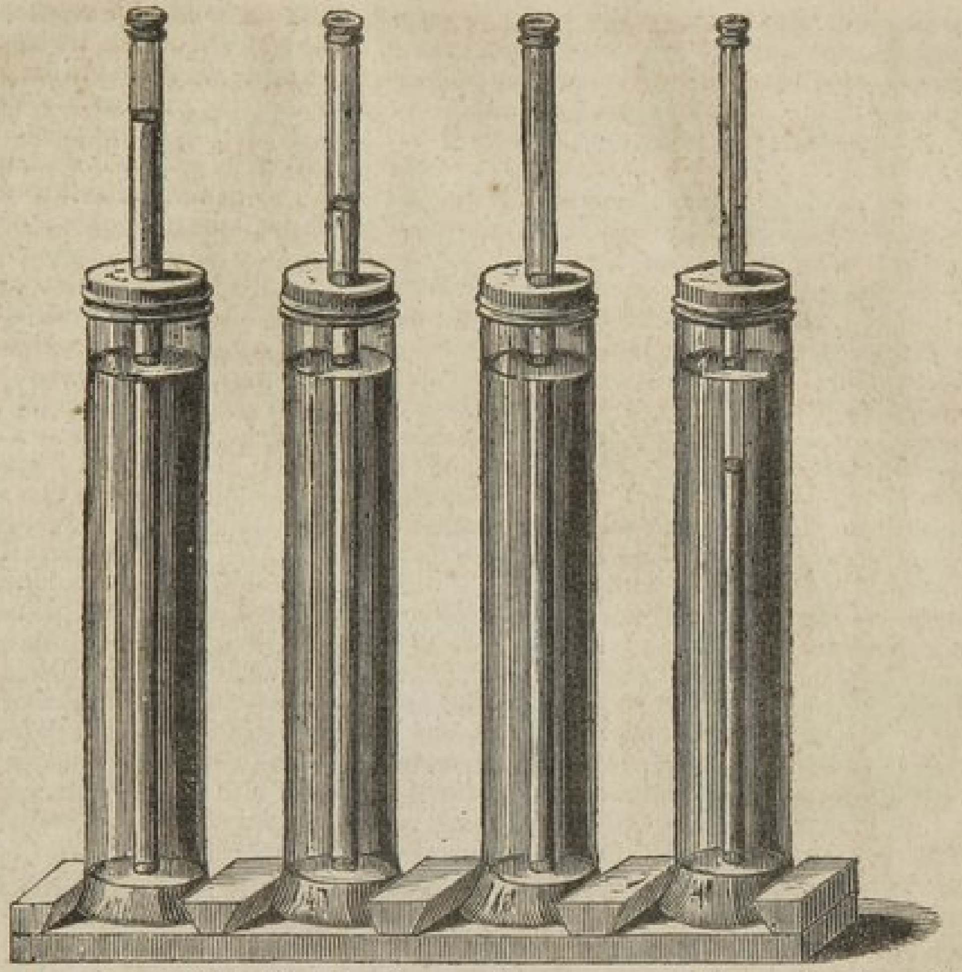
The Illustration extended to the case of Liquids lighter than Mercury.

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.

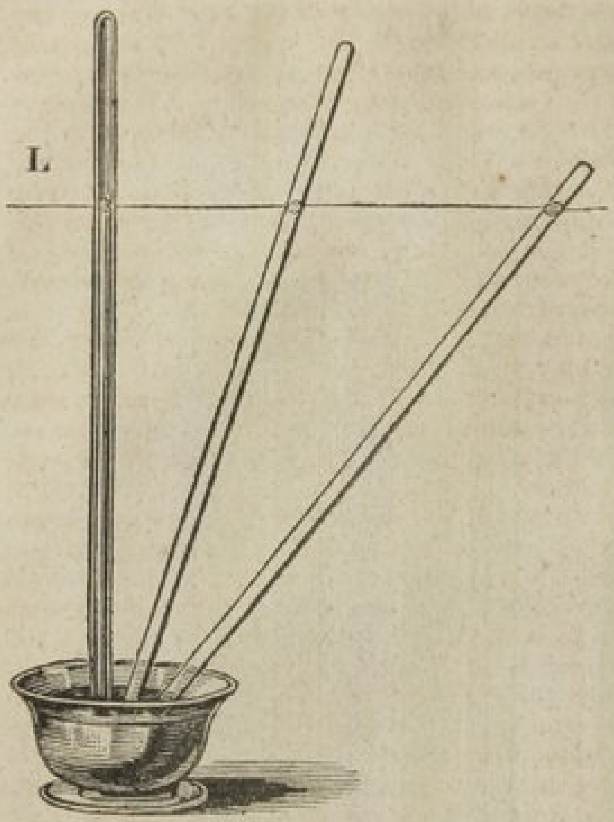
While it is thus proved, that columns of mercury, ether, alcohol, and of a saline liquid, may, in water, be substituted for columns of this fluid; it is also apparent, that they must be as much higher than it, as lighter; as much lower as heavier; or in other words, their heights appear to be inversely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

19.—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, columns 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 analogous to that of the water on the surface of the mercury, outside of the tubes, in the experiments just described, it is only requisite, that this external pressure be unbalanced by the pressure of air within the tube.

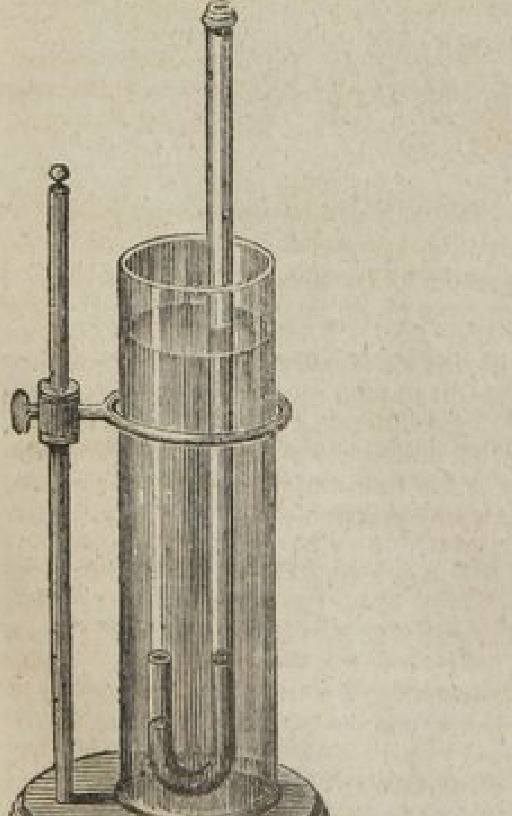
This desideratum is obtained, by filling with mercury, a tube about three feet in length, open at one end, and closed at the other, and covering the open end with the hand, until it be inverted and merged in a vessel containing some of the same metal, without allowing any air to enter. A mercurial column 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, from 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.

20.—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 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 18 miles it will be	$\frac{1}{64}$
9 - - - -	$\frac{1}{8}$	21 - - - -	$\frac{1}{128}$
12 - - - -	$\frac{1}{16}$	24 - - - -	$\frac{1}{256}$.
15 - - - -	$\frac{1}{32}$	27 - - - -	$\frac{1}{512}$
		30 - - - -	$\frac{1}{1024}$

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

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

21.—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, CC, 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, of this little pump, 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, PP, 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 of 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 at 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.

22.—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.

23.—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 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.

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.

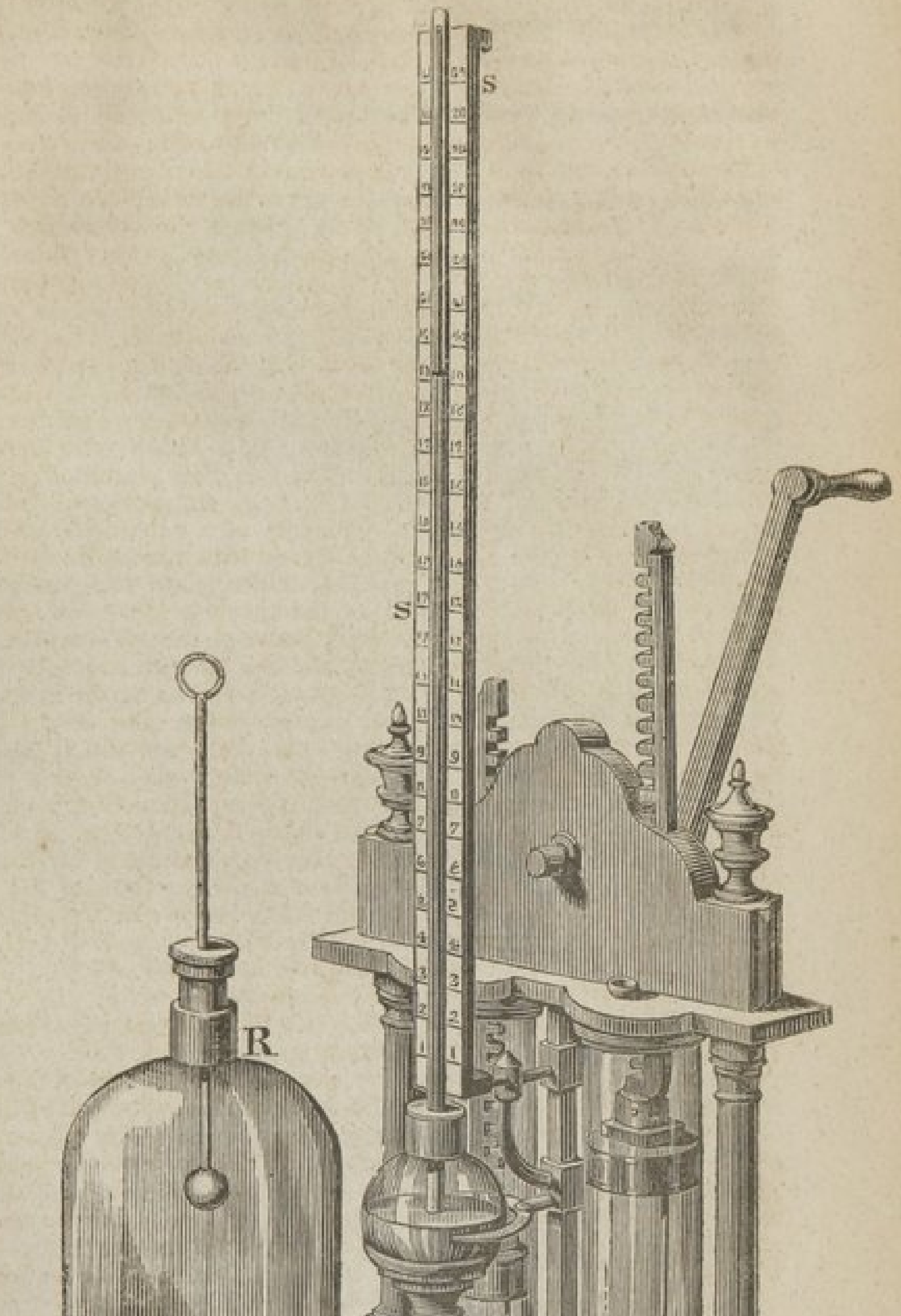
From the figure, it must be evident that this pump has two glass chambers: they are unusually large, being nearly three inches in diameter inside. The lower valve, V, is placed at the end of a rod, which passes through the packing of the piston. Hence, during the descent of the piston, the friction of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



In the original the first figure on the scale is 5, being that number of inches above the mercury. It is here erroneously represented.

23.—EXPERIMENTAL ILLUSTRATION OF THE ELASTIC REACTION OF THE AIR.

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.

24.—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.

25.—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 reenter 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 above-mentioned.

26.—EXPERIMENTAL PROOFS, OF THE WEIGHT OF THE ATMOSPHERE.

EFFECT OF ATMOSPHERIC PRESSURE ON THE HAND.

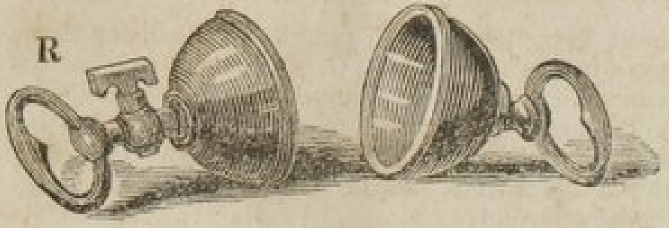
If, as represented in this figure, the air be exhausted from a vessel, covered by the hand, its removal will be found almost impracticable: for, supposing the opening, which the hand closes, to be equal to five square inches, the pressure on it will be seventy-five pounds.

27.—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.

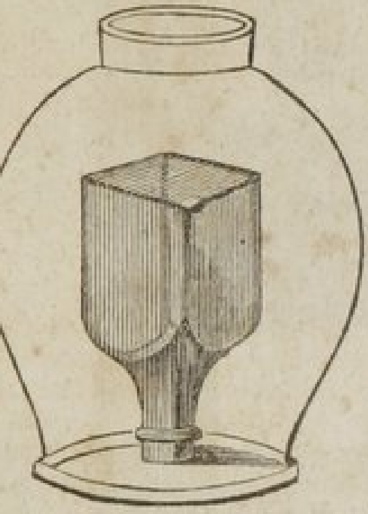
When the bladder is too strong to be broken, by the unassisted weight of the air, a slight score, with the point of a penknife, will cause it to be ruptured, not only where the score is made, but in various other parts, so that it will be, at times, torn, all round, from off the vessel.

28.—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.

29.—BOTTLE BROKEN BY EXHAUSTION OF THE AIR FROM WITHIN.

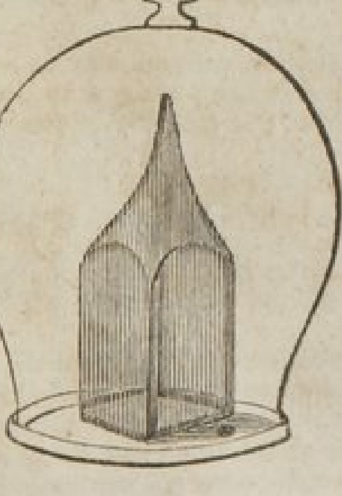


Proof that Atmospheric Pressure on the outside of a square Glass Bottle, will break it, as soon as it ceases to be counteracted by the resistance of the air within.

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 pump, by withdrawing the air from the interior, causes the bottle to be crushed with violence.

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

30.—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.

31.—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.

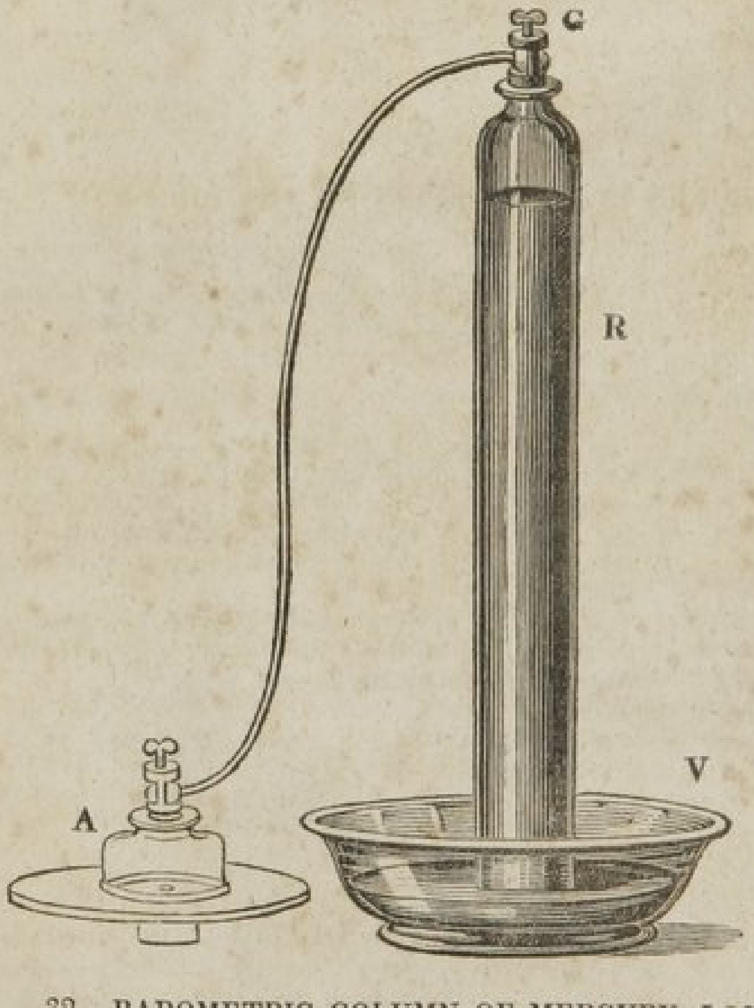


FIG. 2.

32.—BAROMETRIC COLUMN OF MERCURY, LOWERED BY EXHAUSTION.

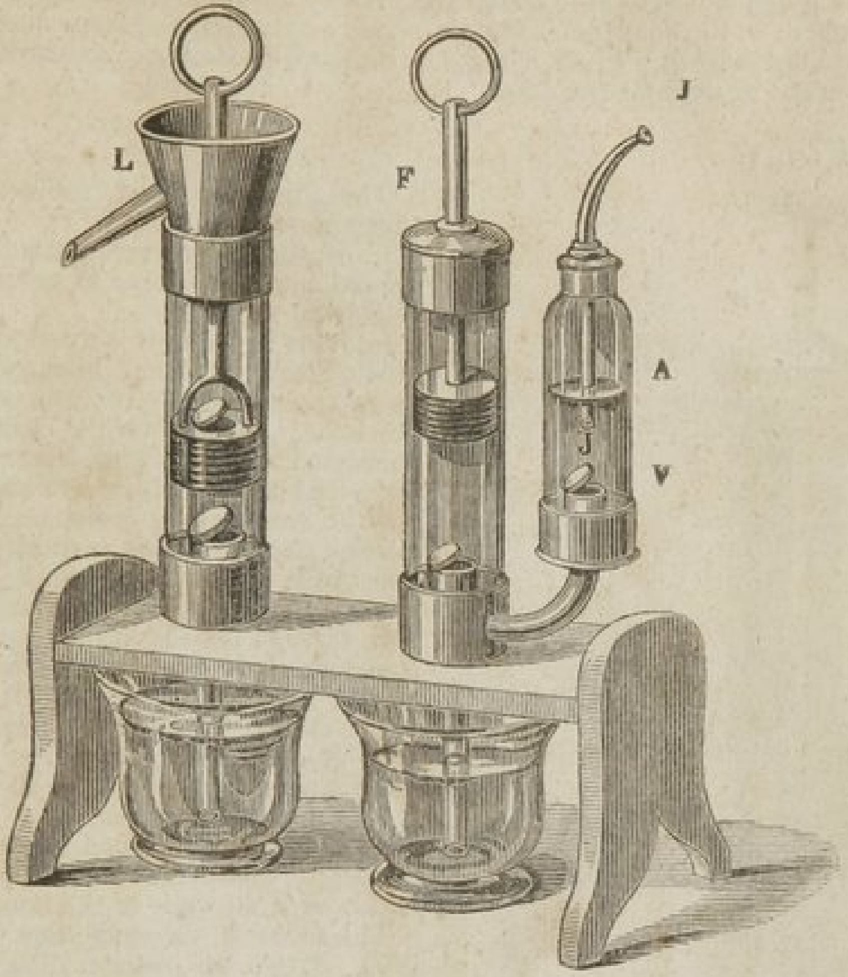
It has been shown, that in a tube void of air, a mercurial column may be supported at the height nearly of thirty inches; and this has been alleged to result from the pressure of the atmosphere on the surface of the mercury on the outside of the tube.

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 is lowered; 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 sinks 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.

33.—APPARATUS FOR ILLUSTRATING THE DIFFERENCE BETWEEN THE LIFTING AND FORCING PUMPS.



This figure represents an apparatus much used, in order to illustrate the action of the lifting and forcing pumps, for water.

The process by which the water is drawn into the chamber, in the case of either pump, is the same as that already described. In the lifting pump L, the water which has entered the chamber, during the ascent of the piston, rises through the piston, during its descent, to be lifted by it, when the motion is reversed. In the forcing pump F, the piston, being imperforate, during its descent, 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 expenditure of this liquid, (through the jet pipe, J J,) commensurate with the supply.

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.

34.—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.

FIG. 1.

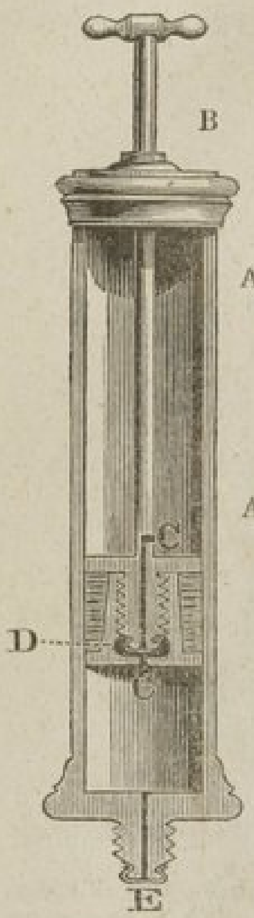


FIG. 2.

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.

35.—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 following figure.

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

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 rises the bladder is inflated, when the receiver sinks 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 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, (11) 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 (24, 25, 26,) 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.

THEORY OF EXPANSION.

The expansion of masses, 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 it will combine with them, and in proportion to the quantity of caloric thus combined, will they acquire that self-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 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.

Water would boil at a lower temperature than 212°, if the atmospheric pressure were 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.

37.—THAT THE BOILING POINT IS LOWERED BY A DIMINUTION OF ATMOSPHERIC PRESSURE, EXPERIMENTALLY DEMONSTRATED.

Water heated to ebullition in a glass vessel, having ceased to boil in consequence of its removal from the fire, will boil again under a receiver, as soon as the air is withdrawn.

38.—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.

39.—AERIFORM STATE DEPENDENT ON PRESSURE.

Proof that some Liquids would always be aëriform, were it not for the Pressure of the Atmosphere.

FIG. 1.

A glass flask, fig, 1, being nearly filled with water, and having the remaining space occupied by sulphuric ether, is inverted in a glass jar, covered at bottom by a small quantity of water, to prevent the air from entering the neck of the flask. The whole being placed upon the air pump plate, under a receiver, and the air exhausted, the ether assumes the aëriform state, and displaces the water from the flask. Allowing the atmospheric air to re-enter the receiver, the ethereal vapour is condensed into its previous form, and the water reoccupies its previous situation in the flask.

FIG. 2.

The return of the ether, to the state of liquidity, is more striking, when mercury is employed, as in fig. 2; though, in that case, on account of the great weight of this metallic liquid, the phenomenon cannot be exhibited, on so large a scale, without endangering the vessels, and risking the loss of the mercury.

RATIONALE.

The particles of the ether, and those of the caloric, in the adjoining medium, are incessantly endeavouring to approach each other; yet, more than a certain number, of particles of the caloric, cannot enter the ether; because, those that are already in union with it, repel the rest. On the other hand, the ethereal particles cannot move outwards, towards those of the caloric, without overcoming the pressure of the atmosphere, and assuming the aëriform state. Hence, although ether remains a liquid, while confined by that pressure, it becomes gaseous, as soon as it is liberated.

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.

40.—BOILING POINT RAISED BY PRESSURE.

As the Boiling Point is lowered by diminution of Pressure, so it is raised if the Pressure be increased.

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 into a foam, produced by the rapid extrication of its vapour.

This experiment may be performed more securely, by employing a vessel of hot water, instead of a flame, to warm the matrass.

41.—COLUMN OF MERCURY RAISED BY VAPORIZED ETHER.

An increase of Pressure results from constrained Ebullition.

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 gradually falls to its previous situation.

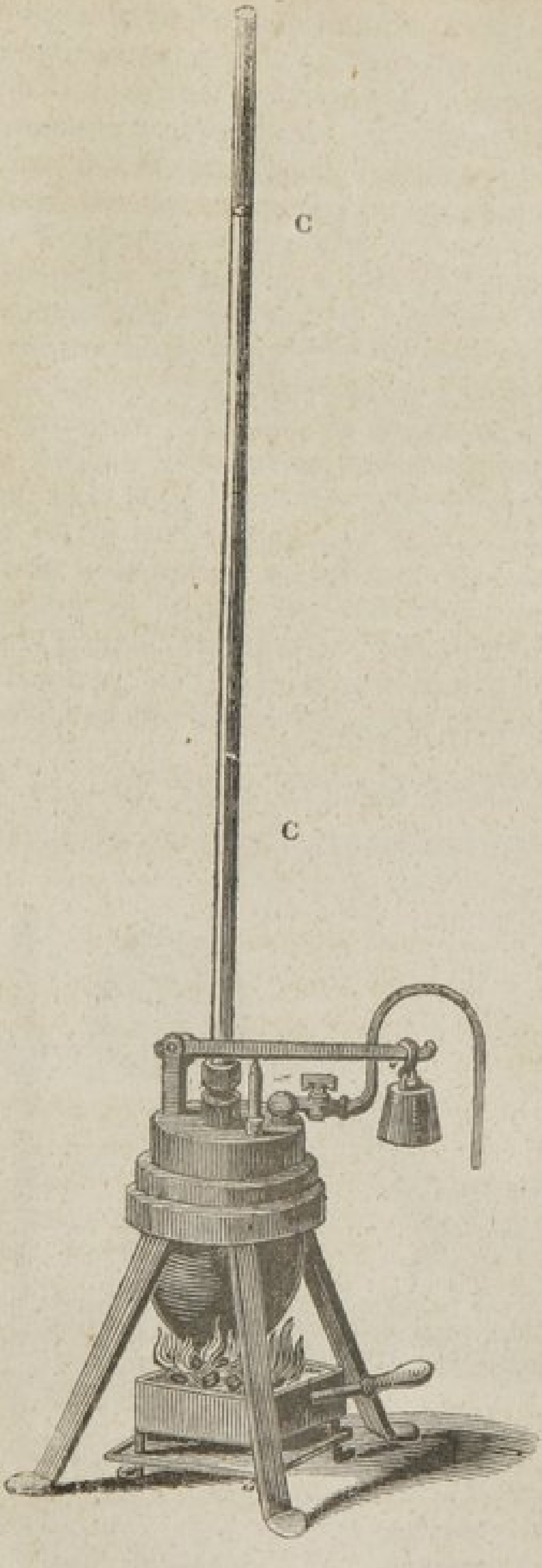
42.—HIGH PRESSURE BOILER.

That the temperature of Steam is directly as the pressure, may be demonstrated by 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 of 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 inserted, 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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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, in this predicament, 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 nine measures of water in the liquid form, one hundred degrees.

43.—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, was opened in a pipe descending into a reservoir of cold water. 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 drew up the piston in the cylinder, and pushed down the pump rod, 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. This being done, the vapour passes almost entirely into the latter. Hence his contrivance of a condenser into which the steam passes from the cylinder in which the piston moves. 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 above the piston, it is condensed below—while it is entering below, it is condensed above.

Of the High Pressure Engine.

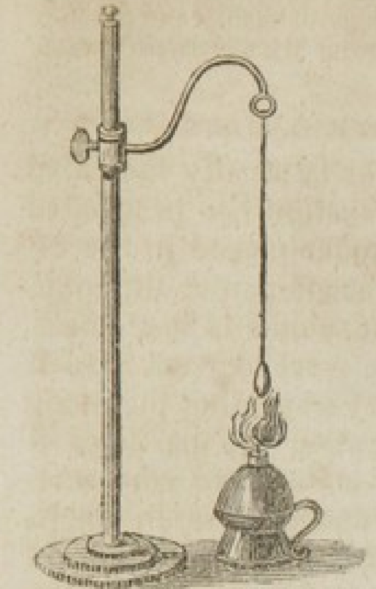
The only material difference between the operation of the high pressure engine, and that above described, is, that the steam escapes alternately, from above, and below the piston, into the air, instead of passing into a condenser.

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.

44.—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 41. 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, somewhat less than 40 degrees (F.).

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 the maximum pressure of water to be 4000 atmospheres. He has also stated 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 $\frac{1}{4}$ of an inch in diameter, the steam will not escape, although upon a reduction of temperature, it will rush out of the vessel with great violence.

RATIONALE.

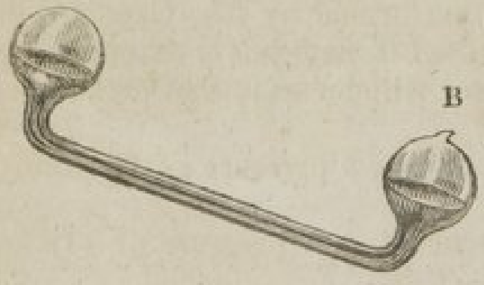
In order to reconcile these surprising facts with our premises, it is only requisite to suppose that the repulsive power of the caloric, combined with the water at a red heat, by which it was impelled to escape, was less than the repulsive power of the caloric combined with the iron, which formed the circumference of the aperture at which the efflux was prevented. As, however, the aqueous particles were enabled to pass through the same opening, at lower temperatures, it seems that their capacity for heat, in proportion to the iron, was lessened as the common temperature became greater.

If, in rising to high temperatures, the elastic force of steam were to increase geometrically in the same ratio as at lower temperatures, doubling the pressure for every increment of forty degrees, at 1000 degrees, the pressure would be nearly fifteen millions of pounds per square inch. It would seem incredible, a priori, that an attraction could exist between the particles of water and those of caloric, adequate to produce such a force: and Mr. Perkins's experiments render it improbable that such a result could be attained. Hence both theory and practice concur to justify the impression, that the attraction between the particles of water and caloric, though great, is not without limitation.

45.—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 41, Theory of Expansion) respecting the mode in which caloric exists in atmospheres, between the particles of ponderable matter, it will not be difficult to understand why aëriform fluids should absorb more caloric, in proportion as, in obedience to it, 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.

46.—CONSTRUCTION OF THE PALM GLASS.
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 fusing it in 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, (14,) with those of the culinary paradox, (38,) 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 of the liquid is forced from the bulb, in the hand, a very 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, (45) both being attributable to the increase of capacity for caloric, resulting from a diminution of density.

47.—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.

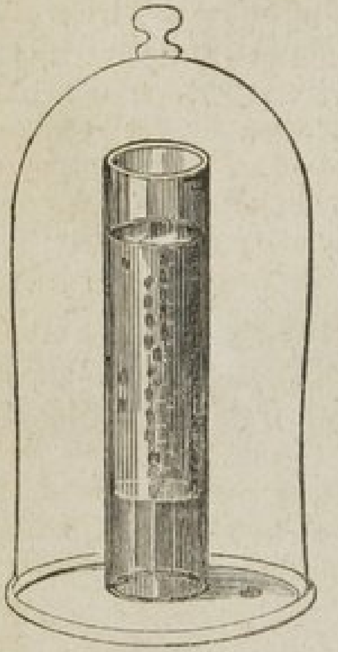
Apparatus for showing the influence of Relaxed Pressure, on the capacity of Air for Heat, or Moisture.

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.

48.—INFLUENCE OF PRESSURE ON THE ESCAPE OF GASEOUS SUBSTANCES FROM COMBINATION.

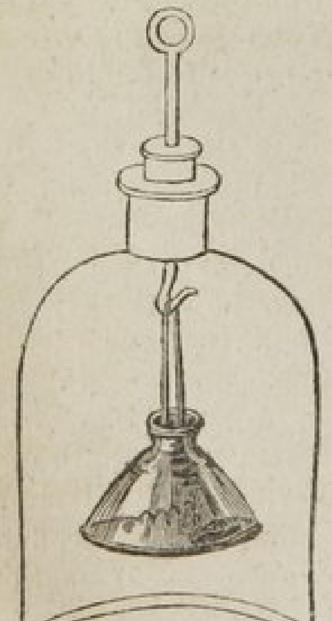
When one of the ingredients of a Solid, or Liquid, is prone to assume the aëriform state, its extrication will be more or less easily effected, in proportion, as the Pressure of the Atmosphere is increased, or diminished.



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 necessity 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.

49.—COLD PRODUCED BY VAPORIZATION IN VACUO.

WATER FROZEN BY BOILING ETHER.



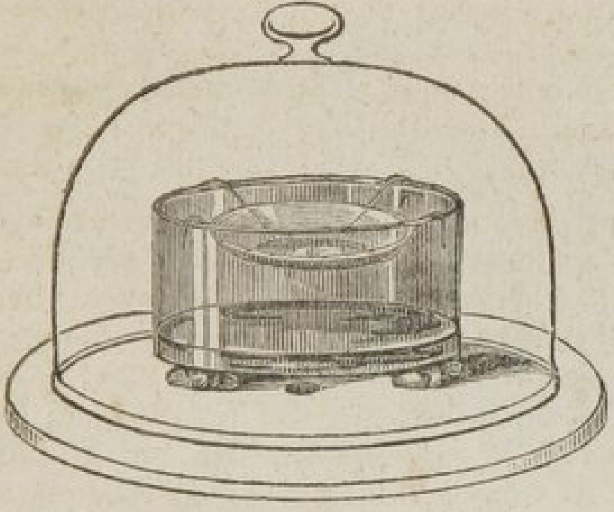
Let a portion of water, just adequate to cover the bottom, be introduced into the vessel, represented in the subjoined drawing, as suspended within a receiver. Over the water, let a stratum of ether be poured, from an eighth, to a quarter of an inch in depth. If, under these circumstances, the receiver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

RATIONALE.

While the particles of the ether are pressed by the weight of the atmosphere, their attraction for caloric is incompetent to cause a union with a quantity of it, adequate to sustain them in the aëriform state; but, when they are no longer subjected to an extraneous cause of approximation, they are at liberty to indulge their partiality for that self-repellent fluid. Under these circumstances they attract caloric more powerfully, than water; and consequently, will cause the congelation, of any portion of this liquid, with which they may communicate, by abstracting from it the principle, to which it owes its fluidity.

50.—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 on the air pump plate within a receiver, as represented in this engraving. Under these circumstances, the exhaustion of the receiver causes the congelation of the water.

RATIONALE.

As the aqueous vapour is absorbed, by the sulphuric acid, as fast as it can be emitted; and as, in the case of its emission, no less than in that of the etherial vapour, in the last experiment, there must be an expenditure of caloric by the subjacent water; the residual portion of this liquid is gradually reduced in temperature, and may finally be frozen.

51.—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 the rapid condensation of vapour in another.

In form, this instrument obviously differs but little from the palm glass, already described (46). It is supplied by the same process, with a small portion of water, instead of alcohol; so that there is nothing included in it, unless water, either liquid, or in vapour.

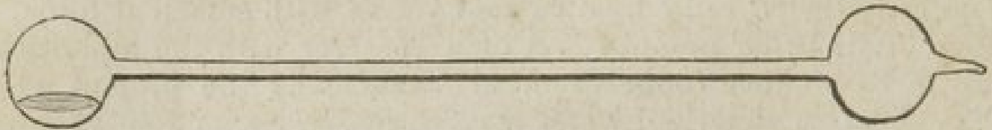
The Cryophorus being thus made, if all the water be allowed to run into the bulb near the bent part of the tube, and the other bulb be immersed in a freezing mixture, the water will freeze in a few minutes.

RATIONALE.

So long as no condensation is effected, of the thin aqueous vapour, which occupies the cavity of the instrument, that vapour prevents, by its repulsion, the production of more vapour: but when, by means of cold, the vapour is condensed in one bulb, its evolution in the other, containing the water, being unimpeded, proceeds rapidly. Meanwhile the water becomes colder, and finally freezes, from losing the caloric which the vaporization requires.

According to Wollaston, one grain of water, converted into vapour, holds as much caloric as would, by its abstraction, reduce thirty-one grains from 60° F. to the freezing point; and the caloric requisite to vaporize four grains more, if abstracted from the residual twenty-seven grains, would convert them into ice.

52.—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.

COLD PRODUCED BY EVAPORATION.

It is well known that the direction of the wind becomes evident, from the sensation of coldness experienced in that portion of the wetted finger on which it beats. 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 is ascribed to the influence of the air in assisting the formation of vapour. Probably the attraction of atmospheric air for liquids, counteracts the influence of its weight in retarding vaporization, as already illustrated in the preceding experiment, and in 37. 39. The extent to which evaporation can be aided by the air, must be dependent on the volatility of the liquid subjected to it, as well as on the extent to which contact may be induced between the aëriform 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.

53.—EXPERIMENTAL ILLUSTRATION.

The cold, produced by evaporation, 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 ethereal particles may be duly mingled just before reaching the bulb. Water freezes when contained in a bulb thus refrigerated.

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 different temperature, will be found very unequal. Thus the effect of a given weight of water being 1000, the effect of a like weight of glass will be 137; of copper, 114; of tin, 60; and of lead, 42; and if equal bulks be tried, the effect of copper will be 1027, glass, 448, lead, 487, tin, 444. 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.

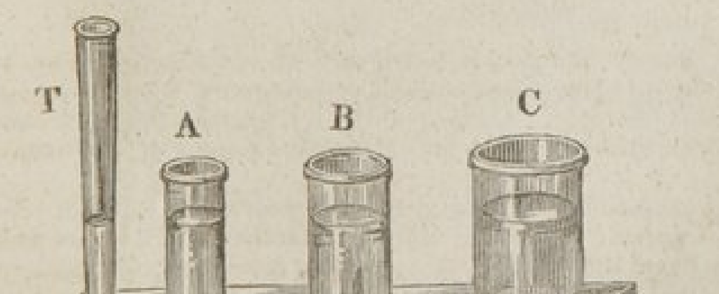
This diversity in the power of substances, equally hot or cold, in influencing temperature, is ascribed to a difference in their capacity to attract caloric, in consequence of which it forms, probably, denser atmospheres about the atoms of some substances, than it does about those of other substances.

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, to its previous condensation in the other. See Theory of Expansion, page 41.

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.

54.—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.

It appears from 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, as in the case of two metals for instance, 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, 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.

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.

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.

The only distinguishing characteristic, derived from its previously superior temperature and density, is a greater velocity of efflux. Moreover, it appears from the principle which has been illustrated, (47,) that any relaxation of constraint sustained by aëriform matter, may be expected to produce a partial condensation of vapour, if present. Thus 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 due distance from the place of its efflux, by its admixture with the atmosphere, agreeably to a principle already illustrated (53).

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 platina and lead, the worst.

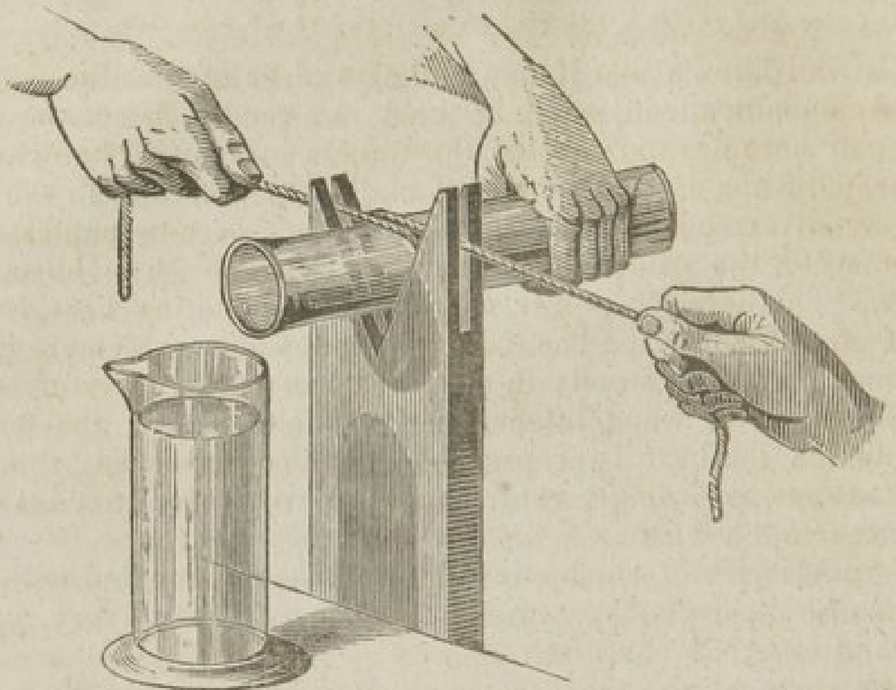
55.—INEQUALITY OF CONDUCTING POWER, EXPERIMENTALLY ILLUSTRATED.

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.

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



Some years ago, Mr. 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 equi-distant 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.

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

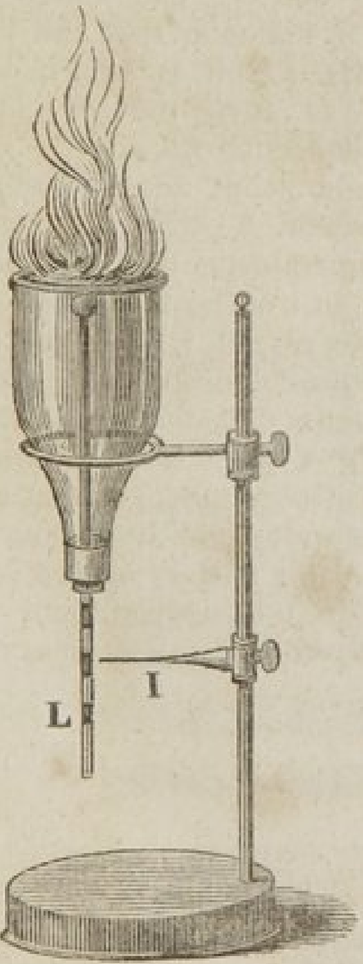
I conceive that in solids, the stratum of atoms, forming the surface first exposed to the heat, combining with an excess of this principle, divides it with the next stratum. The caloric received by the second stratum, is in the next place divided between the second and third stratum. In the mean time 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 is 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?

57.—LIQUIDS ALMOST DESTITUTE OF CONDUCTING POWER.



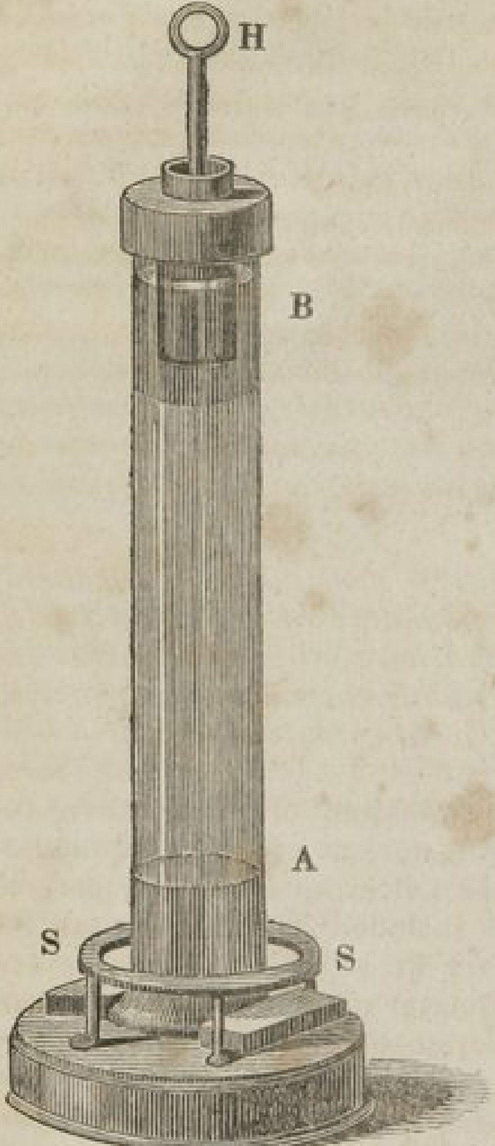
That liquids are almost devoid of power to conduct heat, proved by the inflammation of Ether, over the bulb of an air thermometer, protected only by a thin stratum of water.

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.

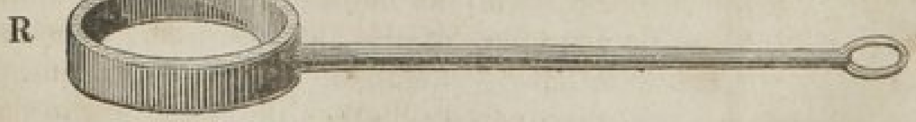
CIRCULATION INDISPENSABLE, TO AN EFFECTUAL COMMUNICATION OF HEAT IN LIQUIDS.

58.—DIFFERENT EFFECTS OF HEAT, ACCORDINGLY AS IT MAY BE APPLIED TO THE UPPER OR LOWER STRATA OF A LIQUID, EXPERIMENTALLY EXEMPLIFIED.



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; but the heat penetrates only a very small distance below the tin cylinder, so that the colourless water, and the coloured stratum, at the bottom of the vessel, remain undisturbed, and do not mingle. 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 a 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 a 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.†

59.—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 supported, so long

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* I used to perform this experiment with an inclined tube, as suggested in Henry's Chemistry. The modification here given, is so far a contrivance of my own, as relates to the use of the heater, tin cap, and iron ring; and the employment of two colours instead of one. On account of the liability of the glass to crack, I found the old method very precarious, when a tube was used large enough to show the phenomena advantageously.

† See Appendix, for essay on the gales experienced in the Atlantic States of North America.

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.

OF RADIATION, OR THE QUICK COMMUNICATION OF CALORIC.

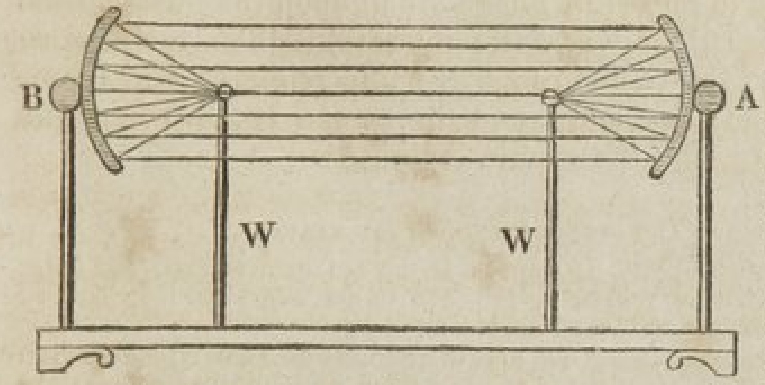
It must be evident that the heat which we receive from a fire, in opposition to the draught, reaches us, neither by the conducting process, nor by circulation. Actual contact is evidently indispensable to the passage of heat in either of these modes. The aëriform matter which is in contact with the embers, 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 aërial 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 abovementioned, 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.

60.—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 axes 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.

61.—PHOSPHORUS IGNITED AT THE DISTANCE OF TWENTY, OR EVEN AT SIXTY FEET, BY AN INCANDESCENT IRON BALL.

Opposite to the next page is a figure representing the mirrors, which I employ in the ignition of phosphorus, and lighting a candle, by an incandescent iron ball at the distance of about twenty feet.

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 ascertain-

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

ed 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.

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.

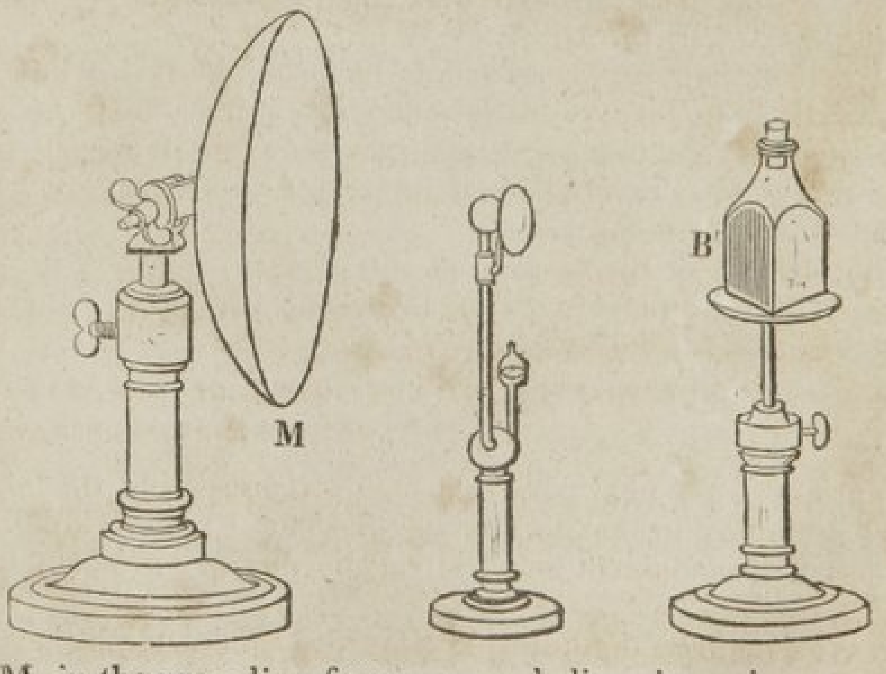
I designed these mirrors, and proposed to have them made out of castings; but pursuant to the advice of Dr. Thomas P. Jones, I resorted to sheet brass, which was rendered the more competent by strengthening the rims with rings of cast brass, about three-fourths of an inch thick each way. For the idea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

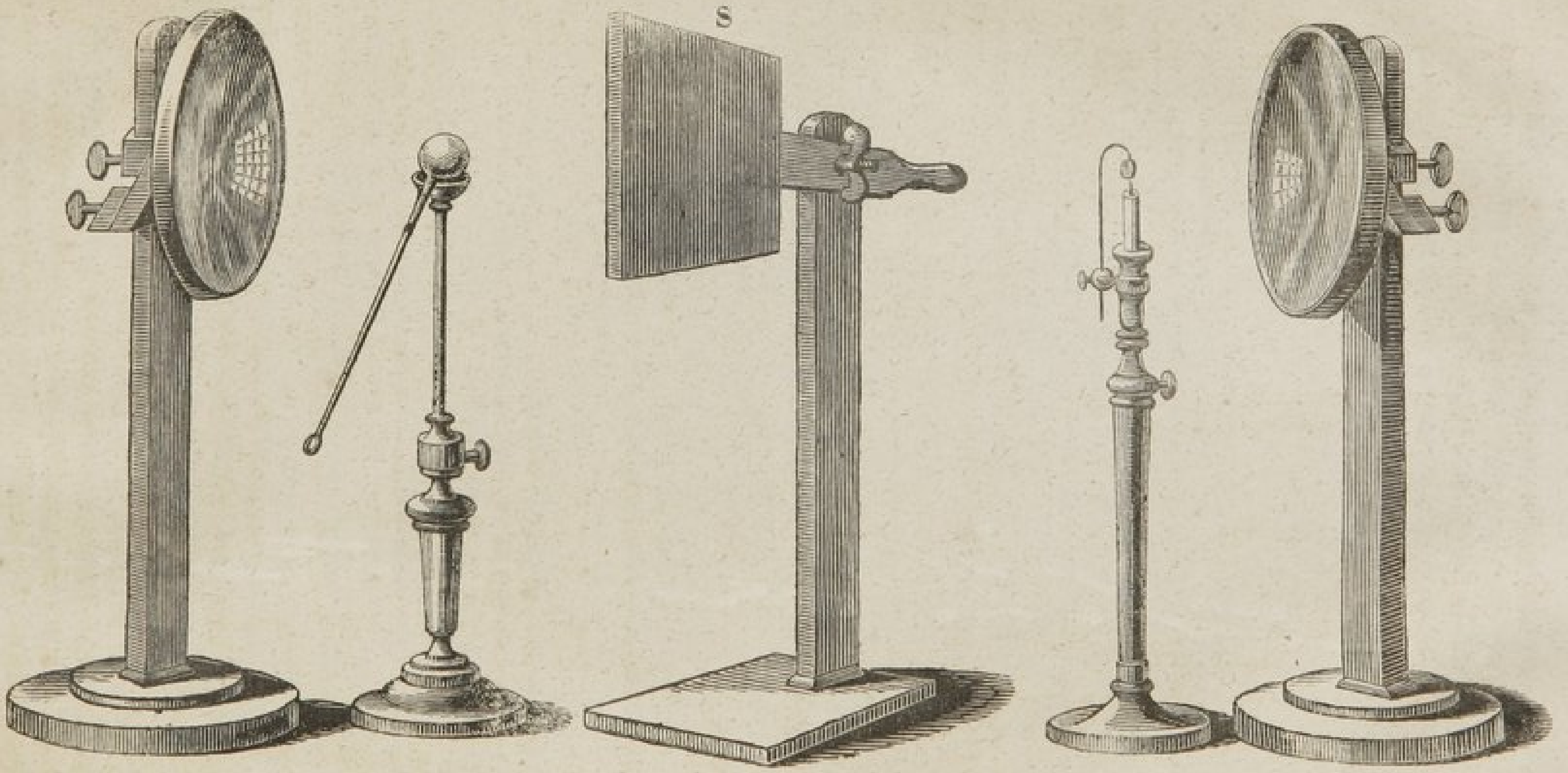
For the rationale of the operation of the mirrors, I refer to the preceding article.

62.—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, a square glass bottle, one side of which is covered with tinfoil, and another so smoked by means of a lamp, as to be covered with carbon. Between the bottle and mirror, and in the


S

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 tinfoil 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.

When a polished brass andiron is exposed from morning till night to a fire, so near as that the hand, placed on it, is scorched intolerably in a few seconds, it does not grow hot.

To preserve heat, in air, or to refrigerate, in water, vessels should be made of bright metal. Fire places should be constructed of a form and materials to favour radiation: flues, of materials to favour the conducting process.

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 pre-eminence 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.

63.—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 ascribed to the radiation of cold, and has been considered as demonstrating the materiality of that principle. 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 in evidence, of a material cause of cold.

The explanation which I give of this phenomenon, agreeably to the opinion that cold is negative heat, is as follows.

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 the density, as in the case of aëriform fluids. It follows that the repulsive power of caloric being in the ratio of the quantity, that either a diminution or increase of temperature in any spot, must equally produce a movement, in the particles of caloric, 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.

64.—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 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 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 make burning glasses or mirrors large enough, and at the same time sufficiently manageable and efficient.

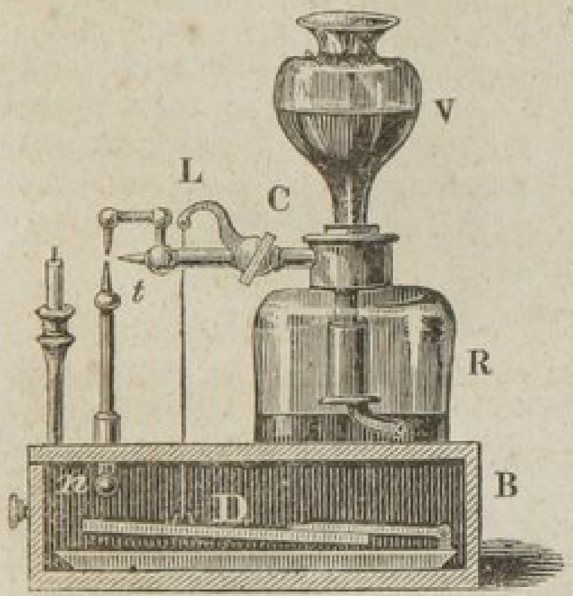
Few of the occurrences of antiquity have excited more attention, than the destruction of the Roman ships, which Archimedes is alleged to have accomplished, by concentrating upon them the rays of the sun.

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 discovery of the heat excited by oxygen gas, the compound blowpipe, or by the 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, or 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. Any further explanation of electrical phenomena, will be reserved for the lectures on electricity.

65.—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 of the insulated wire, *n*. 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 by grinding to the neck, 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.

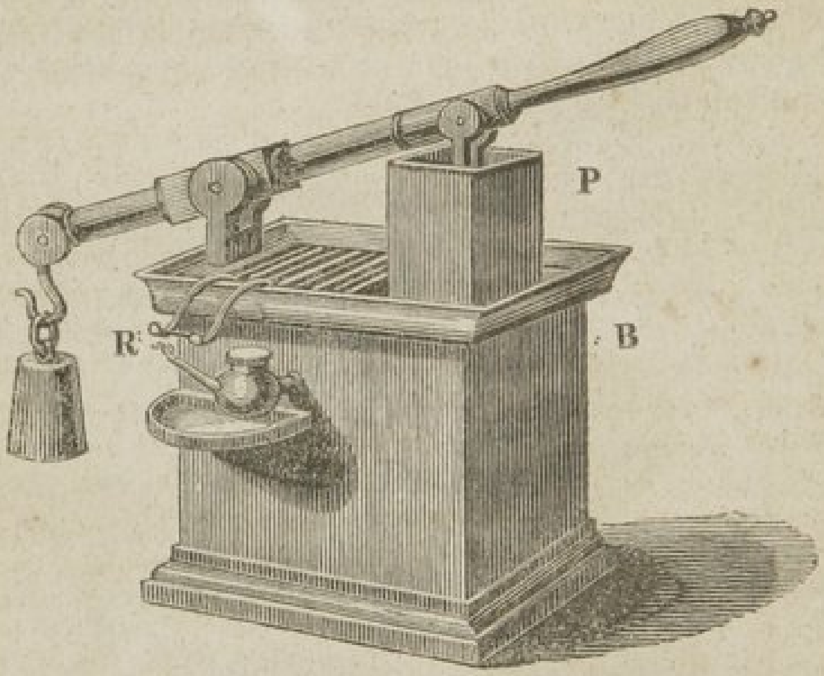
If the reservoir be duly supplied with diluted sulphuric acid, the reaction between this solvent and the zinc, will evolve hydrogen gas. The gas thus evolved, if not allowed to escape, will force the liquid which generates it, through the orifice of the tube proceeding from the vessel, V, into the cavity 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 any portion of the gas is allowed to escape, by opening the cock, 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, duly exposed to its influence.

For a rationale of the Electrophorus, I refer to my Lectures on Electricity.

IGNITION BY GALVANISM.

I will show one convenient mode of producing Galvanic ignition, deferring any further illustration or explanation till Galvanism and Voltaic Electricity shall be regularly discussed.

66.—THE GALVANOPHORUS, OR GALVANIC SUBSTITUTE FOR THE ELECTROPHORUS.



The preceding 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.

67.—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. Prior to Sir H. Davy's invention of the safety lamp, an analogous apparatus, called a steel mill, had long been employed to procure light in mines, infested with carburetted hydrogen. This gas explodes on coming into contact with the flame of a lamp or candle; but is not ignited by the scintillation of the steel mill.

68.—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.

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 57.

69.—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.

The heat, produced by friction, has already been exemplified, (56). 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.

70.—IGNITION BY ATTRITION.

If the circumference of a thin disk of sheet iron, whilst rapidly rotating, 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 the steel, having to encounter successively many of iron, the heat, generated by the attrition, accumulates in the part, nearest to the conflict, 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.

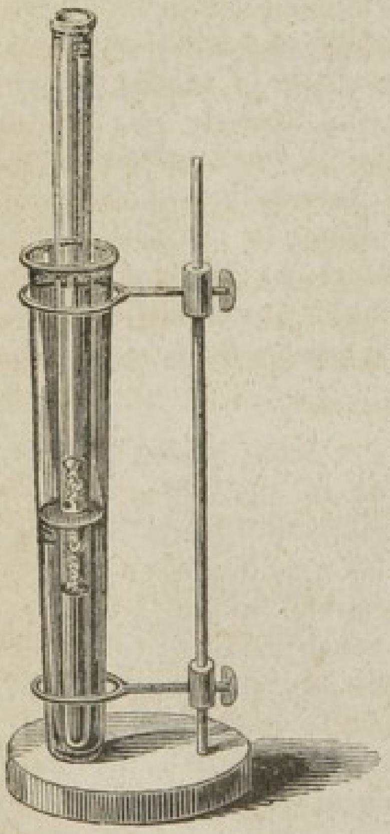
71.—HEAT PRODUCED BY COMBINATION.

Instances of simple chemical combination have been given, page 11, experiment 2.

It has recently excited no small degree of surprise, that the union of tin, or lead, with platina, 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 platina, so as to form a mass as large as can be conveniently ignited by means of a blowpipe. As soon as the roll becomes red hot, it passes instantly to a state of incandescence, the union being effected with an astonishing energy.

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 described in the following article.

72.—BOILING HEAT PRODUCED, BY THE MIXTURE OF SULPHURIC ACID WITH WATER.



Into the inner tube, represented in the adjoining figure, introduce about 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 3 times its bulk of concentrated sulphuric acid. The liquid in the inner tube will soon boil violently, so as to rise in a foam.

73.—CHEMICAL COMBINATION, ATTENDED BY DECOMPOSITION, AS THE MEANS OF EVOLVING CALORIC.

Instances of that species of corpuscular reaction, which comes under this head, were afforded, page 12, in treating of affinity. The extrication of caloric, which is usually more or less a consequence of intense chemical reaction, being a collateral, rather than a necessary consequence of it, was not then properly a subject for discussion.

As an example in which caloric is rendered sensible, by the method in question, the inflammation of turpentine by a mixture of nitric acid, with sulphuric acid, may be adduced.

The inflammation of alcohol, or oil of turpentine, by means of a chlorate and sulphuric acid, as represented by this figure, affords another exemplification perfectly in point.*

About as much chlorate of potash as may be piled upon a half cent, being deposited in a heap, amid the inflammable liquid, the affusion of concentrated sulphuric acid upon the heap, causes the liquid to be inflamed.

As portions of the liquid are sometimes projected into the air, in a state of inflammation, it is expedient, for the security of the operator, to have the glass, used to convey the acid, fastened to the end of a rod.

A compound jet, produced by the concurrence, at the place of efflux, of two jets, one of strong nitric acid, the other of oil of turpentine, would probably produce effects, nearly as terrific as those ascribed to the Greek fire.

RATIONALE.

It would seem as if certain substances, which always, when uncombined with ponderable matter, exist in the gaseous state, on being converted into solids, or liquids, by a union with other ponderable matter, in some cases retain, in others relinquish, the caloric to which they owed the gaseous state. Hence, if from compounds, in which they retain their caloric, they be taken by the superior affinity of substances, whose union with them does not permit the retention of this repulsive principle, its evolution ensues so rapidly, as to produce active ignition. The explosion of gunpowder is an analogous phenomenon.

74.—SOLUTION, AS A MEAN OF 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.

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* Since this figure was drawn, I find a shallow vessel, like a small breakfast-plate, preferable to the cup represented in the figure; which is more contracted at the mouth and deeper than the original. The air requisite to support the inflammation, has a more easy access when a plate is used, and the action of the acid on the chlorate is more generally visible.

75.—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 approach so nearly that they unite more intimately, and therefore emancipate a large quantity of caloric, with which, they were previously combined.

76.—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 air becomes cooler by rarefaction; also warmer by compression (46, 47). It appears that when the compression is carried very far, so much caloric is liberated as to cause ignition. This experiment is performed by means of a small condenser, the construction of which does not differ from that which has been described (34), excepting that a cock for the introduction of spunk, or tinder, 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.

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 dung, 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.

77.—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 the quantity 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 above illustrated.

This vertical current of heated air, in the case of a smoky lamp flame, is well designated 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: it operates also above the flame, where it narrows the heated column, and retards its progress. In the Argand lamp, this evil is prevented by a glass chimney, which 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 the utility of their application will be evident.

78.—OF BELLOWS—OF FORGE FIRES.

Bellows are so universally known, as the means of exciting combustion, 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 which is 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, 33.

79.—LAMP WITHOUT FLAME.

About the wick of a spirit lamp, a fine wire of platina 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 this lamp be lighted; on blowing out the flame, 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.

Instead of blowing out the flame, it is better to put an extinguisher over it, for as short a time as will cause the flame to disappear. For this purpose, a small phial, or test tube, is preferable to the metallic cap usually employed.

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.

80.—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 the abovementioned appellation, 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, to catch the condensed moisture of the breath, as in this figure.

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, and 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.

81.—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 were 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."

The machine, which the following figure represents, does not differ essentially

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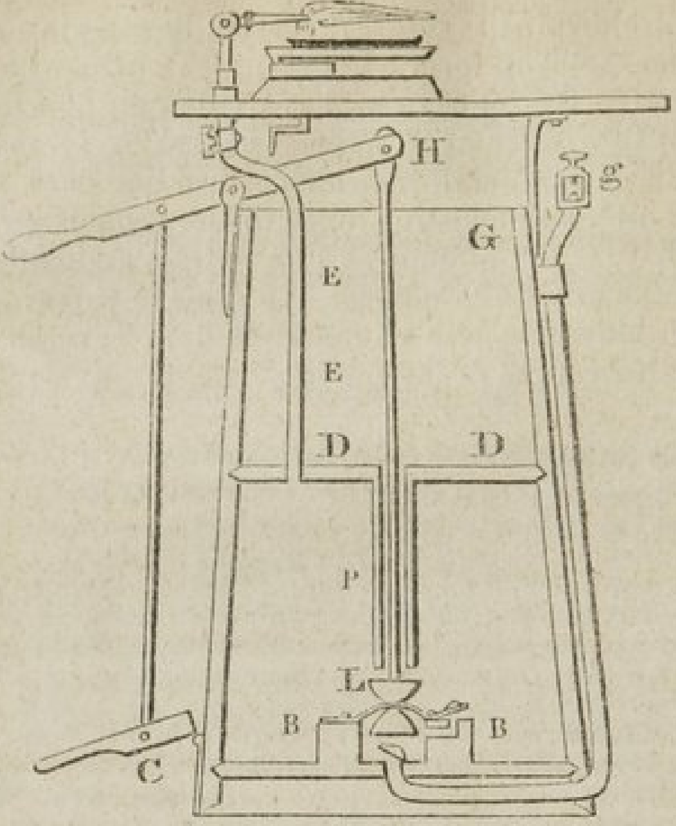
* In consequence of this, some artists have been obliged to abandon the use of the instrument.

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, DD, 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.

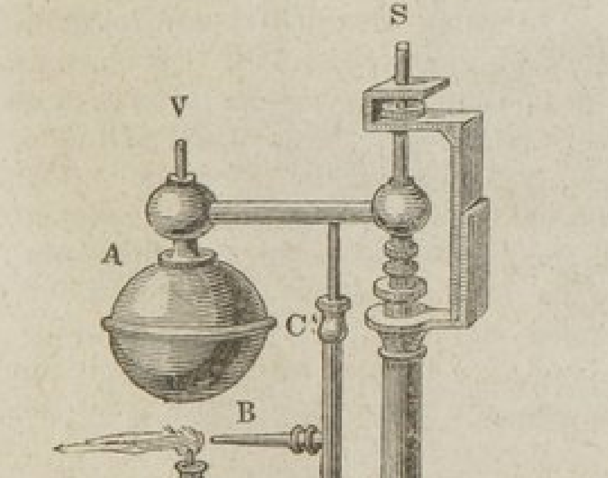
Having used the Hydrostatic Blowpipe for six and twenty years, I am enabled to speak in favour of its conveniency, with the confidence due to this long trial. I am persuaded, that it would be found exceedingly useful, to all artists who employ the blowpipe in soldering, or in blowing, or moulding the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

82.—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 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 pair of double bellows is placed under the table so as to be worked by the foot, and so as to act upon the flame through a pipe terminating in a beak like that of a blowpipe.

83.—ALCOHOL BLOWPIPE.



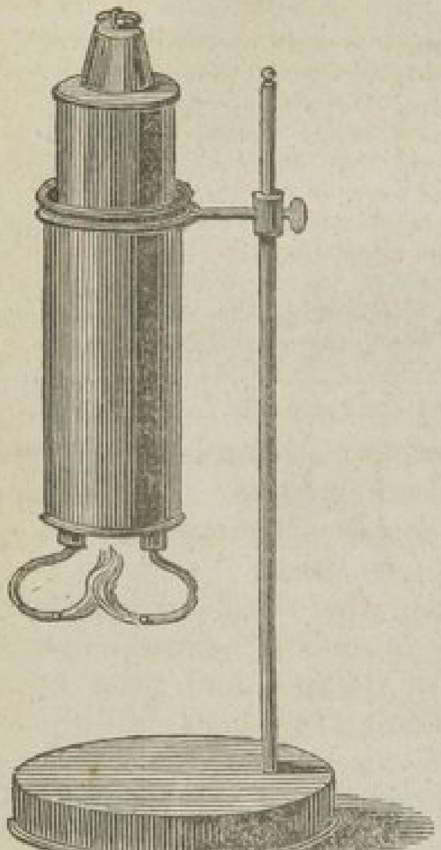
A flame resembling that of the enameller's lamp, may be produced by a small boiler, A, containing alcohol, in which alcoholic vapour is generated, as steam is, by the boiler of a steam engine.

The vapour thus generated, is substituted for air in the blast of the blowpipe, being directed upon the flame of a lamp in the same way, by means of a pipe proceeding from the boiler, and terminating in a beak with a capillary orifice, B. The boiler is furnished with a safety valve, V.

It may be objected to flame thus excited, that as the oxygen is not so copiously supplied, as when a stream of air is used, the oxide of lead in flint glass tubes is reduced by it, and the glass consequently blackened.

The apparatus here represented, is furnished with an adjusting screw, S, by which the height of the boiler is regulated; while the communication is preserved between it and the beak, by means of a tube sliding through a stuffing box, C, which surmounts a larger tube to which the beak is soldered.*

84.—A NEW MODIFICATION OF THE BLOWPIPE BY ALCOHOL.



This figure represents an improved blowpipe, by alcohol. In the ordinary construction of the blowpipe by alcohol, the inflammation is kept up, by passing a jet of alcoholic steam through the flame of a lamp, supported, as is usual, by a wick. The inflammation, of the jet, cannot be sustained without the heat of the lamp flame; since the combustion does not proceed with sufficient rapidity, to prevent the inflamed portion from being carried too far from the orifice of the pipe; and being so much cooled by an admixture of air, as to be extinguished. By using two jets of vapour, in opposition to each other, I find the inflammation may be sustained without a lamp. If one part of oil of turpentine, with seven of alcohol, be used, the flame becomes as luminous as a gas light.

In order to equalize and regulate the efflux, I have contrived a boiler, like a gasometer. It consists of two concentric cylinders, open at top, leaving an interstice of about one quarter of an inch between them; and a third cylinder, open at bottom, which slides up and down in the interstice. The interstice being filled with boiling water, and alcohol introduced into the innermost cylinder, it soon boils and escapes by the pipes. These pass through stuffing boxes in the bottom of the cylinder. Hence their orifices, and of course the flame, may be made to approach to, or recede from, the boiler. It must be obvious that the introduction of the alcohol requires the temporary removal of the intermediate cylinder.

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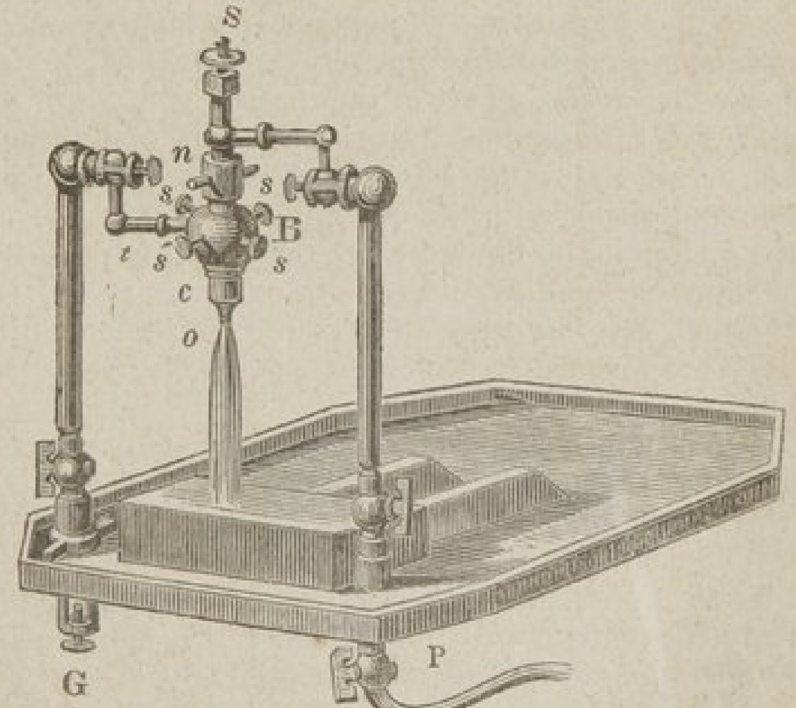
* Stuffing box is the technical name given by mechanics to a small hollow metallic cylinder, in which, by means of another cylinder acted upon by screws, some cotton, tow, leather, or other elastic substance, is packed about a rod, so as to allow it to move to and fro without permitting any fluid to escape from the vessel into which it may enter.

85.—OF THE HYDRO-OXYGEN OR COMPOUND BLOWPIPE.

In the year 1802, by the invention of the hydro-oxygen or compound blowpipe, 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. Yet, excepting the republication of my Memoir in Tilloch's Magazine, (London) and in the Annales de Chimie, (Paris); also the quotation of it by Murray in his System of Chemistry, it was generally neglected. Hence, 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.

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

The following figure represents a compound blowpipe which I contrived and executed myself, about eleven years ago; 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 RENDERING CALORIC LATENT.

86.—COLD BY VAPORIZATION OR EVAPORATION.

The cold produced by evaporation, and by vaporization, has been already sufficiently illustrated. Congelation was effected in one liquid, by the ebullition of another. Pure prussic acid affords the still more surprising phenomenon of a liquid freezing by its own evaporation.*

87.—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. By the mixture of the aqueous particles with any of these substances, a mass is formed, of which the freezing point is far lower than that of water. Hence it thaws at any temperature above its freezing point, and abstracts caloric from substances in contact with it, until they are refrigerated to that point.

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 evi-

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* It must be observed that vaporization, and evaporation, are not to be confounded. By the former, vapour is produced, by the agency of caloric alone; in the latter, atmospheric air co-operates with caloric. The preservation of this distinction, is the more important, because some liquids, which are more easily evaporated, are less easy to vaporize. Thus essential oil of turpentine (commonly called spirit of turpentine) is more susceptible of evaporation, and less susceptible of vaporization, than water. In other words, one boils at 212° F.; the other requires more than 300°; yet it is well known, that spirit of turpentine, is more "*drying*" than water. A correct idea of the distinction between vaporization, and evaporation, is very important in pharmaceutical operations.

dently 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. Far from decomposing these substances, it is notorious that cold does not even lessen their fulminating power.

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.

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.

Nature of Light.

According to Newton, and a majority of modern philosophers, it 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.

Velocity of Light.

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.

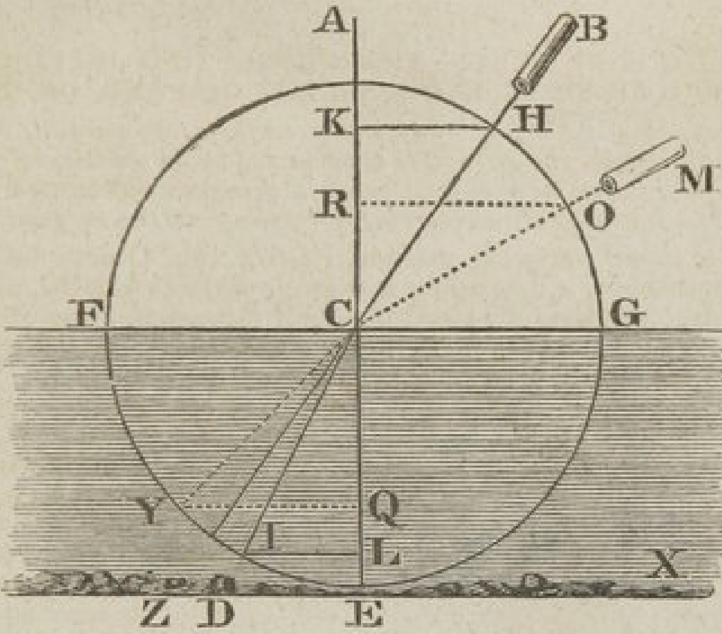
Inconceivable Minuteness of Light.

The loss of weight in combustion, which can be ascribed to the escape of light, is inappreciable; 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.

88.—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.

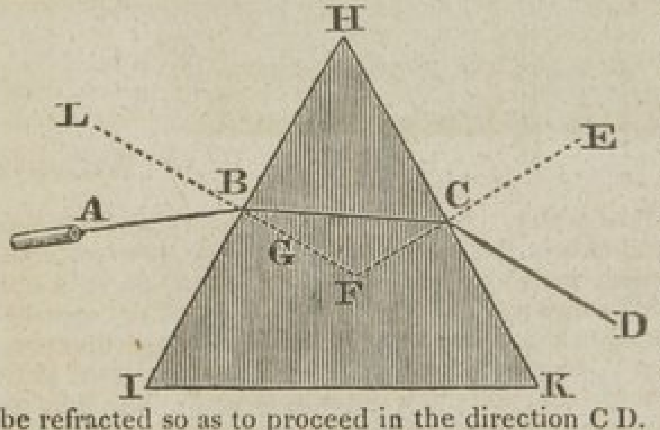
As an illustration of the case of light refracted, in passing out of denser matter into rarer, let us imagine the eye of an observer placed at the upper orifice of the tube, B, in the figure. Instead of the pebble, Z, which he would see, if the water were removed, the pebble, D, will be seen by him. 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.

89.—DIFFERENCE BETWEEN THE REFRACTING INFLUENCE OF A TRIANGULAR PRISM AND 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 again be 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.

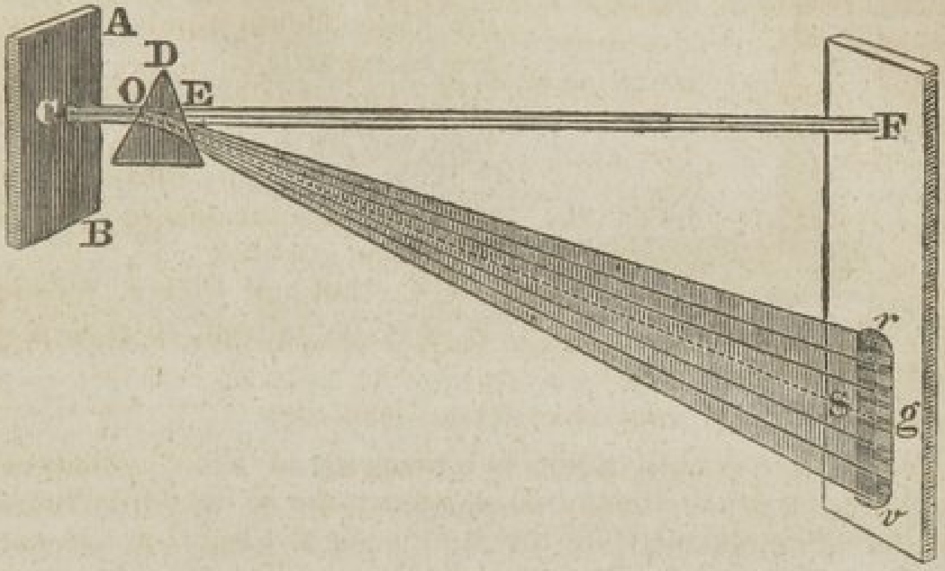
The lines, L F, and E F, being perpendiculars to the surfaces of the prism, A B L, is the angle of incidence, and G B C, the angle of refraction, to the surface at which the rays enter the prism. F C B, is the angle of incidence, and E C D, the angle of refraction to the surface, from which the rays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

90.—DISPERSION OF LIGHT.

Besides the refraction sustained by a pencil of rays, agreeably to the previous 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 deoxydizement.

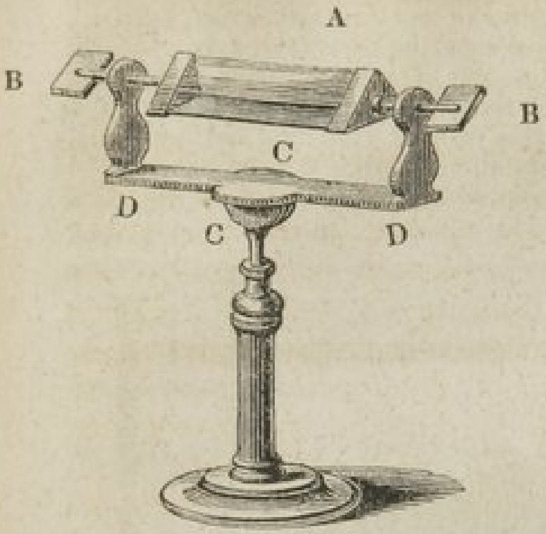
In the middle of the spectrum, the rays have the highest power of illumination.

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. Subsequent experiments have led to the impression, that the highest degree of heat is exerted on the confines of the red rays, and the highest deoxydizing power on the confines of the violet.—Still, however, the fact has been confirmed of the existence of rays, possessing these powers, and yet incapable of influencing the sight.

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.

The angle *g* O F, which is included between the path of the rays after refraction, and that which they would have pursued had not the prism intervened, is called the mean angle of refraction. *v* O *r*, is called the angle of dispersion, or dissipation, and is always in the same medium in proportion to the mean angle of refraction. Hence when this angle is small, the rays are not separated so as to produce their appropriate hues. It is surprising, that the ratio of the angle of dispersion, to that of refraction, is not the same in different refracting media. The difference, in this respect, in the case of different kinds of glass, enabled Dollond to construct his telescopes, called achromatic, because objects seen through them, do not appear tinged with prismatic colours, as they are liable to appear when viewed through other telescopes. The ratio of the refracting power, to that of dispersion, being greater in crown, than in flint glass; by opposing the influence of the one to the other, the dispersion of the rays by the former was counteracted, while sufficient refracting power was left in force to answer the purposes of the optician.

91.—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.

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 they 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 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.

ON THE EFFECTS OF LIGHT.

In the old bleaching process, by means of the solar rays, light is probably efficient, by promoting the transfer of oxygen, from water to the colouring matter, which it destroys. 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 gas and chlorine gas, will, in the dark, remain for a long time, without combining; but in the rays of the sun, will explode.

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 assume the specific gravity of water as the unit, by means of which their specific gravities are to be expressed.

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-fourth as heavy, the quotient, being less than one, is expressed by a decimal fraction. Thus the specific gravity of cork is stated to be .24 or .25.

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.

Hence the *general rule*, that in order to obtain the specific gravity of a body, in the numbers now generally used, we have only to divide its weight by the weight of a quantity of water, equal to it in bulk.

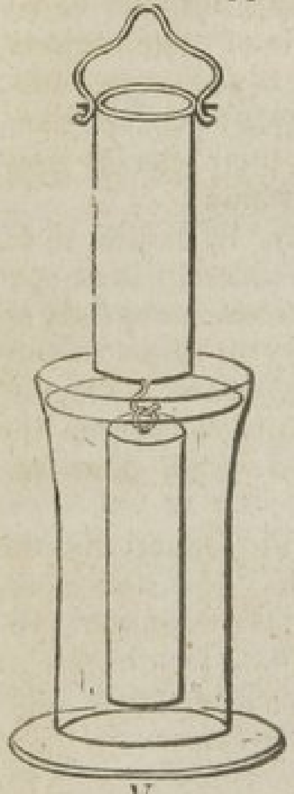
The weight of a quantity of water, equal to the body in bulk, is equal to the resistance which the body encounters in sinking in water. Hence, if we can ascertain, in weight, what is necessary to overcome the resistance which a body encounters in sinking in water, and divide, by the weight thus ascertained,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

92.—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.



V

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 is 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.

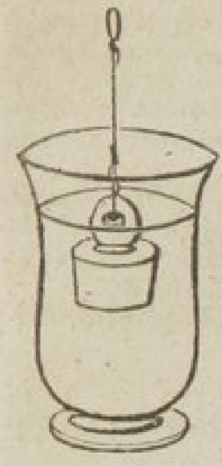
RATIONALE.

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.

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

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

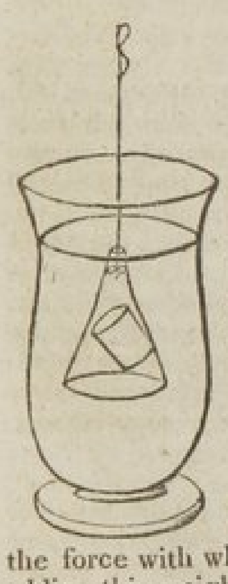


First counterpoise the stopple by means of a scale beam and weights, suspending it by a fine metallic wire. Place under the stopple, a vessel of pure water, and lower the beam, so that, if the stopple were not resisted by the water, it would be immersed in that fluid. Add just as much weight, as will 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 required to sink the stopple, is equal in weight to the bulk of water which the stopple displaces. 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.

94.—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 is 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, dividing the weight of the cork, agreeably to the general rule, the specific gravity of the cork will be found.

95.—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.

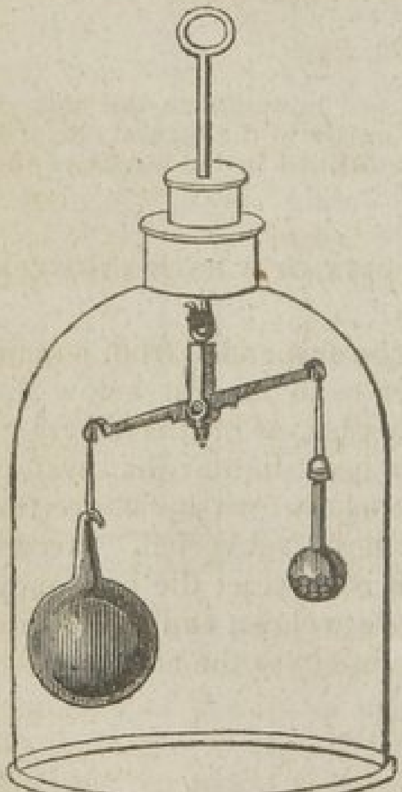
RATIONALE.

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, gives 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.

96.—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.

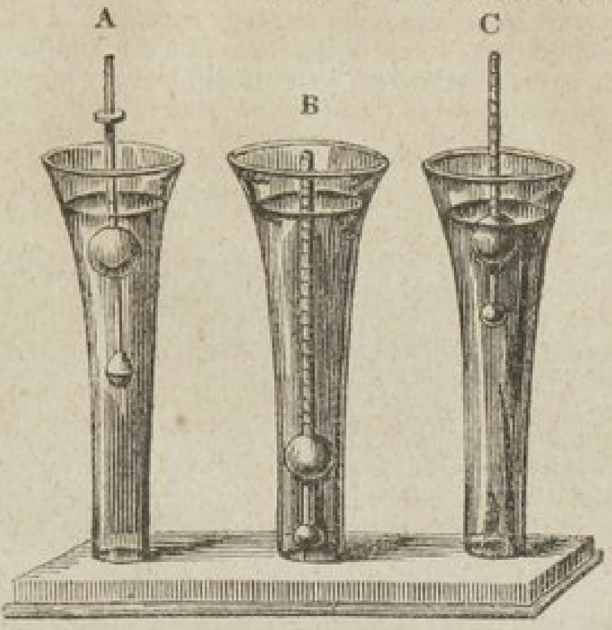
It appears from a preceding illustration, 92, that, when any body is surrounded by a fluid, it is buoyed up with a force in proportion to the weight of the fluid, and the quantity displaced by the body. Of course, the more space it occupies, in proportion to its weight, the more will its weight be counteracted. 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," is less than 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 is ascertained, until the student is better acquainted with them.

97.—ON 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 quantum 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 immerged, 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 every spirituous mixture, of water with alcohol. To render such graduation sufficiently discernible, the stem would have to be of a 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.

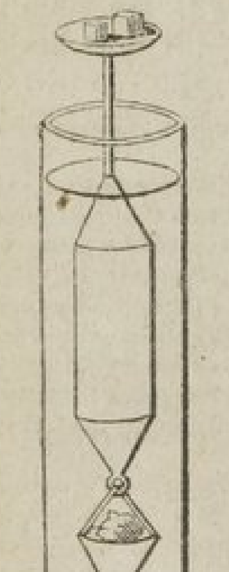
An instrument, sometimes called a Saccharometer, but precisely similar in principle, is used for infusions of vegetable matter, especially for the wort of brewers and distillers—excepting, that the scale begins at the top of the stem, with a line which coincides with the surface of pure water, at sixty 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. Either in this case, or in that of a liquid lighter than water, the weights must form a series, each of which differs from that next to it, by a weight equal to that of a quantity of the liquid which it is destined to assay, equivalent in bulk to the graduated part of the stem.

In fact, the difference must be such, that if, while supported with any weight on it, in a liquid, the lowest graduation on the hydrometer corresponds with the surface of the liquid, when the next heavier weight is substituted for the one thus employed, the liquid must reach the highest graduation. The difference between the weights, is therefore equal to the resistance encountered in sinking, by the portion of the stem immerged, by adding the second weight; and is, of course, equal to the weight of a bulk of the liquid equal to said portion of the stem.

As each weight is destined to assay a liquid, of a different gravity, and as the graduated part of the stem, displaces always the same bulk, it follows, that the difference between the weights must be less, in proportion as the liquid for which they are intended, is lighter; and greater, as it is heavier.

98.—NICHOLSON'S GRAVIMETER.

ON THE USE OF NICHOLSON'S GRAVIMETER, IN 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.

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

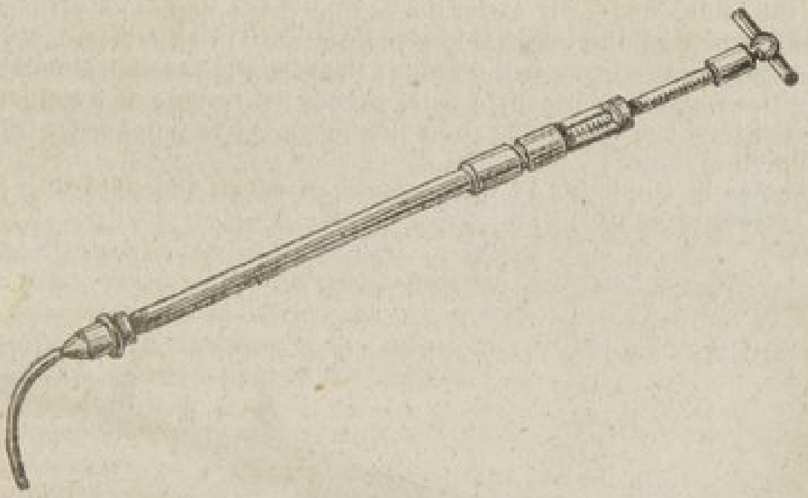
Should the gravity of a light body, as a piece of cork, for instance, be in question, place it on the upper scale of the Gravimeter, load the instrument, so as that the mark on the stem may coincide with the surface of the water, as in the case above stated; a leaden disk being previously laid upon the 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.

ON THE APPLICATION OF THE SLIDING ROD MEASUREMENT, IN HYDROMETRY.

There is, in my opinion, no mode of measuring fluids, heretofore contrived, so accurate and convenient, as that which I have employed in my Eudiometers. I allude to the contrivance of a rod, or piston, sliding through a collar of leathers into a tube, and expelling from it any contained fluid, in quantities measured by degrees marked upon the rod.

One of the most advantageous applications of the mechanism alluded to, is, in ascertaining specific gravities, in the case either of liquids or solids. To assay liquids which are not corrosive, I have employed two instruments like that represented in the following figure, severally furnished with rods, graduated into 100 larger divisions, each of which is subdivided into five, so that by estimating each subdivision, as two, the whole graduation may be considered as equivalent to 1000.

100.—CHYOMETER.



In order to avoid circumlocution, I shall, to the instrument here represented give the name of *Chyometer;* from meter, measurer, and the Greek, *χυω*, to pour.*

Instruments of this kind enable us to use measures of water, in lieu of weights.

Instead of ascertaining the number of grains which a body will weigh, or which may be equal to the resistance which it may encounter in sinking; the number of measures of water which will balance it, or compensate the resistance, to its sinking, are ascertained. In other respects, the process, and the calculation, are the same as usual.

The following process may, however, be found amusing and instructive, as it renders the ratio between the weight of a body, and the resistance to its sinking, more evident to a great number of spectators, than it can be rendered, in the ordinary method.

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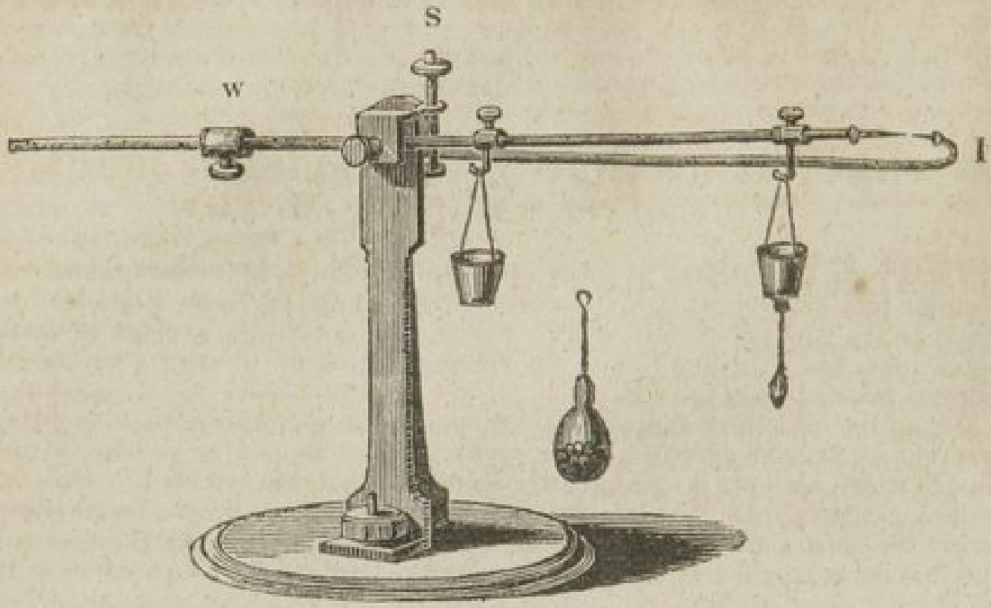
* Meter is by some writers derived from the Greek *μετρον*, but Johnson derives it from the verb to mete, and this verb from the Latin metior.

101.—TO FIND THE SPECIFIC GRAVITY OF A MINERAL, WITHOUT CALCULATION, AND WITHOUT DEGREES.

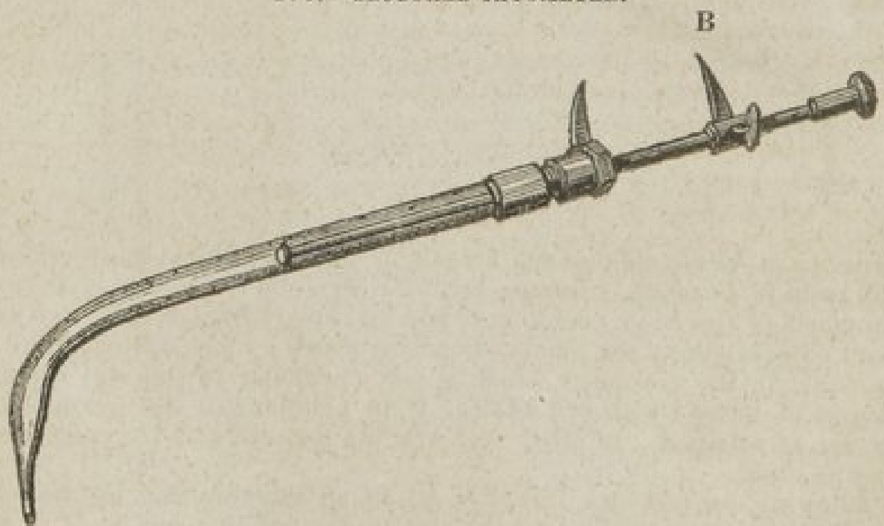


The preceding figure represents a balance employed in this process. It is, in two respects, more convenient than a common balance. The moveable weight on one of the arms, renders it easier to counterpoise bodies of various weights; and the adjustment of the index (I) by the screw (S) to the beam, saves the necessity of adjusting the beam to the index; the accurate accomplishment of which, by varying the weights, is usually a chief part of the trouble of weighing.

One of the buckets, suspended from the beam, is five times as far from the fulcrum as the other.

A chyometer is employed in this process, of which the following figure will convey a correct idea.

102.—SECTORAL CHYOMETER.



The rod of this instrument is not graduated, but is provided with a band, (B) which can be slipped along the rod, and fastened at any part of it by means of a screw.

Let a mineral be suspended from the outer bucket, and rendered equiponderant with the counter-weight, W, by moving this further from, or nearer to the fulcrum, till the index, I, may be exactly opposite to the point of the beam. Place under the mineral a vessel of water, and add as much of this fluid to the bucket, by means of the chyometer, as will cause the immersion of the mineral. The band (B) which is made to slip upon the rod, should be so fastened, by means of the screw, as to mark the distance which the rod has entered, in expelling the water, requisite to sink the mineral. Having removed the vessel of water, and the mineral, ascertain how many times the same quantity of water, which caused the immersion of the mineral, must be employed to compensate its removal.

Adding to the number, thus found, one for the water, (previously introduced into the bucket, in order to cause the immersion of the mineral) we have its specific gravity; so far as it may be expressed without fractions. When requisite, these may be discovered by means of the second bucket, which gives fifths for each measure of water; which, if added to the outer bucket, would be equivalent to a whole number. By the eye, the distance is easily so divided, as to give half-fifths, or tenths. Or, the nearest bucket, being hung one half nearer the fulcrum, the same measures will become tenths in the latter, which would be units, if added to the outer bucket.

RATIONALE.

The portion of the rod, marked off by the band, was evidently competent, by its introduction into the tube of the chyometer, to exclude from the orifice a weight of water, adequate to counteract the resistance encountered by the mineral in sinking in water: consequently, agreeably to the general rule, to find the specific gravity of the mineral, we have only to find how often this weight (of water) will go into the weight of the mineral—or, what is the same in effect, how often the former must be taken, in order to balance it.

Indeed, it must, otherwise, be sufficiently evident, that the mineral, and the water introduced into the bucket, being equal in weight, their specific gravities must be, in the inverse ratio of their bulks, as ascertained by the chyometer.

The inner bucket may be dispensed with, and greater fractional accuracy attained, by means of a sector, graduated into 100 parts. It is for this purpose that the sliding band, and the ferrule at the butt-end of the tube, are severally furnished with the points. The assistance of a sector is especially applicable, where liquids are in question, since it is necessary to find their differences in thousandths.

In order to convey an idea of the nature of the sector, to any reader who may be unacquainted with it, I trust it will be sufficient to point out, that its construction is similar to that of the foot rule used by carpenters. We have only to suppose such a rule, covered with brass, and each leg graduated into 200 equal parts, in order to have an adequate conception of the instrument employed by me.

A more particular explanation of the principle of the sector, may be found in any Encyclopedia, or Dictionary of Mathematics.*

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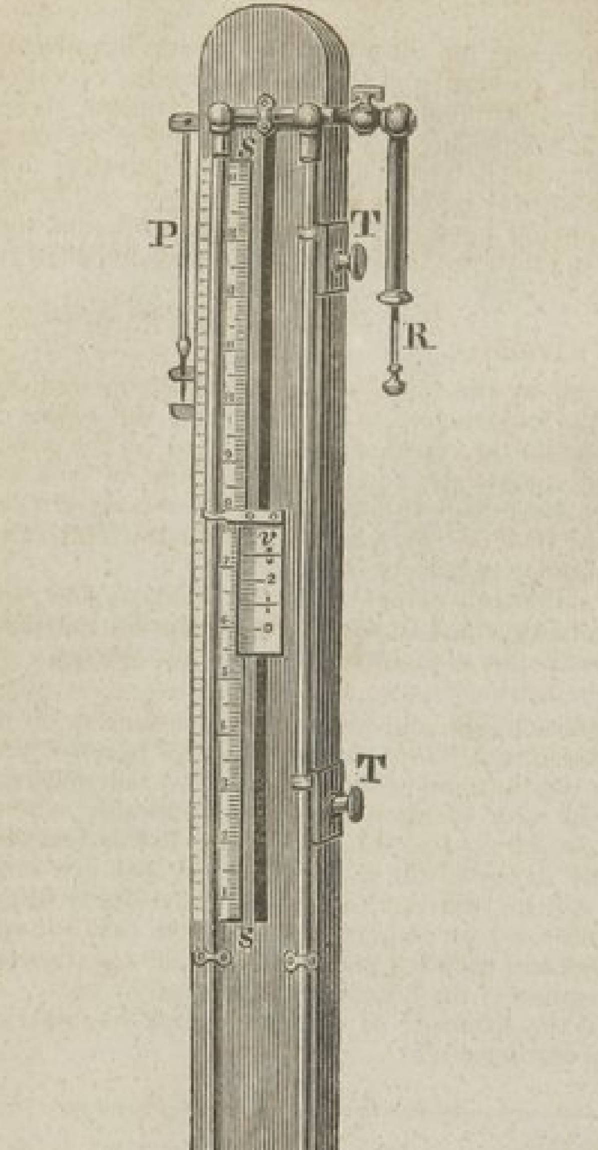
* The glass bulb, represented in the figure, as partially filled with shot, being suspended from the bucket, and the different *quantities* of *water* required to sink it in *different liquids*, ascertained by the sector, and chyometer; the *specific gravities*, will be directly as the *quantities*.

103.—ON THE LITRAMETER.



This name is derived from meter, and the Greek λιτρα, weight, and is given to one of the instruments which I have contrived for ascertaining specific gravities. The litrameter owes its efficiency to the principle, that when columns of different liquids are elevated by the same pressure, their heights must be inversely as their gravities.

Two glass tubes, of the size and bore usually employed in barometers, are made to communicate internally, with each other, and with a syringe, R, by means of a brass tube and two sockets of the same metal, into which they are severally inserted. The brass tube terminates in a cock, to which the syringe is screwed.

The tubes are placed vertically, in grooves, against an upright strip of wood, tenanted into a pedestal of the same material. Parallel to one of the grooves, in which the tubes are situated, a strip of brass, S S, is fastened; and graduated, so that each degree may be about equal to 1-110 of the whole height of the tubes. The brass plate is long enough to admit of about 70 degrees. Close to this scale, a vernier, *v*, is made to slide, so that the divisions of the scale are susceptible of subdivision into tenths, and the whole height of the tubes, into about 1100 parts, or degrees.

On the left of the tube, there is another strip of brass, with another set of numbers, so situated, as to divide each of the degrees, in the scale abovementioned, into two: so that, agreeably to this enumeration, the height of the tubes is, with the aid of a corresponding vernier, divided into 2200 parts, or degrees.

A small strip of sheet tin, *k*, is let into a kerf in the wood, supporting the tubes, in order to indicate the commencement of the scale. At distances from this, of 1000 parts, and 2000 parts, (commensurate with those of the scale) there are two other indices, T T, to the right hand tube. Let a small vessel, containing water, be made to receive the lower end of the tube, by the side of which the scale is situated; and a similar vessel of any other fluid, whose gravity is sought, be made to receive the lower end of the other tube; so that the end of the one tube, may be covered by the liquid in question, and the end of the other tube, by the water.

The piston of the syringe, being previously pushed into the chamber as far as possible, is now to be moved in the opposite direction. By these means the air is rarefied in the chamber and in the glass tubes, and consequently it allows the liquids to rise into the tubes, in obedience to the greater pressure of the atmosphere without. If the liquid to be assayed, be heavier than water, as, for instance, let it be concentrated sulphuric acid, it should be raised a little above the first index, at the distance of 1000 degrees from the common level of the orifices of the tubes. The vessels holding the liquids, being then lowered, so that the result may be uninfluenced by any inequality in the height of the liquids in them, the column of acid must be lowered, until its upper surface coincide, exactly, with the index of one thousand. Opposite the upper surface of the column of water, the two first numbers of the specific gravity of the acid, will then be found; and, by duly adjusting and inspecting the vernier, the third figure will be ascertained. The liquids should be at the temperature of 60°.

If the liquid under examination, be lighter than water, as in the case of pure alcohol, it must be raised to the upper index. The column of water, measured by the scale of 1000, will then be found at 800 nearly; which shows, that one thousand measures of alcohol, are, in weight, equivalent to 800 measures of water—or, in other words, 800 is ascertained to be the specific gravity of the alcohol.

The plummet, P, and the screws, at L, enable the operator to detect, and rectify any deviation, in the instrument, from perpendicularity.

ADDITIONAL ILLUSTRATION.

The proposition, illustrated by the 17th and 18th experiments, that the heights of columns, of different liquids subjected to the same pressure, will be inversely as their gravities, may be verified by ascertaining their specific gravities, in the ordinary way, and then examining their heights, when respectively occupying the tubes of the litrameter.

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 aëriform, 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.

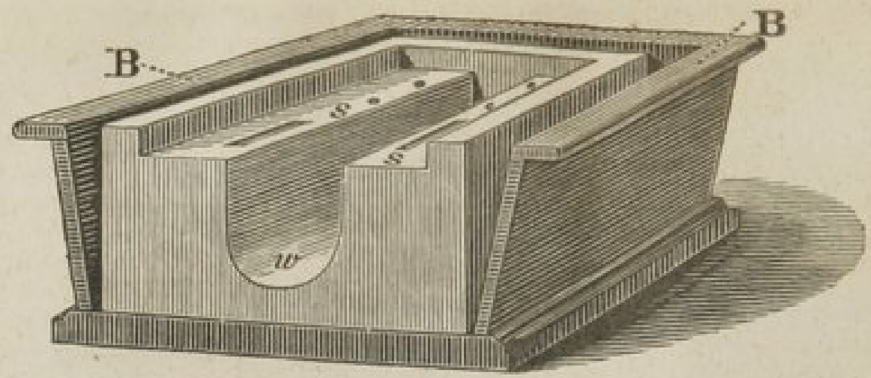
All gases were considered as common air, variously modified by impurities, until Dr. Black ascertained the nature of carbonic acid gas. Incited by this discovery, oxygen, nitrogen, hydrogen, chlorine, and many other substances susceptible of the gaseous state, were discovered, or distinguished, by Scheele,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

104.—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 19). Any gas emitted under the mouth of a vessel, so filled, and situated, rises and displaces the contained liquid.

105.—MERCURIAL PNEUMATIC CISTERN.

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



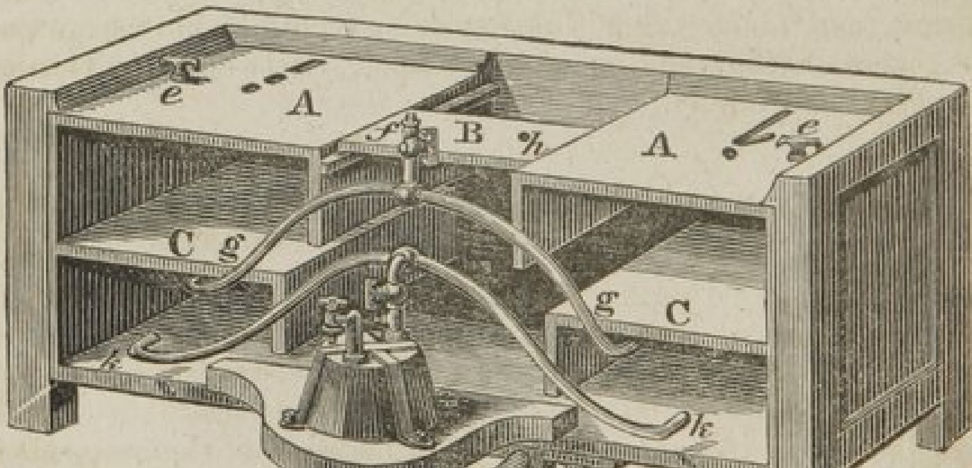
B B, is a wooden box, which encloses the reservoir so as to catch any of the metal which may be propelled over the margin of the cistern. This box is bottomed upon stout pieces of scantling, tenanted together and grooved so as to conduct the mercury towards one corner, where there is a spout to allow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

This reservoir requires nearly 600 pounds of mercury to fill it completely.

106.—HYDRO-PNEUMATIC CISTERN.

FIG. 1.



This engraving is intended to convey to the student an idea of my Hydro-Pneumatic Cistern. It is constructed upon the principle of one contrived by Professor Silliman and myself, when we operated together in 1803, and which we have used under various modifications, since that time.

The figure, here given, is such as would be presented to the eye, were the front of the cistern removed.

A A, are two shelves formed by two inverted chests, which are used as cells to contain gas: B is a sliding shelf, over a deep place between the shelves, A A, which is called the well of the cistern.

Fig. 2.

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.

Besides the chests abovementioned, there are two others, C C, near the bottom of the cistern, but not so close as to prevent the water from passing freely into and out of them.

In front of the cistern may be seen an inverted brass kettle, held firmly to a wooden plank by straps and iron screws. This kettle covers a circular hole in the plank. The hole is somewhat less in diameter than the kettle inside, so as to leave a bearing for the brim of the latter. Between the brim of the kettle and the margin of the hole, cut in the plank, the margin of a disk of sole leather is included, at about half an inch from its circumference all round, in such manner as to form an air tight juncture. The leather is perforated at the centre, and is pressed between the summits of two perforated leaden hemispheres, by a rod of iron which passes through the perforations in them, and in the leather. The compression is effected by means of a screw and nut, and a shoulder on the iron rod. The rod thus fastened to the leather disk, is connected with the bent lever, *b, l,* which is carried under the cistern, and being bent at right angles, is flattened, so as to form a treadle. When the treadle is forced down by the foot, the arm connected with the rod rises, and causes the leather to be bulged up into the kettle; when the pressure of the foot ceases, the weight, *w*, suspended from the lever, causes the descent of the rod, and the leather is bulged downwards, so as to cause air to enter the kettle, and to be expelled from it, successively. See description of the bellows of the hydrostatic blowpipe, 81.

Into the bore of the cock, which extends from the upper surface of the kettle to the arched pipe, *k k*, there is a valve opening outwards. Within the pipe in the form of an elbow on top of the kettle in front of this cock, there is a valve opening inwards; it is through the valve last mentioned, that the ingress of air takes place, while the egress is effected through the other.

In order to put this apparatus into operation, the kettle* cistern and upper air cells must be filled with water, until it is about an inch deep on the shelves, A A, the lower air cells remaining full of air. Bell glasses, or other vessels, being plunged in the well, filled with water, and inverted and placed, while full, over one of the holes, *h*, on the sliding shelf, B, are afterwards easily filled with any gas; for any gaseous fluid escaping from a retort beak, or from a tube, will be easily caught in the cavity, excavated in the wood of the lower side of the shelf, and thence rising through the hole into the inverted vessel, will occupy it to the exclusion of the water.

Having filled one vessel with gas, it may be transferred to another, filled with water, and inverted upon the shelf, B, by depressing the brim of the vessel containing the gas, under the shelf, and then inclining it so as to allow the gas to escape gradually into the cavity under the shelf, whence it rises into the other vessel, as already described.

When the air cells under the shelves, A A, are to be filled with gas, a flexible leaden pipe, passing from a vessel containing the generating materials, is curved into a hook, and placed so that the orifice may be within the cell. As the gas enters the cell, the water must of course be displaced from it, and would in consequence overflow the cistern, were not the cock, *f*, opened.

This cock communicates with the bore of the arched pipe, *g g*, to which it is soldered. The orifices of this pipe enter severally the chests, C C, so that their cavities communicate with each other and with the cock, *f*. Hence by opening

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* It is requisite to the operation of the bellows, that the kettle be filled with water first, otherwise the air remaining in it, will, by its elasticity, diminish the effect.

this cock, the air may be allowed to escape from those chests in such quantities, as to compensate the gas introduced into the upper air cells.

The gas, contained in the cells, is easily transferred to any vessel by bringing it over a hole, which communicates with the cell, through one of the cocks, *c c*, in the shelves, A A.

The vessels may be previously filled with water and inverted, but in the case of oxygen gas, if an open neck bell-glass, or a tall cylindrical vessel, open at both ends, be placed over the hole, and a jet of the gas allowed to enter it, the atmospheric air being lighter, is driven out before the entering gas. It may easily be ascertained when the vessel is full of oxygen, by the greater brightness of a taper flame held over the upper orifice.

As the escape of gas from the cells, permits the subsidence of the water into them, it is necessary to countervail the deficiency thus produced, by the action of the bellows pump, formed as already mentioned, by the kettle and its appurtenances, in duly replenishing the chests, C C, with air.

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 metals, 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 γιενομαι, to generate.

On the means of procuring Oxygen.

Per se* it can only be procured 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, unadulterated.

Properties of Oxygen Gas.

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.

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

It has been mentioned, (page 14) that chemical equivalents are usually assumed, so as either to make the representative of oxygen, or that of hydrogen, unity. The least combining proportions of these substances, as ascertained by the decomposition of water, being as one to eight, if the equivalent of hydrogen be unity, that of oxygen will be eight; but if the equivalent of oxygen be unity,

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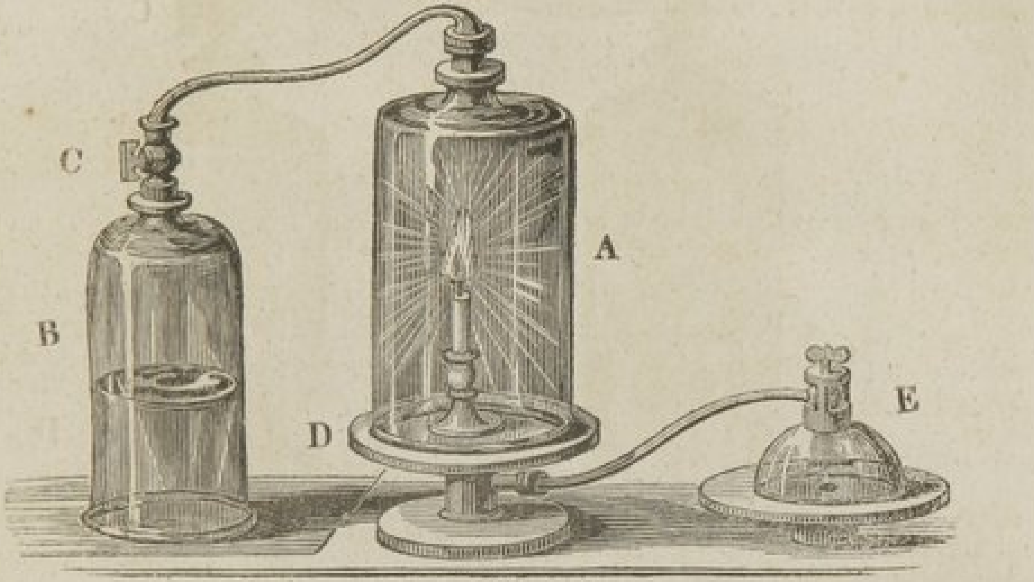
* Per se means, independently of the affinity, of any other ponderable matter.

hydrogen will be represented by the decimal fraction .125. As in the two most elaborate works upon the subject of equivalents, those of Thomson and Berzelius, oxygen is made the standard, I deem it expedient to follow the example of those great chemists.

EXPERIMENTAL ILLUSTRATIONS OF THE PROPERTIES OF OXYGEN GAS.

107.—CANDLE IN AIR, IN VACUO, AND IN OXYGEN GAS.

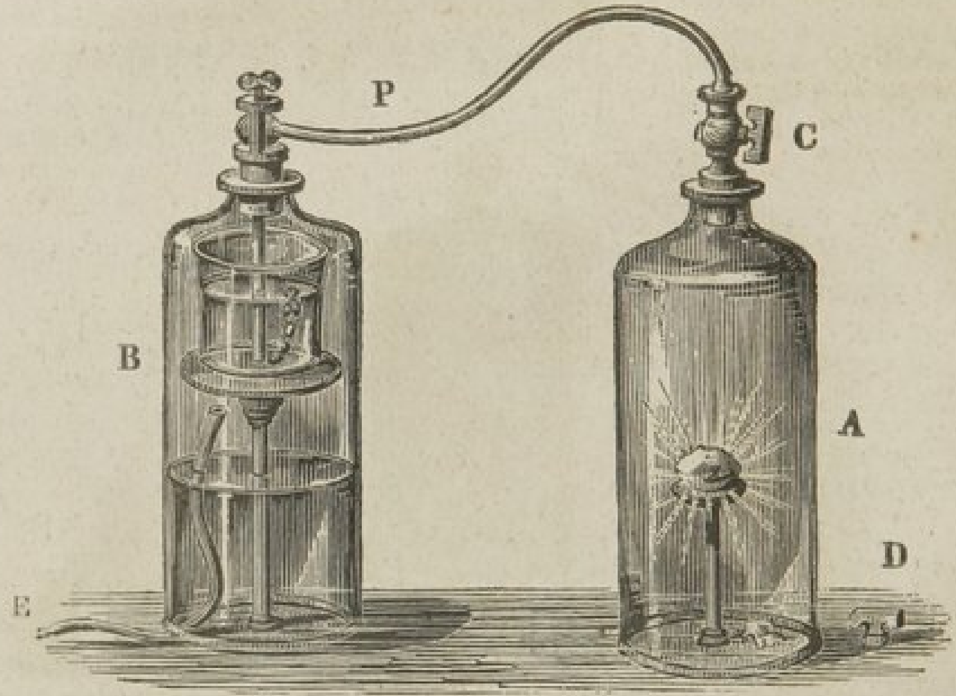


A candle will burn only for a limited time with a limited supply of air; it will not burn in vacuo, but, burns brilliantly in oxygen gas, and much longer than in a like quantity of air.

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.

Let the experiment be repeated with the following change. Let the air be exhausted from both vessels, the cock, C, remaining open, until the bell, B, is filled with water from the shelf of the pneumatic cistern, on which, for this experiment, it must be placed. The cock being closed, fill the bell, last mentioned, with oxygen gas, from the cell of the cistern. Now lift the bell, A, which may be easily done, the pipe having a due flexibility, and introducing a candle, set the bell again on the plate. Next exhaust the air until the candle is nearly extinguished, and then open the cock, so as to allow the oxygen to enter.—The candle will now burn far more brilliantly, and for a much longer time, than it had done, when the bell contained atmospheric air.

108.—COMBUSTION OF CHARCOAL OR OTHER COMBUSTIBLES IN OXYGEN GAS.



The preceding figure represents an apparatus which I have contrived for exhibiting the combustion of charcoal or other combustibles in oxygen gas. Two large glass receivers or bells, A, B, each furnished with a tubulure at the apex, are associated by means of the pipe, P, which in one of the receivers, B, communicates with a tube, extending about five inches within the receiver, below its neck, so as to reach into some lime-water, or an infusion of litmus, contained in a glass vessel. The wooden stand which holds the glass vessel, and the iron stand which supports the coal in the receiver, A, must be previously fixed on the shelf of the Pneumatic cistern, as observed in the drawing, so that the receiver, A, when including the coal, may be over the mouth of the cock, D, which communicates with one of the cells, made under the shelves of the Pneumatic Cistern for the purpose of holding gas, and which for this experiment is filled with oxygen.

Into the receiver, 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 receivers 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 the receivers are restored to their previous situations, the suction pump must be put into operation, and the cock, D, of the cell 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 carbonized, 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 the receiver, 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.

A candle, lamp, sulphur, or phosphorus, may be substituted for charcoal in this experiment.

109.—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, as 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.

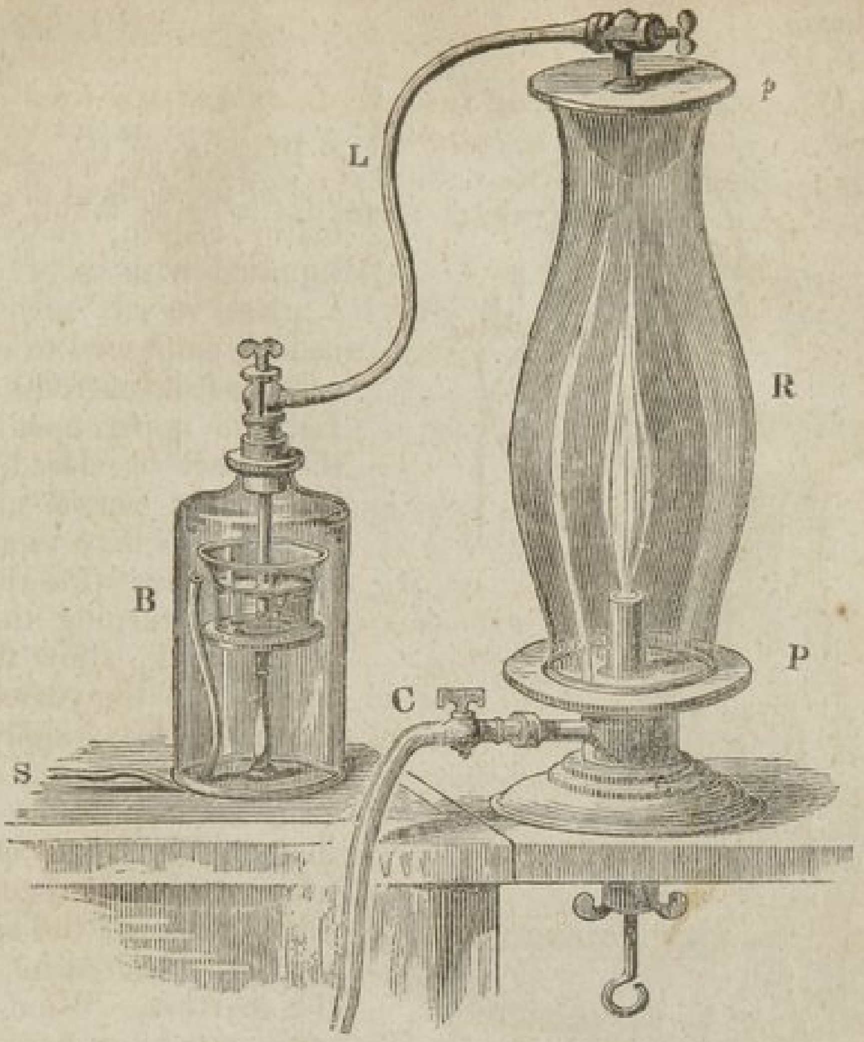
The enlargement of bulk, arising from the heat, may be provided for by a bag or bladder, a communication with which being opened, a portion of the heated air is enabled to retire till the condensation of the oxygen, together with the phosphorus, into phosphoric acid, compensates the expansion.

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 consequence 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.

110.—COMBUSTION OF SULPHUR IN OXYGEN GAS.

Suppose 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 within the bell, proceeds, is made to act, the air of the receiver will press through the water in the vase upon the stand, as in the previous experiment. 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 vessel, 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.

111.—COMBUSTION OF IRON WIRE IN OXYGEN GAS.

Place over the cock of one of the cells of the pneumatic cistern, sufficiently supplied with oxygen gas, 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 cell. 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. Wind a fine wire round any hard cylindrical body of about an inch in diameter. By these means, the wire is easily made to assume the form of a spiral. Near the end of the spiral, wind it about a piece of spunk about as large as a pin. Having lighted the spunk, remove the cover from the aperture in the lid of the vessel, and lower the end of the wire to which the spunk may be attached, into the oxygen gas. The access of the oxygen causes the spunk to be ignited so vividly, that the wire 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.

ADDITIONAL EXPERIMENTAL ILLUSTRATIONS OF THE PROPERTIES OF OXYGEN GAS.

Spontaneous ignition of Homberg's Pyrophorus. Flame of Caoutchouc brightened. Candle relighted. Effect of Oxygen on the flame of an enameller's lamp.

Let the glass vessel employed in the preceding illustration, of the combustion of iron in oxygen, be prepared, as prescribed for that experiment: but in lieu of introducing the wire, let Homberg's pyrophorus be thrown in, a spoonful at a time. The powder in descending through the gas, being spontaneously ignited, appears like a shower of fire.

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

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 cylinder, 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.

If the hydrostatic blowpipe be supplied with oxygen, and be made to act upon a lamp flame, an intense heat will be excited, 81.

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

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

Bottles may be filled with chlorine gas, by means of a tube reaching from the generating vessel, to the bottom of the bottle 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.

Properties of Chlorine.

When pure and dry, it is a permanent gas, of a greenish yellow colour. When moist, it congeals at 40 degrees of Fahrenheit. 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 the most fatal consequences.

Mr. Faraday has shown that, under great pressure, chlorine becomes a liquid.

That species of chemical action, which is attended by the phenomena of combustion, is supported by this gas with great energy. 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. 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 seventeen years. It is now, generally deemed an elementary substance, rendered gaseous by caloric. Oxygen being one, the chemical equivalent, or atomic weight, of chlorine, is 4.5; but if hydrogen be one, $4.5 \times 8 = 36$.

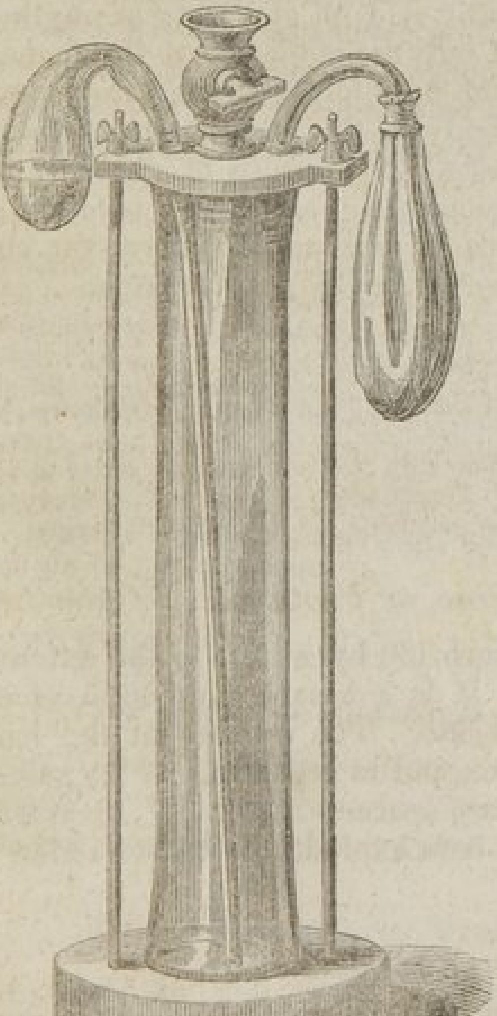
EXPERIMENTAL ILLUSTRATIONS OF THE PROPERTIES OF CHLORINE.

112.—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.

The handle of the ladle, L, is so fastened into a cork, or stopple, as to be easily inserted, air tight, into the neck of the globe, G, previously filled with chlorine, over the pneumatic cistern. The phosphorus being placed in the cup of the ladle, which is but shallow, the stopple may be put into its place before the action becomes sufficiently powerful to expand the gas. Hence, by the time that the gas is expanded by the heat evolved by the spontaneous combustion of the phosphorus and chlorine, there can be no escape of the fumes, unless into the bladder; which, being emptied of air before the experiment, dilates sufficiently to afford them room.

113.—COMBUSTION OF PULVERIZED METALS IN CHLORINE.



A jar, about 30 inches in height, is placed between two iron rods, which, towards their upper terminations, have been cut by a screw-plate, and duly furnished with screw nuts. By these means, a lid is pressed upon the mouth of the jar, so as to be air tight. 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.

There is inserted into the lid, on one side, a recurved tube, to which a large uninflated bladder is tied, so that the cavity of the bladder, may freely communicate with that of the jar. On the other side, the beak of a retort is introduced, so as to reach the bottom of the jar.

The body of the retort, being properly supplied with muriatic acid, and manganese, and heat being applied, chlorine is evolved; which being heavier than atmospheric air, soon occupies the greater part of the jar, the air being expelled through the aperture, by which the beak of the retort enters, without closing it air tight. The retort being removed, and the hole well corked, 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 is converted, as it falls, into a shower of fire. Considerable expansion ensues; but the bladder receives so large a portion of air, as to prevent any explosion; while 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.

OF EUCHLORINE, OR PROTOXIDE OF CHLORINE.

Means of obtaining Euchlorine.

It is obtained by heating, gently, a portion of chlorate of potash, under about twice as much muriatic acid, of moderate strength, as will cover it. The retort should only be subjected to the flame of a small spirit lamp. This should be applied immediately under the acid, so as not to heat the body of the vessel,—otherwise an explosion will probably take place. A mixture of chlorine and euchlorine is evolved in the gaseous state, and being received, in small bell glasses, over the mercurial pneumatic cistern, the chlorine is absorbed by the mercury—the euchlorine remains.

RATIONALE.

Muriatic acid consists of hydrogen and chlorine; the chlorate, of chlorine, oxygen, and potassium.

The oxygen leaves the chlorine in union with the potassium, in order to unite in part with the hydrogen of the acid. The chlorine of the acid, consequently escapes, partly free, partly in the state of protoxide, by uniting with oxygen.

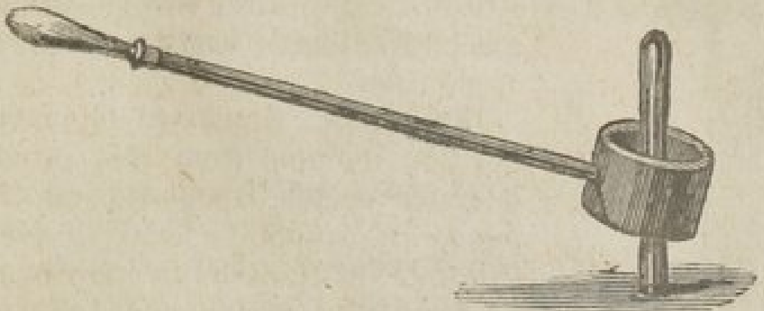
Of the Properties of Euchlorine, or Protoxide of Chlorine.

Euchlorine is gaseous, but absorbable by water, to the extent of eight or ten times its volume. It is a binary compound of one atom of oxygen, and one of chlorine. The warmth of the hand, is sufficient to cause it to detonate, and to separate into its gaseous elements, occupying one-fifth more space. Antimony, or arsenic, in powder, or Dutch leaf, causes it to explode, by an attraction for the chlorine.

114.—EXPERIMENTAL ILLUSTRATIONS.

Euchlorine is generated by the process abovementioned, and collected over mercury. Portions of euchlorine are exploded, by Dutch gold, antimony or arsenic.

115.—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 $\frac{5}{8}$ 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 one volume oxygen, and two volumes chlorine.

The chlorine is subsequently absorbed by the mercury.

Thenard advises the application of a spirit lamp to produce the necessary temperature. It is much easier, and much more safe, to use the hot ring. The tube must be supported by an iron wire, which has been overlooked in sketching this figure.

RATIONALE.

Agreeably to the idea that aëriform fluids owe their repulsive power to caloric, after an evolution of heat, there ought 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 TRITOXIDE OR PEROXIDE OF CHLORINE.

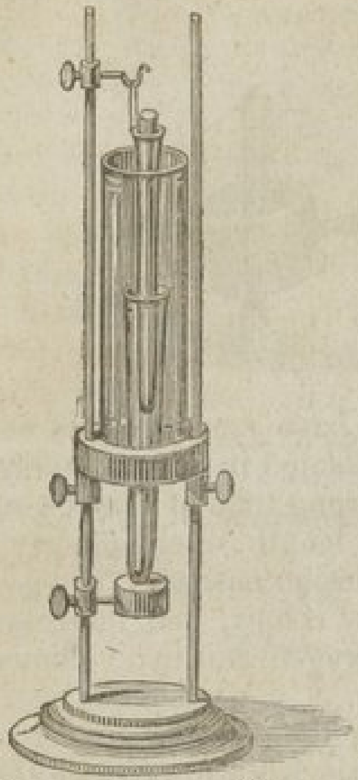
On the means of obtaining Tritoxide of Chlorine.

It is obtained by mixing chlorate of potash, with sulphuric acid, and distilling with great caution, at a heat below 212°. The process is too dangerous to be repeated without great caution.

Of the properties of Tritoxide of Chlorine.

The colour and the explosive power of this oxide, are similar to those of euchlorine; but are more intense.

116.—APPARATUS FOR EXHIBITING SAFELY THE EXPLOSION OF TRITOXIDE OF CHLORINE.



The annexed figure represents an apparatus for exhibiting, without danger to the spectators, the detonation of the tritoxide of chlorine.

Into a tube, supported on a table in a position inclined from that in which the operator stands, about an eighth of an ounce of sulphuric acid is introduced. Chlorate of potash in powder is added gradually in very small quantities, till a paste is formed, of an orange colour.

The tube being thus charged, it is corked gently, and suspended within the stout 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 paste: but, as soon as the inner tube is pervaded by a greenish yellow colour, demonstrating the evolution of the gaseous tritoxide, 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.

RATIONALE.

The superior affinity of sulphuric acid displaces the chloric acid from its union with potash; and as this acid cannot exist in an isolated state, it is decomposed into oxygen gas and tritoxide of chlorine.

OF CHLORIC ACID.

Means of obtaining Chloric Acid.

It is obtained by passing chlorine through water, containing oxide of silver in suspension.

Of the properties of Chloric Acid.

It is colourless, sour and astringent. When warm and concentrated, its odour is pungent. It reddens 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.

Of the composition of Chloric Acid.

It consists of one atom of chlorine, and five atoms of oxygen.

OF PERCHLORIC ACID.

This name has been given to an acid supposed to consist of seven atoms of oxygen united with one of chlorine.

It seems to me that it would be more consistent, with the received nomenclature, if it were called oxychloric acid. So little has been ascertained respecting it, that I do not recommend it particularly to the student's attention.

IODINE.

Iodine derives importance from its analogy with oxygen, and, especially, with chlorine.

Until within the last two years, it had only been discovered in certain vegetables and marine worms. In 1825, Vauquelin discovered it in a specimen of silver ore, in which it existed in union with that metal. It was named from ιοειδης, violet coloured.

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.

Of the properties of Iodine.

When solid it is of a bluish black colour—friable—acrid—and almost insoluble. It stains the skin yellow. It fuses at 225° F. and volatilizes at 350° in a most beautiful violet vapour.

Iodine is considered as an element. It is incombustible either in oxygen, or atmospheric air; but forms acids severally with oxygen, hydrogen, and chlorine, called iodic—chloriodic—hydriodic acids. In its habitudes with the Voltaic pile, it is more electro-negative, than any other matter, excepting oxygen, chlorine, and probably fluorine. With starch, (fecula,) iodine produces an intense blue colour; so that these substances are reciprocally tests for each other. The equivalent (or atomic weight) of iodine, is 15.5.

117.—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.

OF THE NOMENCLATURE OF THE COMPOUNDS OF CHLORINE, OXYGEN, AND IODINE.

Agreeably to the nomenclature proposed by the celebrated Lavoisier, and his coadjutors, and generally adopted by chemists; when oxygen, in combining, does not acidify, the resulting combinations are called oxides. Hence, by analogy, the compounds of chlorine with other substances, when not acidified by it, are called chlorides; those of iodine, iodides.

OF FLUORINE.

By many chemists, the existence is inferred of a principle, called fluorine, which appears to be very analogous to chlorine; and even more active in its properties. I have myself little doubt of the existence of fluorine. I shall, however, defer, for the present, giving any farther account of this principle; as the intricate combinations, in which it is supposed to exist, will be more easily understood, when the student has acquired a knowledge of the substances, with which it is alleged to be united.

OF BROMINE.

This name has been given to a substance analogous to chlorine and iodine, from the Greek βρωμος, fetid.

Means of procuring Bromine.

The mother waters of marine, or common salt, are impregnated with chlorine, until they acquire a hyacinth red tinge. The chlorine combines with the hydrogen and earth of a hydrobromate of magnesia, which exists in those waters. The bromine, thus displaced, combines 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.

Properties of Bromine.

Bromine is a liquid, which freezes at 13° below zero. It has a powerful odour, resembling that of chlorine. When seen in a deep stratum, it is of a deep brown; in a thinner mass, appears of a hyacinth red. At the temperature of 137° F. it takes the form of a vapour, resembling that of nitrous acid. Chlorine disengages bromine, and bromine, iodine, from all combinations. It is considered as an element. It has little affinity for oxygen, but forms a powerful acid with hydrogen. With metals, and metalloids, it forms compounds, which, by analogy, must be called bromides. Like chlorine, it forms an oleaginous ethereal compound with olefiant gas. It is soluble either in water, alcohol, or ether.

The account which I have given of the substance, which is the subject of this article, rests mainly upon the authority of Mr. Ballard, a young chemist, of Montpellier, by whom it appears to have been discovered in 1826. It was named brome, by the French chemists, and its compounds, bromures; but as chlore, is, in English, chlorine, and chlorure, chloride, I have translated brome, into bromine, and bromure, into bromide.

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 υδος, water, and γεινομαι, 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:—also, by means of potassium. It may be evolved from water by galvanic agency, and is then purest.

On the Properties of Hydrogen Gas.

It is the lightest of all ponderable substances. A cubic inch weighs only about a fiftieth of a grain. It is about 200,000 times lighter than mercury, and 300,000 times lighter than platina. In its ordinary state, it smells unpleasantly. When pure, it is alleged to be without odour. It has never been rendered liquid. Its capacity for heat is very high. It does not support life, but is not injurious to it. In consequence of its levity, it escapes rapidly from an open vessel, unless inverted. It is preeminently inflammable, yet a taper when immersed in it, is extinguished. A jet of it ignited, appears like a candle flame, feebly luminous: and if surrounded by a glass tube, produces a remarkable sound. Subjected to the electric spark, when mixed with oxygen, or atmospheric air, it explodes. The oxygen present cannot be less than one-third, nor the hydrogen less than two-thirds, of the deficit caused by the explosion; because these are the only proportions in which these gases unite, when pure. Consequently the quantity of either, in any gaseous mixture, may be known, (the other being in excess,) when the deficit caused by their combustion, can be ascertained. The ponderable base of hydrogen gas forms water, with oxygen; muriatic acid, with chlorine; hydriodic acid, with iodine; ammonia, with nitrogen; and prussic acid, with cyanogen. It combines also with carbon—with sulphur—and with phosphorus.

Hydrogen gas is considered as an elementary substance, so attractive of caloric, as that, per se, it cannot be separated from it. The equivalent, or atomic weight, of hydrogen is .125.

118.—EXPERIMENTAL ILLUSTRATIONS OF THE PROPERTIES OF HYDROGEN GAS.

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.

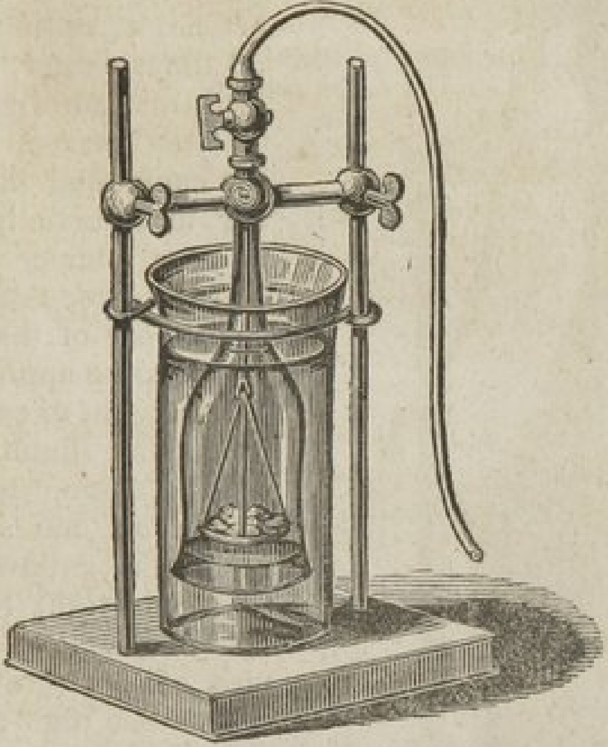
119.—PHILOSOPHICAL CANDLE.

Granulated zinc, or turnings of iron, being introduced into a glass flask, so as to occupy about one-third 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 four 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.

120.—SELF-REGULATING RESERVOIR, FOR HYDROGEN AND OTHER GASES.

The following figure, represents a self-regulating reservoir for hydrogen gas.



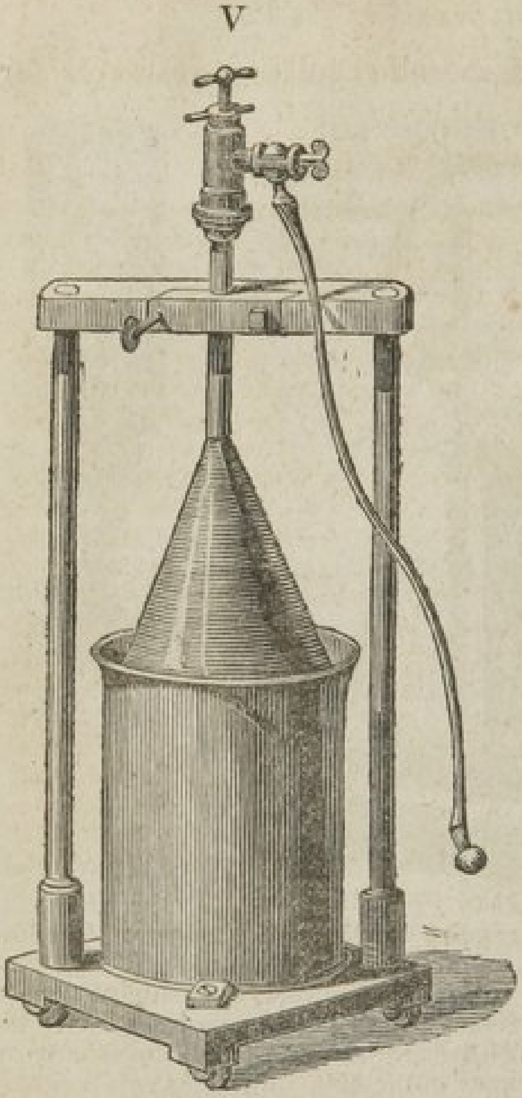
This very perspicuous engraving can require but little explanation. Suppose the glass jar without, to contain diluted sulphuric acid; the inverted bell, within the jar, to contain some zinc, supported on a tray of copper, suspended by wires, of the same metal, from the neck of the bell. The cock being 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 Williamsburgh, 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.

121.—LARGE SELF-REGULATING RESERVOIR, FOR HYDROGEN.



This figure, represents a self-regulating reservoir, for hydrogen gas; it is constructed like that described in the preceding article, excepting that it is about 50 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 hydrostatic blowpipe, 85.

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.

122.—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.

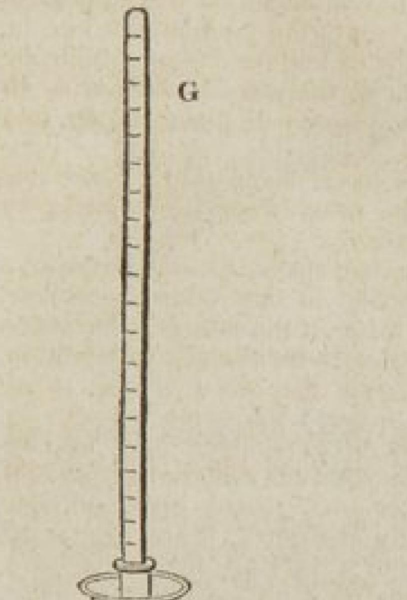
For this purpose a stout tube, sealed at one end, at the other shaped liked a trumpet, has holes drilled into it, near the sealed end, for the introduction of metallic wires, the ends of which approach near enough to each other, within the tube, for the passage of an electric spark. A known volume, of the explosive mixture, being introduced into the tube, and exploded, 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.

The eudiometer, described in the next article, was contrived by Volta, for the analysis of gaseous mixtures, and compounds containing oxygen, or hydrogen.

123.—VOLTA'S EUDIOMETER.



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, the 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 the insulated wire for passing the electric spark, I have employed a wire to be ignited by galvanism. This I accomplished in the following manner. Upon a brass cylinder, a screw and shoulder were made in the lathe so as to fasten into the female screw, which received the insulated wire for the electric ignition. The cylinder of brass was plugged with wood, and the wood drilled to receive a piece of brass wire, which extends a little beyond the brass cylinder inside, and about ¾ of an inch beyond it externally. The wooden plug also extends beyond the brass cylinder. An arc of platina wire was soldered at one end, to the wire within the wooden plug; at the other end, to the brass cylinder. This cylinder being screwed into its place, in the eudiometer, if any part of the cap of this instrument be in contact with one pole of a calorimotor, and the wire, insulated by the wood, communicate with the other pole, on exciting the plates of the calorimotor, the platina arc will be ignited, and of course any gas in contact with it, will be inflamed.

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.

124.—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.

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 platina, 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 160 degrees.*

So easy is manipulation, with this sliding rod eudiometer, that any number of experiments may be performed in as many minutes. The ignition of the platina wire is caused by either of four calorimotors, each consisting of four plates of zinc, and five of copper. They are all suspended to one beam as may be seen in the next page, fig. 2.

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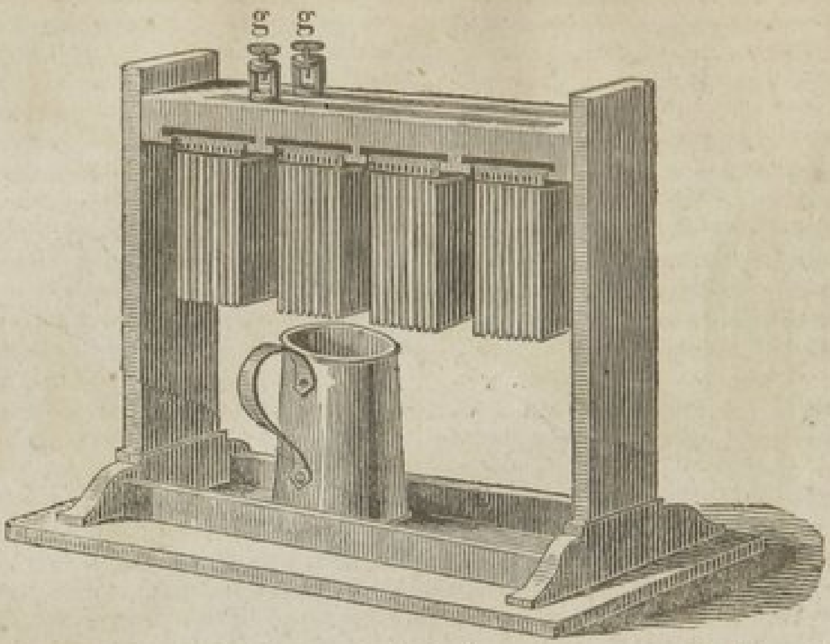
* Since the foregoing engravings were completed, I have found it expedient to secure the valve which closes the aperture in the apex of the instrument, from the possibility of leakage during explosions, by means of an iron staple, with a screw, which is here represented. This fastens upon two pivots, 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.

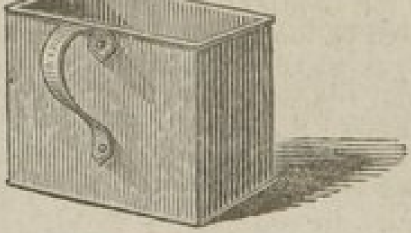
I have also found it better to interpose a cock, between the sliding rod and the recipient. This cock being closed during the explosion, the chances of any leakage by the rod in consequence of any imperfections, are lessened.

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.

FIG. 3.



Or by using a vessel, fig. 3, large enough to receive, and containing acid enough to excite, two of the calorimotors at once, the igniting power may be doubled. The vessels for holding the acid are made of copper, covered with a cement of rosin, rendered tough by the admixture of mutton suet.

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 ca-

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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.

pillary 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 out the rod 200 measures; 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 about 100 degrees; 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 as 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.

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, 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 hydrogen; then on taking three hundred measures of the mixture, into the eudiometer, there will be the same quantity of each gas, as if 100 measures of hydrogen, and 200 of oxygen 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 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.

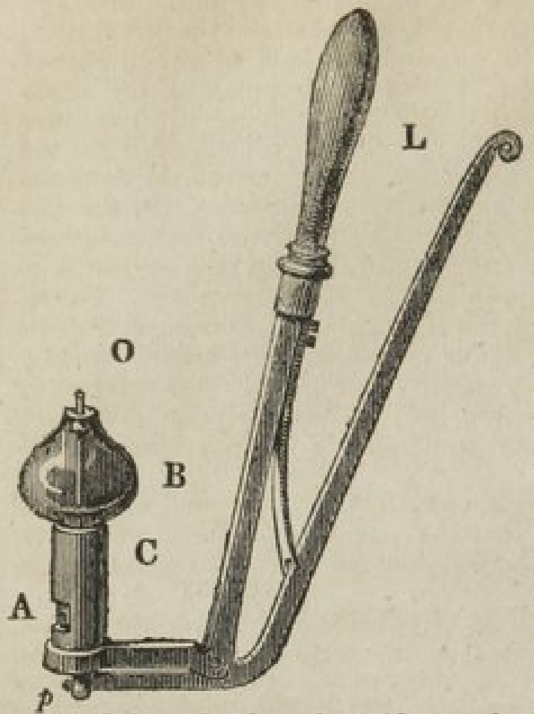
If hydrogen were to be assayed, as for instance the gas evolved by the reaction of diluted sulphuric acid with zinc, as in experiment 119, it would be proper to take equal parts of the hydrogen, and oxygen, as the gas which is not to be analyzed, must always be in excess. Taking then two hundred measures 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 implements, described in the three following articles, 125, 126, 127.

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.

125.—PISTON VALVE VOLUMETER.

I have contrived some instruments for taking volumes of gas, at one time, precisely equal to those taken at another time. I call them volumeters, to avoid circumlocution. They are of two kinds, one is filled by introducing it into a bell glass, over water, or mercury; 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 due conception 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 quantity, 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, subsequently, as attached to the mercurial sliding rod eudiometers. The other is simply an inverted glass syphon.

SLIDING ROD GAS MEASURE.

126.—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 the mixture is to be made. 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.

127.—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.

128.—BAROMETER GAGE EUDIOMETER.

The following is an engraving of the barometer gage eudiometer. Within the receiver near W, is an arc of platina, by the ignition of which the gas is inflamed. C, is a cock with three orifices, either of which may be made to communicate with the receiver, according to the position of the lever, L. More than one of the orifices cannot be open at once, but all may at the same time be closed. The barometer gage, G G, is seen beside the receiver, with which it communicates through the pipe, P, and the valve cock, V, by means of which the communication, between the gage and receiver, may be suspended at pleasure.

The gage consists of a barometer tube about three feet long, associated with a scale thirty inches in height, and divided into 450 equal parts or graduations.

The pipe, A, conveys to the receiver, the gaseous mixture from the bell glass, B. By one of the pipes, D, a communication with the air pump may be established. The other pipe is used when different kinds of gas are to be successively introduced; or when a portion of residual gas is to be drawn out for examination. T T, are rods by which ignition is conveyed to the platina wire. *m*, is a wooden dish, holding mercury for the gage tube.

It is well known, to those who are familiar with pneumatics, that if a receiver communicate simultaneously with an air pump, and a barometer gage, the extent of the exhaustion will be indicated by the height of the mercury in the gage tube; so that if there be a scale of equal parts associated with the tube, the quantity of air taken from the receiver at any stage of the exhaustion, will be to the quantity held by it when full, as the number opposite the mercurial column, when the observation is made, to that to which it would rise, if the receiver were thoroughly exhausted.

Hence having exhausted the vessel, thoroughly, if the mercury stand at 450 degrees, by the gage, on allowing any gaseous matter to enter till it sinks to 150°, the quantity in the receiver will be 300 parts; and if of this, by explosion, or any other means, any number of parts be condensed, the mercury in the gage must rise that number of degrees.*

The tube above described as forming the recipient is cemented, at the larger end, into a brass ferrule, which is screwed into a casting of the same metal; and fastened to iron feet. Into the same casting, a brass plug screws, through which are inserted stout wires, one of them insulated, for producing galvanic ignition, in the arc of platina wire, as already described in the case of my other eudiometers.†

With the gage tube, is associated a scale divided into 450 equal parts.

This eudiometer may be charged by taking successively, by means of the gage, proper quantities of the gases to be exploded; but it is better to have them mixed previously, by means of a volumeter, as already described in article 124, on the Sliding Rod Eudiometer. This last mentioned mode is preferable, from its saving trouble, and lessening the chances of error in the measurement; also because the gaseous ingredients become more thoroughly blended. This result does not ensue as soon as might be expected, especially where there are no means of accelerating it by mechanical agitation.

Having prepared a mixture of two volumes of atmospheric air, with one of hydrogen, and the receiver being exhausted as far as practicable, if any small quantity of the mixture be exploded in it, by exciting ignition in the platina wire, W, all the oxygen will be condensed. The residuum, consisting of hydrogen, and nitrogen, will not interfere with the result of any subsequent experiment, although the receiver should not be thoroughly exhausted. Under these circumstances, let the exhaustion be carried to 400 degrees, and let 300 measures of the mixture enter, so as to depress the mercury in the gage to 100 on the scale. An explosion being effected, the mercury in the gage will rise at first to about 215 degrees, and after the gas shall have regained its previous temperature, will be found somewhat above 220 degrees.

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[*] That portion of the bore of the tube which is not occupied by mercury, adds to the capacity which influences the gage, and the portion of the gage which is emptied of mercury, varies in extent; but as the air, which remains in the gage, is not subjected to the explosion, the extent of the condensation, is uninfluenced by it.

A slight error may arise from the sinking of the mercury, in the dish, as the quantity in this receptacle, lessens by its rise in the tube: and, vice versa, when subsidence ensues. This movement will be to the movement of the mercurial column, in the tube, as the square of its diameter, to the square of the diameter of the mercurial stratum in the dish, and the diameters of these being respectively as 20 to 1, it would be 1-400 of the whole height of the scale. This difference may be allowed for, or may be remedied by raising or lowering the dish, by an appropriate screw, or employing a dish of a superficies so large, and a gage tube with a bore so small, as to render the effect of the rise, or subsidence of the mercury in the gage, insignificant.

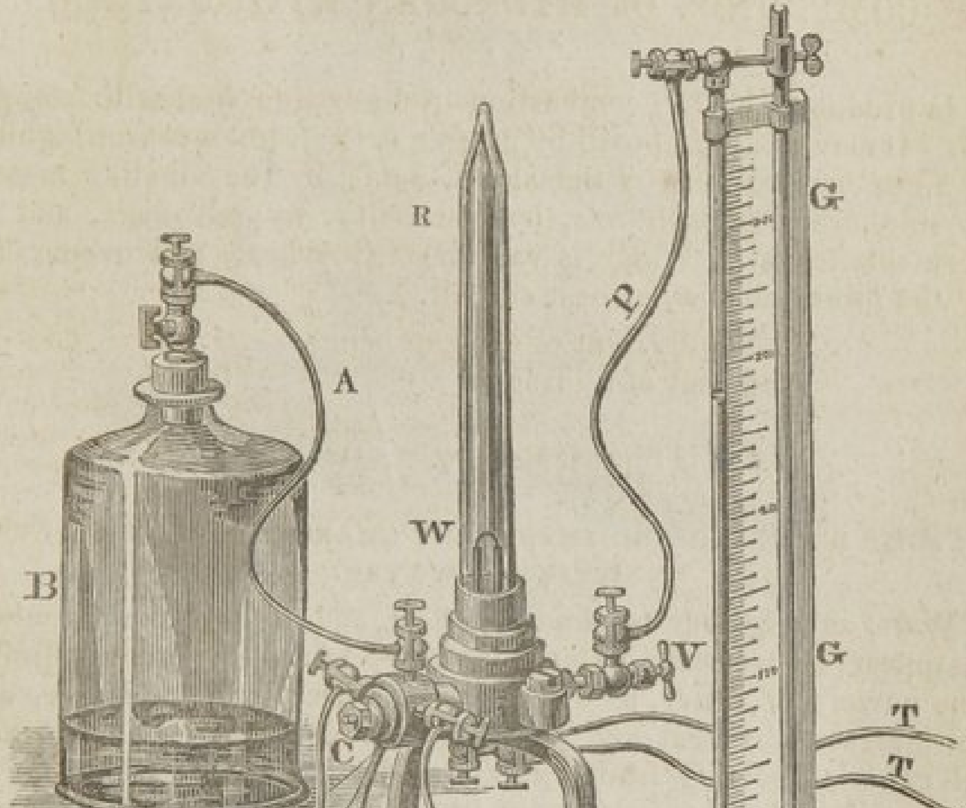
[†] One of the greatest difficulties, which I encountered, was in the imperfection of stop-cocks, in the common form. This I obviated by two contrivances, of my own; one invented about 16 years ago, the other in the summer of 1825. Of these I shall publish a description, with engravings, at some future period.

Of course there will be a deficit produced of more than 120 parts, of which one-third, or little more than 40 parts, will be the quantity of oxygen in 200 parts of the air, subjected to analysis.

In order to ascertain the influence of temperature, a thermometer is placed in the receiver, the state of which is noted before, and after the explosion; and the deficit is estimated, either, by allowing for the difference, produced by the temperature, or awaiting the refrigeration, until the mercury, in the thermometer, be at the same height as before the explosion.

A great number of experiments performed by means of the barometer gage eudiometer, and those of the sliding rod construction, gave $20\frac{66}{100}$ as the quantity of oxygen in 100 parts of the air. In 20 experiments the greatest discordancy did not amount to $\frac{1}{1000}$ in 100 measures of air.

BAROMETER GAGE EUDIOMETER.



129.—LEVITY OF HYDROGEN ILLUSTRATED.

Upon the arm of a scale beam, let a light glass globe, with an orifice of about two inches in diameter, be suspended and accurately balanced by a counter-weight, the orifice being lowermost. Allow a tube proceeding from a self-regulating reservoir of hydrogen, to pass up vertically into the globe, so that on opening the cock between the tube, and the reservoir, the gas will enter the globe, and displace the air, the hydrogen, from its lightness, occupying the upper part of the cavity.—Under these circumstances, the counterweight will preponderate in consequence of the buoyancy of the hydrogen.

Air balloons are large silk bags, rendered impervious by varnish, and filled with hydrogen gas. The power of balloons to rise in the air, and the buoyancy communicated to the glass globe in the experiment above described, are evidently due to the levity of the hydrogen gas.

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	1.
And that of hydrogen	0.125
Water is represented by	1.125

ON SOME PECULIAR AND IMPORTANT CHANGES, OR CHARACTERISTICS OF WATER.

Water is necessary to some crystals, and to galvanic processes. It appears to a certain extent necessary to acidity and alkalinity. The powers of water, as a solvent, are peculiarly extensive, and are increased by heat and pressure. It seems to be a substance, sui generis, isolated from oxides, acids, and alkalies. It unites with, and becomes consolidated in, the earths and alkalies; and produces heat during combination with them. The compounds resulting, are called hydrates.

130.—EXPERIMENTAL ILLUSTRATIONS OF THE AGENCY OF WATER.

No reaction ensues between tartaric acid and a carbonated alkali, until water be added, when a lively effervescence arises.

In like manner, concentrated sulphuric acid and zinc remain inactive, until water be 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.

131.—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 the barrel, the beak of a half-pint glass retort, about half full of water.—To the other end of the barrel, lute 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 galvanism, by sulphurets, phosphurets and the metalloids, will be illustrated in due time.

SYNTHESIS, OR RECOMPOSITION OF WATER.

132.—WATER PRODUCED BY AN INFLAMED JET OF HYDROGEN.

The recomposition of water may be rendered evident, by means of the philosophical candle, 119, 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.

133.—WATER RECOMPOSED BY GALVANIC IGNITION.

The barometer gage eudiometer, 128, may be employed in the recomposition of water. When used for this purpose, the receiver is transferred to a stand, by which it is so supported, that the apex being lowermost, the moisture arising from the union of the hydrogen and oxygen, may descend towards the sealed end of the tube, which is purposely contracted in diameter, in order to render a small quantity of water visible.

The apparatus thus modified, is represented by the opposite figure.

R, the receiver; P, pipe leading to the gage; A, pipe leading to a large bell glass; D, pipe, which is the mean of communication with the air pump; T T, leaden rods, proceeding from the galvanic poles.

By means of the simple valve volumeter, 125, introduce into the bell glass, one measure of oxygen, and two measures of hydrogen, each as pure as possible. Let the receiver be exhausted, and as much of the gaseous mixture admitted into it from the bell glass as will sink the gage one-sixth of the whole height of the scale. In this state of rarefaction, the explosion may be safely effected by igniting the wire, as already described, 128. After the explosion, the mercury in the gage will rise again more or less nearly to the point, from which it had fallen, accordingly as the gas may be more or less pure.

The admission of gas, and the explosion, may be repeated, until an observable quantity of water is produced.

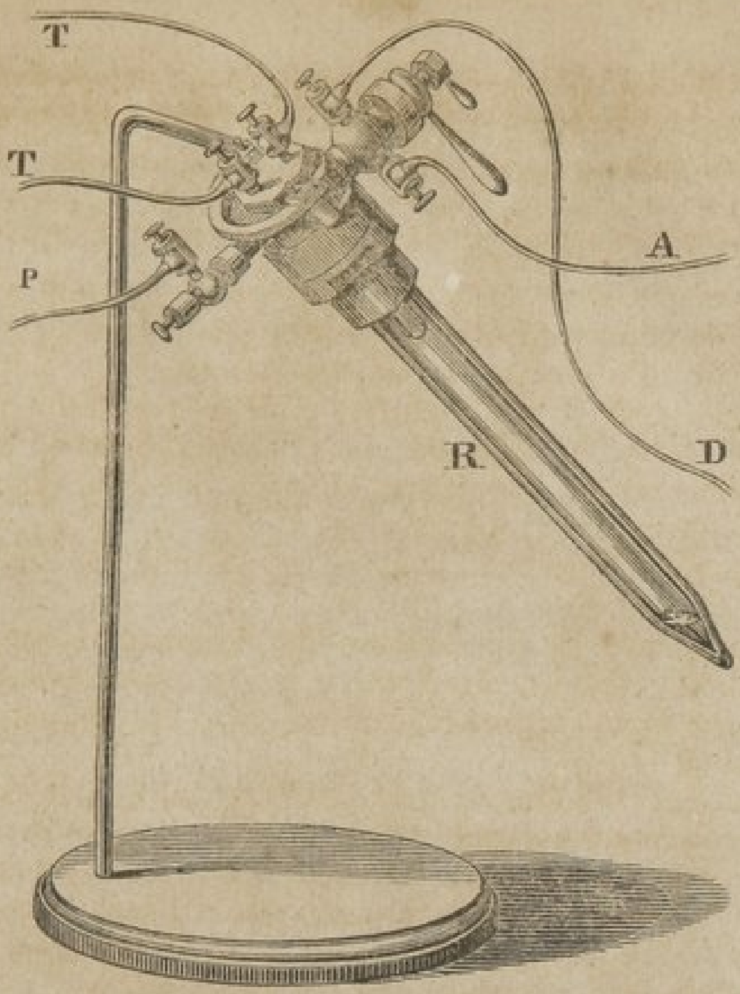
The lower end of the tube being kept in cold water, the aqueous vapour condensing into a fog, after every explosion, will be seen to subside into the refrigerated portion of the receiver.

134.—OF LAVOISIER'S APPARATUS FOR THE RECOMPOSITION OF WATER.

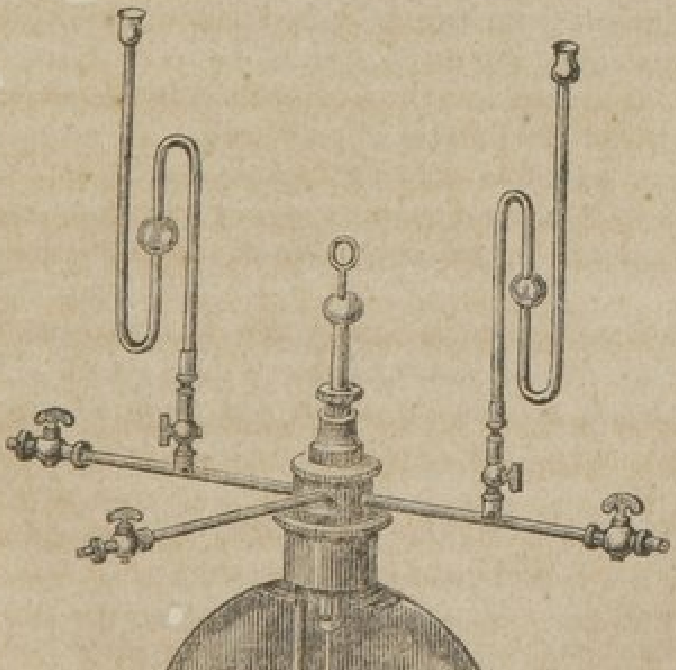
This apparatus consists of a glass globe, with a neck cemented into a brass cap, from which three tubes proceed, severally communicating with an air pump, and with reservoirs of oxygen, and hydrogen. It has also an insulated wire, for producing the inflammation of a jet of hydrogen, by means of an electric 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.

APPARATUS FOR RECOMPOSING WATER BY GALVANIC IGNITION.



LAVOISIER'S APPARATUS FOR THE RECOMPOSITION OF WATER.



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 blood. Fishes cannot live in water, which, either by boiling or exhaustion, has been entirely deprived of air.

135.—EXPERIMENTAL PROOF OF THE PRESENCE OF AIR IN WATER.

Fill the sliding rod eudiometer with water, and while the orifice is closed, draw out the rod briskly. Air bubbles will appear disseminated throughout the water.

The habitudes of other gaseous substances, with water, will be more advantageously described, or illustrated, when those substances are under consideration.

OF THE MOISTURE IN THE AIR.

Air is not more invariably an *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.

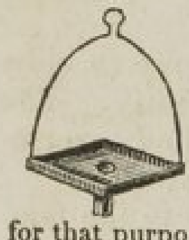
According to Mr. Dalton, the less the degree of cold requisite to produce this phenomenon, the greater the quantity of moisture in the air. Hence, by ascertaining the highest temperature at which the water may be, when capable of producing the condensation, the quantity of moisture may be known from 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, 52. 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 difference of the temperature necessary to the precipitation of moisture on the refrigerated bulb, increases. This difference of temperature is ascertained by the thermometers, the quantity of water in the air, by reference to a table.

136.—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.

137.—HYGROMETRIC PROCESS BY MEANS OF A CHYOMETER AND 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 the chyometer and a delicate scale beam, or the balance described in article 101, be used as an hygrometer. If it be suspended to the balance and equipoised, the counterweight will, in a few minutes preponderate, in consequence of the loss by evaporation. If at the end of an hour, or any other period which may be found convenient, the equiponderancy be restored by adding water from a chyometer, (100,) the quantity requisite for that purpose will be known. Hence the sizes of the evaporating dishes, and the value of the graduations on the chyometers employed, being reduced to a common standard, we may ascertain the rate of evaporation relatively to the time, at different times in the same place, or in different places at the same time.

The comparative drying power of the air may, in this way, be accurately ascertained; but as the evaporation is more or less rapid in proportion as there may be more or less agitation, it would not be right to infer that aqueous vapour in the atmosphere, is inversely as the rate of evaporation, unless the process were uninfluenced by the wind.

DEUTOXIDE 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, 50. In its most concentrated form, it has not been congealed by any degree of cold, to which it has been subjected.

The most anomalous 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 79.

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 using 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 respectable chemists conceive it to be a protoxide, and of course consider water as a suboxide, containing two atoms of hydrogen, and one of oxygen.

HYDROGEN WITH CHLORINE.

OF MURIATIC, OR HYDROCHLORIC, 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, muriatic, or hydrochloric acid gas is produced, without any reduction of volume, if no water be present.

For the purposes of the chemist, muriatic acid is obtained in the gaseous form, by the process described in the following article.

138.—GENERATION OF MURIATIC, OR HYDROCHLORIC ACID GAS.

Into a tubulated retort, introduce about as much chloride of sodium (common salt) as will occupy nearly one-third of the bulb, 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 $\frac{3}{4}$ 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 muriatic 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 muriatic acid gas.

PROPERTIES AND COMPOSITION OF MURIATIC 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—100 cubic inches weigh 39 grains. 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.

The alkaline metalloids decompose it, by combining with its chlorine, while its hydrogen assumes the gaseous state. Equal weights of potassium separate the same weights, or volumes of hydrogen, from muriatic acid, and from water; a result coincident with the atomic theory. It combines with pure barytes and strontites, producing a chloride and water.

When a mixture of oxygen gas and muriatic acid gas, is electrified, or passed through a red hot porcelain tube, the oxygen unites with the hydrogen of the acid, while the chlorine is liberated.

One atom of chlorine, equivalent	4.5
And one atom of hydrogen, equivalent	.125
Constitute one atom of muriatic acid gas, equivalent	4.625

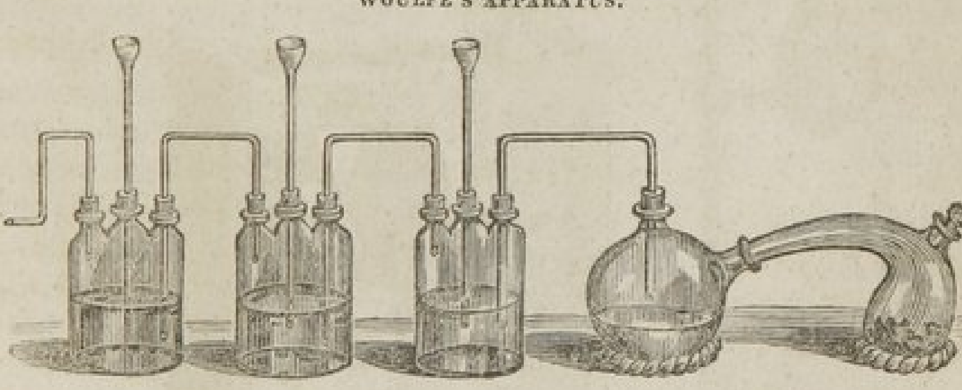
139.—OF LIQUID MURIATIC ACID.

Means of obtaining Liquid Muriatic Acid.

It may be obtained by saturating water with the gas, in Woulfe's apparatus.—See 140. 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 muriatic acid, and generally where liquids are to be impregnated with any gas.

WOULFE'S APPARATUS.

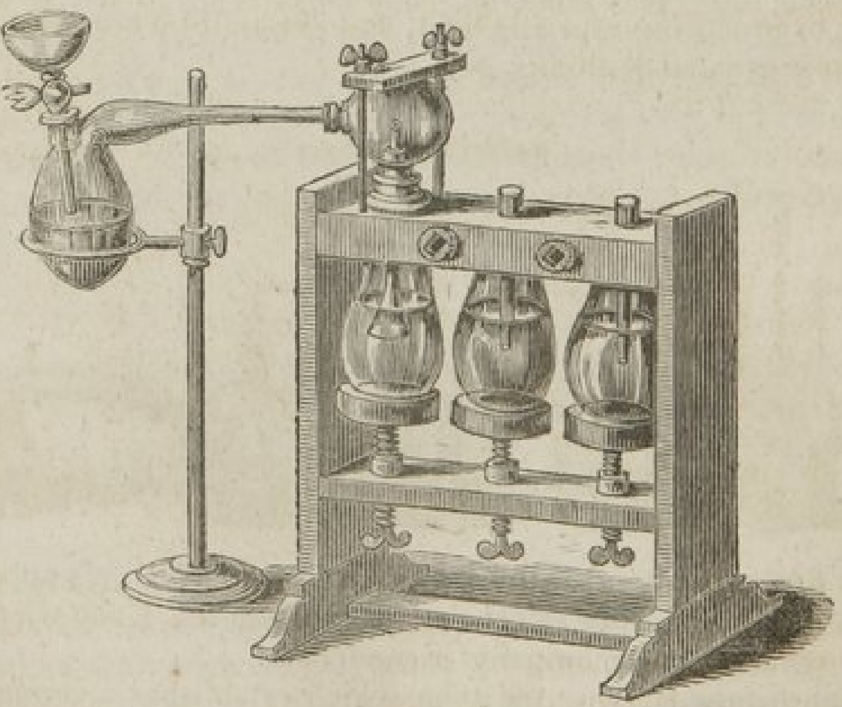


This figure is intended to convey an idea of Woulfe's apparatus. The gas evolved in the retort first passes into the globe where any vapour which may accompany it condenses.

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 triad, 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 muriatic 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.

140.—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, as in ordinary apparatus. 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 condensible 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 cocks. 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 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. Muriatic acid *can be said to combine with those alkalies, earths, and oxides only, which form, with it, soluble salts.* Its combinations are, for the most part, by heat and desiccation, convertible into chlorides. Muriate of magnesia, and muriate of alumine, are exceptions—also muriate of ammonia, of which there can be no chloride, since chlorine decomposes it, by its affinity for hydrogen.

Dr. Thomson informs us that the strongest acid, which he could obtain, consisted of one atom of acid, equivalent 4.625, united with six atoms of water, which being 1.125 each, makes the aggregate weight of the water 6.75. Of course the proportion of the one to the other was as those numbers, or nearly as 60 to 40.

OF THE OLD THEORY OF THE NATURE OF CHLORINE AND MURIATIC ACID.

Muriatic 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 charcoal, even when ignited by the voltaic pile, is not acted upon by dry chlorine, nor are metals oxydized. They are converted into substances, now called chlorides. The chloride of sulphur, and deuto-chloride 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 phosphoric acid, the other, into muriatic and sulphurous acid.

If chlorine be muriatic acid oxygenated, the discovery of the protoxide and peroxide of chlorine, and of chloric and perchloric 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 132, that Thenard oxygenated the water in muriatic acid; yet the liquid thus containing oxygen, in excess, had no resemblance to chlorine.

Agreeably to the doctrine, now almost universally sanctioned, by chemists, muriatic acid, consisting of chlorine and hydrogen, is deprived of hydrogen, in all those processes in which it formerly was supposed to be oxygenated.

EXPERIMENTAL ILLUSTRATIONS.

Equal volumes of hydrogen and chlorine, being mixed and subjected to the solar rays, or galvanic ignition, explode, and form muriatic 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.

THEORY OF VOLUMES.

The student is now so far advanced, that it will be, upon the whole, advantageous for him to be made acquainted with the theory of volumes; otherwise, the language now usually employed, in treating of combinations, resulting from the union of gaseous substances, will not be intelligible to him.

It has been advanced by Gay-Lussac, that substances, when aëriform, 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 aëriform 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.

If in passing to the aëriform state, each atom were to acquire the same bulk, the atoms would be as well represented by equal volumes, as by the equivalents; 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 aëriform, 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 more or less voluminous than the rest. This is all, that the hypothesis of Gay-Lussac requires. Thus whatever may be the volume of a gaseous atom of oxygen, the atoms of hydrogen, nitrogen, and chlorine, when gaseous, and subjected to the same temperature and pressure, will occupy two such volumes; the gaseous atoms of muriatic acid and ammonia, under like circumstances, will occupy four such volumes, and consequently to make the numbers which represent the volumes in combination, correspond with those which represent the atoms, it is only necessary to divide by two, in the case of hydrogen, nitrogen, and chlorine, by four in the case of muriatic acid and ammonia.

This will be seen from an inspection of the following table, in which, the number of atoms, and the number of volumes which enter into several important compounds, are exhibited. It is, in truth, well ascertained, that equal volumes, or multiples of them, are naturally equivalents of the substances of which they are constituted.

Instances, supporting the theory of Volumes.

	Vols.	Atoms.		Vols.	Atoms.
Protoxide of chlorine consists of	2	1 Chlorine	with	1	1 Oxygen
Water	2	1 Hydrogen		1	1 Oxygen
Muriatic acid	2	1 Hydrogen		2	1 Chlorine
Nitrous oxide	2	1 Nitrogen		1	1 Oxygen
Nitric oxide, or nitrous gas	2	1 Nitrogen		2	2 Oxygen
Hyponitrous acid	2	1 Nitrogen		3	3 Oxygen
Nitrous acid vapour	2	1 Nitrogen		4	4 Oxygen
Ammonia	2	1 Nitrogen		6	3 Hydrogen
Hydrocyanic acid vapour, or prusisc acid	2	1 Cyanogen		2	1 Hydrogen
Carbonate of ammonia	2	1 Carbonic acid		4	1 Ammonia
Bi-carbonate of ammonia	4	2 Carbonic acid		4	1 Ammonia
Sesqui-carbonate of ammonia	6	3 Carbonic acid		8	2 Ammonia
Muriate of ammonia	4	1 Muriatic acid		4	1 Ammonia

If all the numbers in the preceding table, denoting volumes, were divided by two, it must be evident, that they would convey essentially the same idea with respect to the ratios upon which they are founded. In that case, the atom of oxygen, would be represented by a half volume, while chlorine, hydrogen, nitrogen, carbonic acid, and cyanogen, would be represented by one volume. Accordingly, I shall pursue this method, of representing volumes, as it is the most convenient, and is now generally adopted.

In bringing forward atoms and volumes simultaneously, it will be my object to show the relation which subsists between equivalents in volume, and equivalents in weight, and to inform the student of the ratios in which substances unite, whether measured or weighed.

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.

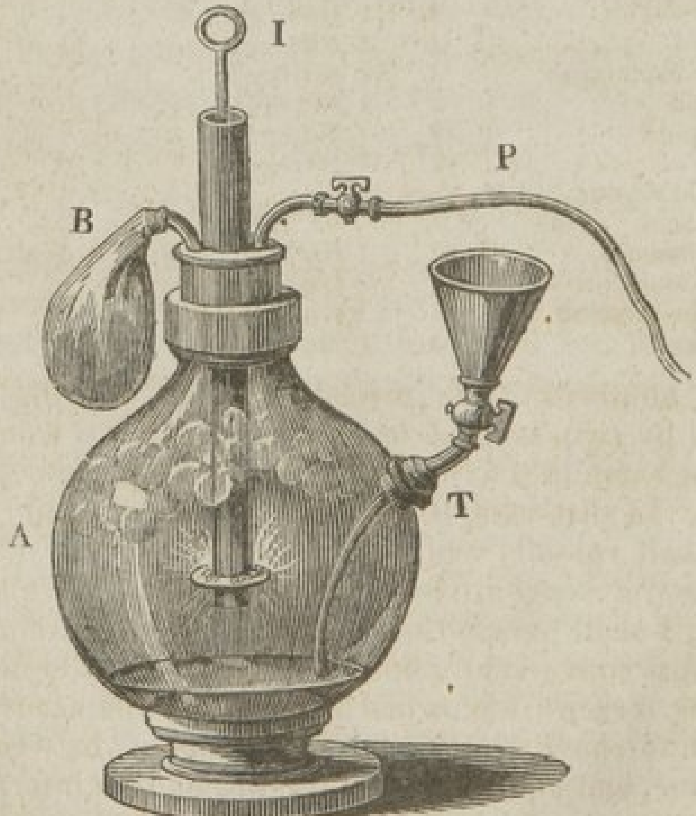
Nitrogen is derived from the same Greek verb as oxygen, combined with the word nitre or nitric. Hence nitrogen signifies a capacity to produce nitre, or nitric acid, as oxygen conveys the idea of a capacity to produce acids.

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.

141.—APPARATUS FOR PROCURING NITROGEN.

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.



Concentric with the axis of the globular glass vessel, **A**, is a portion of a gun barrel, which is soldered to a large stopple of brass, ground to fit, air tight, in a brass collar cemented upon the neck of the vessel. On one side of the gun barrel, a flexible lead pipe, P, with a cock, is soldered into a perforation in the stopple, which enables it to communicate with the interior of the globe. In like manner another tube is soldered into the stopple, which establishes a communication between the cavity of the uninflated bladder, B, and that of the globe. Into a tubulure, T, another larger pipe is luted, so that while one part proceeds, within, to the bottom of the vessel, the other is surmounted without, by a cock and funnel. The gun barrel is closed at the lower end —at the upper end is open. Near the lower end is soldered, a cup of sheet copper, perforated so as to allow the gun barrel to pass through it for about an inch.

On this cup, the phosphorus in small pieces is placed, and the bottom of the vessel being covered by water, the stopple is seated in the brass collar, as seen in the figure. The cocks being all shut, the phosphorus is heated through the gun barrel by a red hot iron, I, passed down the bore of the barrel, until the heated part is opposite the copper cup. As soon as the combustion begins, the hot iron should be withdrawn; but when the flame burns dimly, the iron, meanwhile, returned into the fire, must be again applied, to support the temperature, until all the oxygen may have united with the phosphorus. At the commencement of the combustion, the bladder is inflated in consequence of the expansion of the air arising from the heat; but, as the volume of the air is reduced, about one-fifth, by the condensation of its oxygen, and as the heat causing the expansion escapes, the air which had inflated the bladder, returns into the globe. Its return should be accelerated and completed, by compressing the bladder, the neck of which, while compressed, should be tied. Water should then be introduced through the funnel, the cock being opened for the purpose, until the deficit caused by the loss of oxygen, be compensated. By the introduction of a farther quantity of water, any requisite portion of the gas may be made to flow out, through the pipe, P; which, in the original, is long enough to reach under the sliding shelf of the pneumatic cistern.

Of the properties or characterestics 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 does not support either life or 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. The equivalent, or atomic weight, of nitrogen, is 1.75.

142.—EXPERIMENTAL ILLUSTRATION OF THE PROPERTIES OF NITROGEN GAS.

A portion of the residual air, of the preceding experiment, 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 muriatic 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 salt, 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 attraction exists between them, than that which is known to cause the equable diffusion of gases among each other, notwithstanding the difference of their specific gravities.

In all cases of chemical combination, unless where there is a consequent condensation of caloric, as in nitrous oxide,* the difficulty of removing either of the ingredients, by any substance having an affinity for it, is increased in proportion as the ratio which it bears to the other ingredient, lessens. Atmospheric air is, of all the *gaseous* compounds of its elements, that from which oxygen is most easily removed, although it is the one, in which there is the least oxygen in proportion to the nitrogen.

In its qualities, it 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 25, 41. 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, have been described. Others will be mentioned under the heads of nitric oxide, of sulphurets and phosphorus.

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.

Means of obtaining Nitrous Oxide.

It may be obtained by the action of dilute nitric acid upon zinc: by exposing nitric oxide gas to iron filings, sulphites, or other substances, attractive of oxygen. It is best procured by exposing nitrate of ammonia to heat, and receiving the product in an apparatus described in the following article.

143.—APPARATUS FOR EVOLVING AND PRESERVING NITROUS OXIDE GAS.

A, represents a copper vessel of about 18 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 cullender. 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.

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* The oxygen of the protoxide, is more easily separated by iron, or hydrogen, than that of the deutoxide of nitrogen. This exception to the rule above stated, may arise from the fact that, in the former, two volumes of nitrogen, and one of oxygen gas, are condensed into two volumes; whereas, in the latter, the gaseous elements exist without condensation. It may be presumed that caloric, being in nitrous oxide one-third denser than in the deutoxide, co-operates more forcibly, with the affinities, which tend to sever the elements.

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 & 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.

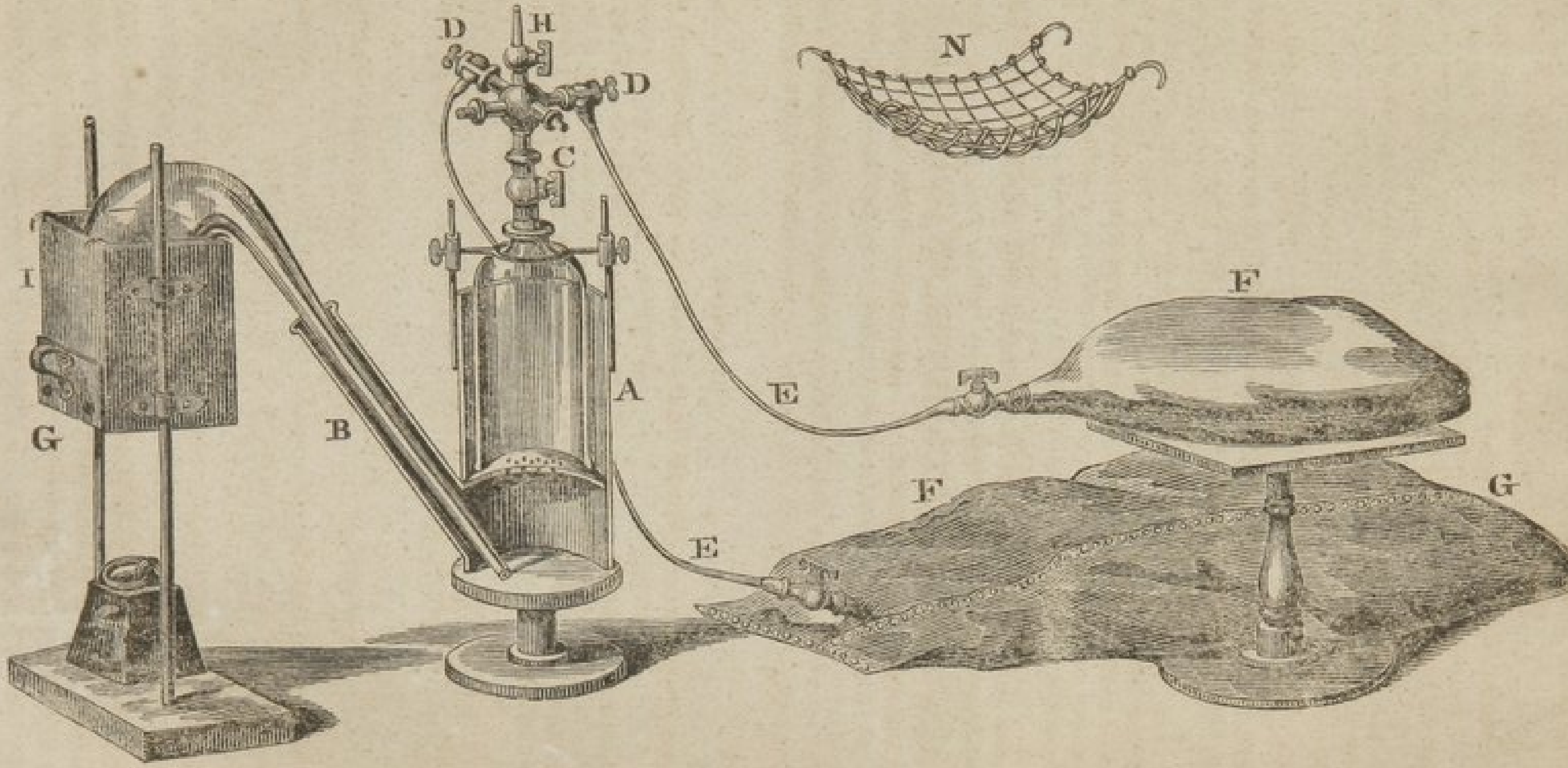
RATIONALE.

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 all five atoms of oxygen, three of hydrogen, and two of nitrogen are present, in one atom of the salt. 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. Nitrous oxide may be exploded with hydrogen, forming water, and sometimes nitric acid. It has no attribute of acidity. It stimulates and then destroys life. Its effects on the human system are analogous to a transient, peculiar,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various, and generally very vivacious ebriety. It is much more rapidly and extensively soluble in water, than oxygen.

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.

One volume, or one atom of nitrogen	=	1.75
And half a volume, or one atom of oxygen	=	1.
Condensed into one volume, constitute one atom of nitrous oxide, equivalent to		2.75

EXPERIMENTAL ILLUSTRATIONS.

The process and apparatus, for producing, catching, and breathing, the nitrous oxide gas, exhibited. The effect on a lighted candle, and on an iron wire, shown.

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.

144.—SELF-REGULATING APPARATUS FOR GENERATING NITRIC OXIDE.

The best method of procuring this gas, is analogous to that described in the case of hydrogen, 120, excepting that, instead of zinc and diluted sulphuric acid, we must use copper and nitric acid; and that in lieu of a copper tray and wires, we must employ a platina wire, or a glass rod.

If a glass rod is used, it must be enlarged at the lower end, and the copper formed into a coil, or punched so as to be secured upon the rod, the smaller end of which, is fastened afterwards in the axis of the inner glass vessel by cement, or by means of a stuffing box, through which it is passed.

By means of a platina wire, soldered to the cap of the inner vessel, it is easy to suspend a coil of copper, in place of the copper tray and zinc.

Properties and Composition of Nitric Oxide Gas.

It is permanent over water, by which it is slightly absorbed:—is rather heavier than common air. 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. It is fatal to animals—renders the flame of hydrogen green by mixture—does not explode with it, but does explode with ammonia.

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 sulphate or muriate of the black oxide of iron. The solution acquires the property of absorbing oxygen, and is, therefore, used in eudiometry. Nitric oxide is decomposed by moistened iron filings, by ignited charcoal, arsenic, zinc, or potassium.

One volume, or one atom, of nitrogen, equivalent - -	1.75
And one volume, or two atoms, of oxygen, equivalent	2.
Constitute two volumes, or one atom, of nitric oxide, equivalent - - - - - -	3.75

Of course the volumes of oxygen and nitrogen exist in this gas without condensation.

145.—EXPERIMENTAL ILLUSTRATIONS OF THE PROPERTIES OF NITRIC OXIDE.

Copper or silver 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 green muriate, 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.

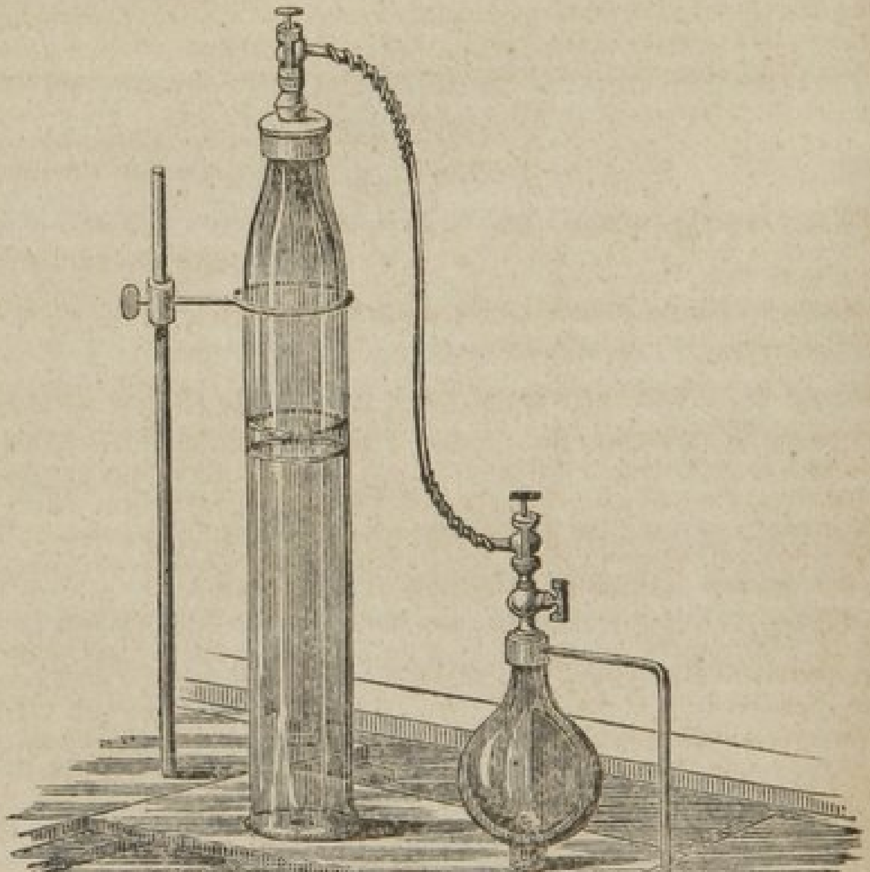
Self-regulating reservoir of nitrous gas, for eudiometrical experiments. Absorption of oxygen gas, by nitric oxide, and the consequent acidity, made evident by the effect on litmus. Homberg's pyrophorus in falling through the gas is ignited.

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 its liability to be absorbed in a small extent by water, and the variable proportions in which the abovementioned compounds are liable to be formed, the results, thus obtained, have been deemed uncertain, and the directions for using nitric 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 nitric oxide consists of a volume of nitrogen and a volume of oxygen uncondensed, to convert it into nitrous acid, which consists of a volume of nitrogen, and two volumes, of oxygen, would require one volume of oxygen. Of course, if nitrous acid be the product, one-third of the deficit produced, would be the quantity

NEW EUDIOMETRICAL APPARATUS BY NITRIC OXIDE.



of atmospheric oxygen present. This would be too much to correspond with the formula of Gay-Lussac.

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 1 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	

This result is evidently dependent upon the contingencies, which may prevent nitrous acid from being the predominant product. I have accordingly found it precarious, in at least 100 experiments accurately made with the sliding rod eudiometer, described in the next page.

146.—NEW EUDIOMETRICAL PROCESS BY MEANS OF NITRIC OXIDE.

Suppose a tube of about three inches in diameter, and two feet in height, closed at one end, to be marked by a diamond at the point to which it becomes charged, by receiving, when filled with water, over the hydro-pneumatic cistern, nine hundred measures of air, from the sliding rod gas measure, 127, also, at the point to which it becomes charged after receiving one thousand such measures. Into the tube thus prepared, while filled with water and inverted over the hydro-pneumatic cistern, introduce one thousand measures of air. Then add five hundred measures of nitric oxide, by means of a volumeter, holding exactly that quantity. After the red fume produced by this addition is washed away, by agitation with the water, there will be about eight hundred and fifty measures left. This will appear, upon adding from the sliding rod gas measure, as many measures of hydrogen as are necessary to cause the residual air to extend to the mark for nine hundred measures. The whole quantity of the air and gas taken, being fifteen hundred measures, if only eight hundred and fifty are left, six hundred and fifty have disappeared, which, divided by 3, gives 216.6 in 1000, or 21.6 in 100.

The result corresponds more nearly with those obtained by the hydro-oxygen eudiometer, when, by means of a flexible leaden pipe, forming a communication between a volumeter and the top of the tube, we are enabled to introduce the nitric oxide over the air instead of passing it up through the water.

The volumeter with which the pipe forms a communication, is, in shape, like the glass of the simple valve volumeter; but instead of being similarly accoutred, has only a brass cap and cock. To the latter, the pipe is attached. It should hold exactly five hundred measures of the sliding rod gas measure, in order to correspond with the marks, upon the tube, made as above described.

Supposing that there is 21 per cent. of oxygen in the air, there would be 210 parts of oxygen, in the 1000 measures taken, which would require 420 measures of nitric oxide. Hence, it is probable that a volumeter holding a smaller quantity than five hundred measures, would answer for a thousand measures of air. The less nitric oxide there may be unnecessarily present, the less the risk of error, from its absorption.

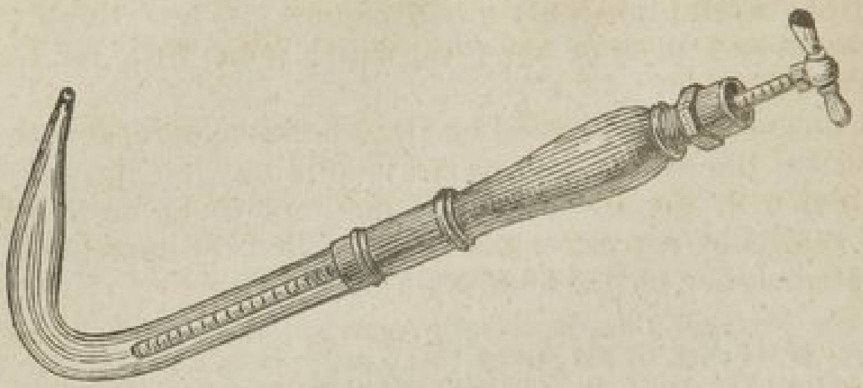
147.—SLIDING ROD EUDIOMETER FOR NITRIC OXIDE.

Fig. 2, represents the form of the sliding rod eudiometer, which I have found most serviceable for experiments with nitric oxide gas, or those in which sulphate, or muriate 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.

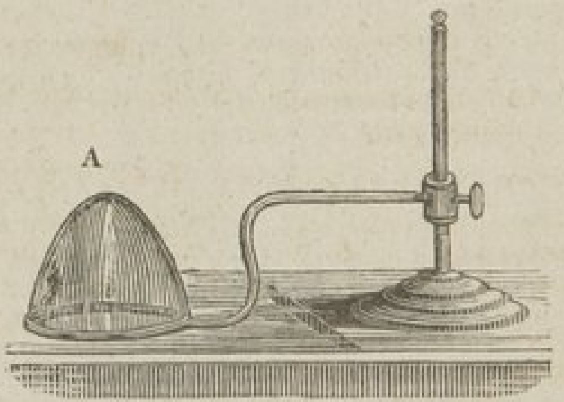
The mode in which the rod is made to measure gaseous fluids, has been explained, 124.

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, without allowing the gas to have any contact with the water, which is not inevitable. 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.

METHOD OF ASCERTAINING THE PURITY OF NITRIC OXIDE.

148.—EUDIOMETRICAL PROCESS BY NITRIC OXIDE AND GREEN SULPHATE, OR MURIATE OF IRON.

The purity of nitric oxide is easily ascertained, by means of a solution of green muriate, 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 abovementioned 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 muriate 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.

ON THE THEORIES OF COMBUSTION, ACIDITY, AND ALKALINITY; AND ON NOMENCLATURE.

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 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 supposed 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 the compounds were assumed to be lighter, and to be contained by one of their constituents! Lavoisier's theory was correct, in suggesting, that in all ordinary cases of combustion, oxygen is absorbed. It was erroneous, in not providing for exceptions, as, when metals enter into combustion, with sulphur, or with chlorine.

Combustion, according to common sense, is a state of intense corpuscular reaction, accompanied by an evolution of heat and light.

It is a general law of nature, that the capacities for caloric, of compounds, are sometimes greater, sometimes less, than those of their constituents. Hence chemical combination, is sometimes productive of heat, sometimes of cold.

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.

The heat of combustion appears to be principally due to the gaseous agent; the light, to what is called the combustible.

The idea of a class of supporters of combustion, and of combustibles, has no other foundation, than that certain substances are more frequently agents in it, and therefore called supporters. Thus, hydrogen will produce fire, only with oxygen and chlorine; sulphur, with metals;—and carbon, with oxygen; but as either oxygen or chlorine, will burn with a great variety of substances, they are called supporters of combustion, and the substances with which they combine, during combustion, are called combustibles. Iodine is classed among the supporters also, because it combines with almost all the substances with which they unite, and forms analogous compounds. Yet iodine is not gaseous, like chlorine and oxygen, and, upon the whole, is as analogous to sulphur as to chlorine.—The propriety is questionable, of taking it into the class of supporters, and excluding sulphur.

Sulphur is intermediate, in its habitudes, between phosphorus and iodine. The habitudes of selenium, a newly discovered substance, seem to lie between the metals and sulphur.

Hydrogen, phosphorus, carbon, boron, and silicon, deserve as well to be called combustibles, as oxygen, chlorine, and iodine, to be called supporters: but 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.

OF ACIDITY AND ALKALINITY.

Acidity was originally synonymous with sourness—but all the substances now called acids, are not sour. They generally 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. Acids are generally very soluble in water. Silex furnishes an exception.

The idea of a universal acid principle, commenced with Paracelsus,—was supported by Beecher and Stahl, and afterwards by Lavoisier:—but it was questioned by Berthollet. The existence of a common cause, not only of acidity, but of alkalinity, still, to me, appears probable.

It will be shown hereafter, that if any light bodies, be electrified, either by glass or resin, they will separate: but that if one, be electrified by glass, and the other by resin, they will attract each other.

The cause of galvanic phenomena has been supposed by many philosophers, to be the same as that of electricity, produced by glass, or resin; but modified by some unknown principle, so as to act between atoms, instead of masses.

The pole, or end of a galvanic or voltaic series, terminating with the most oxidable metal, has been found to show a very feeble electrical excitement, of the same kind as that produced by glass; —while the other termination of the galvanic series, displays the opposite excitement of resin.

Agreeably to a very extensive experience, it would seem, that of any two substances in nature, simultaneously exposed to wires, severally proceeding from the different poles of a galvanic series, —one will go to the positive, the other to the negative pole. Atoms are inferred to be in electrical states, different from those of the poles to which they are severally attracted: and are said to be electro-negative, when attracted by the positive pole—and electro-positive, when attracted by the negative pole. Oxygen is conceived to be more invariably attracted by the positive pole, than any other substance. Next to oxygen, chlorine is most electro-negative:—and iodine next to chlorine. Other substances, as for instance, metalloids, and metals,—also hydrogen, carbon, sulphur, and phosphorus, are comparatively electro-positive. Substances, of the two opposite classes, in combining with each other, constitute compounds, which are either electro-positive, or electro-negative, accordingly as the different energies of their ingredients preponderate. Thus, in alkalies, consisting of oxygen united with metalloids, the electro-positive character of the metalloids predominates; but the reverse is true, of acids consisting of the same electro-negative principle, oxygen, in combination either with sulphur, nitrogen, phosphorus, carbon, boron, or other substances, of an electro-positive character.

At a mean point, between the extremes, at which oxygen and the alkaline metalloids are placed, there are substances, whose relation to the pile is equivocal, or wavering; and it should be understood, that this relation is always comparative. Chlorine is electro-positive with oxygen, and electro-negative with every other body. Iodine is electro-positive, either with chlorine, or oxygen, and, with other substances, electro-negative.

I avail myself of the language, which has arisen from the hypothesis, according to which these polarities are ascribed to electricity, though I do not think it accounts satisfactorily for their existence.

I suspect, that alkalinity, and 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 adventitious, being attached to elements, which exist in other compounds, without inducing acidity, or alkalinity.

SALT DEFINED.

It is not possible now to give a satisfactory definition of the meaning of the word salt. Formerly, it would have been defined a soluble compound of an acid and an alkali; but the substance (common salt) which gave its name to the genus, would be excluded from it, by that definition. I would define a salt to be a soluble compound, (containing one or more acid or corrosive ingredients) the qualities of the ingredients being either neutralized or modified.

ON THE NOMENCLATURE OF OXIDES, ACIDS, AND SALTS.

It may be proper, before we proceed 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.

A substance, converted into an acid, by oxygen, or chlorine, is called the radical of the acid. When an acid is discovered, having less oxygen than one with the same radical, ending in *ous*, *hypo* is prefixed. Hence the terms *hypo*nitrous, *hypo*sulphurous. This word is also applied where the state of oxygenation is more than in that of an acid, ending in *ous*, but less than that of one ending in *ic*: hence *hypo*sulphuric.

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 there be a third acid having still more oxygen, the letters oxy are prefixed. 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 *pro*toxides, have the word *proto* prefixed, as in the instances of *proto*-nitrate, *proto*-sulphate.

OF NITROUS ACID.

This is a compound of one atom of nitrogen, with four atoms of oxygen. It is formed by mixing, in an exhausted receiver, one volume of oxygen gas, with two volumes of nitric oxide. As nitric oxide contains a volume of each gas, the acid formed must comprise two volumes of oxygen, equivalent to four atoms, and one volume of nitrogen, equivalent to one atom.

This acid is formed when nitrates are moderately heated, in which case, they lose a half volume of the oxygen, from each atom, of their nitric acid, or just so much as is requisite to convert the one acid into the other. Thus the nitrates are converted into nitrites, the nitrous acid remaining in union with the base.

From the nitrite of lead thus produced, the acid may be liberated, by sulphuric acid, and may be condensed in water, or in a receiver, surrounded by snow and salt.

Nitrous acid is interesting, rather as an object of scientific curiosity, and from its relation to nitric acid, than from any inherent usefulness.

149.—PRODUCTION OF NITROUS ACID ILLUSTRATED.

Let the volumeter, of the apparatus described in article 146, be filled with pure oxygen gas; and let double the quantity of nitric oxide be introduced into the tube. On opening the cock, between the volumeter and tube, the water being much higher in the latter, the oxygen will pass over into the tube, and mixing with the nitric oxide, dense red fumes of nitrous acid will be produced, which will be rapidly absorbed by the water.

OF NITRIC ACID.

It has already been stated, that the atmosphere consists of gaseous nitrogen and oxygen, in a state of mixture, not of combination, with rather less than 1 part in 1000 of carbonic acid, and some aqueous vapour. Nevertheless, nitrogen and oxygen, if in due proportion subjected to a succession of electric sparks, combine, and form nitric acid, one of the most active and important agents of chemistry. There is some other unknown mode, in which chemical union is induced between these atmospheric ingredients, whence the great quantity of nitrate of potash found in nature.

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. It is accompanied always, more or less, by red fumes, arising probably from the partial decomposition of nitric by sulphurous acid, which usually accompanies the sulphuric.

Properties and Composition of Nitric Acid.

Nitric acid is nearly one half heavier than water, usually orange coloured—when pure, colourless. It 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 the matter of atmospheric air, in the liquid form; but with ten times as much of the active principle, oxygen. It is the most energetic principle in gunpowder. It ignites oil of turpentine, charcoal and phosphorus.

Nitric acid consists of one volume, or one atom of nitrogen,	1.75
With 2½ volumes, or five atoms of oxygen,	5.
Hence the equivalent of the dry acid, is	6.75

The strongest acid which Dr. Thomson was enabled to procure, had the specific gravity of 1.534. He infers that if the acid contained for every atom, only one atom of water, its gravity would be 1.55.

150.—EXPERIMENTAL ILLUSTRATIONS.

The extrication and distillation of nitric acid, shown by means of a glass retort and receiver, heated by a lamp—a chauffer—or small sand bath. Its action on various substances exemplified.

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.

Until of late, 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 aëriform, has been called the volatile alkali. A new mineral fixed alkali has been discovered lately, and named Lithia. It is procured from a stone called Petalite. Hence its name from the Greek λιθειος, stony.

The alkalies have all a peculiar taste, called alkaline. They all produce, in certain vegetable colours, characteristic changes, which differ according to the matter subjected to them, but is not varied by changing the alkali.

They restore colours changed by acids, and are generally capable of neutralizing acidity.

They combine with oils, rendering them 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.

It is, however, my present intention, as introductory to the subject of ammonia, only to adduce a few experiments which illustrate the properties of alkalies in general.

151.—EXPERIMENTAL ILLUSTRATIONS.

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.

AMMONIA, OR THE VOLATILE ALKALI,

Is named from sal ammoniac, the salt from which it is usually obtained.

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 explodes 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. Its weight to common air, is nearly as 3 to 5.—100 cubic inches weigh 18 grs. Water absorbs it with surprising velocity; and will hold from 450 to 670 times its bulk. Ice melts in ammonia quicker than in 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.

152.—EXPERIMENTAL ILLUSTRATIONS.

Sal ammoniac, and quick-lime, being powdered and mixed in small glasses, pungent fumes are emitted. The same mixture contained in Florence flasks, being exposed to a chauffer of coals, the ammonia is extricated, 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.

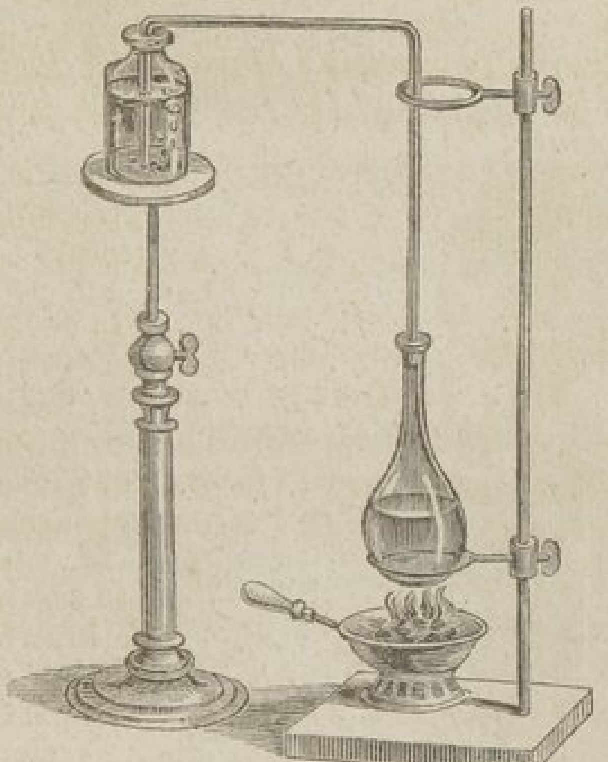
153.—PROCESS FOR OBTAINING GASEOUS AMMONIA.

A flask, containing equal parts of slaked lime, and muriate of ammonia, 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 catch any gas which may pass from the orifice of a tube luted at one end into a flask, and the other entering the mercury so as to be under the bell.

154.—PROCESS FOR OBTAINING LIQUID 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 aquæ ammonia, or liquid ammonia.



EXPLANATION *of the* PROCESS *for obtaining Gaseous, and of that for obtaining Liquid Ammonia.*

The lime, having a greater affinity for muriatic acid than ammonia, on mixing this earth with the muriate of ammonia, the acid and the earth unite, and the alkaline gas being liberated, escapes from the mouth of the tube, and rising into the bell glass, displaces the mercury. When made to pass into water, by means of a tube reaching from a flask to the bottom of a phial, as in this figure, the gas is most rapidly absorbed, on account of its great affinity for water.

COMPOSITION AND ATOMIC WEIGHT OF AMMONIA.

Ammonia consists of one volume or one atom of nitrogen	1.75
And three volumes or three atoms of hydrogen	.375
Its atomic weight is therefore	2.125

The four volumes, of which it consists, are condensed into two.

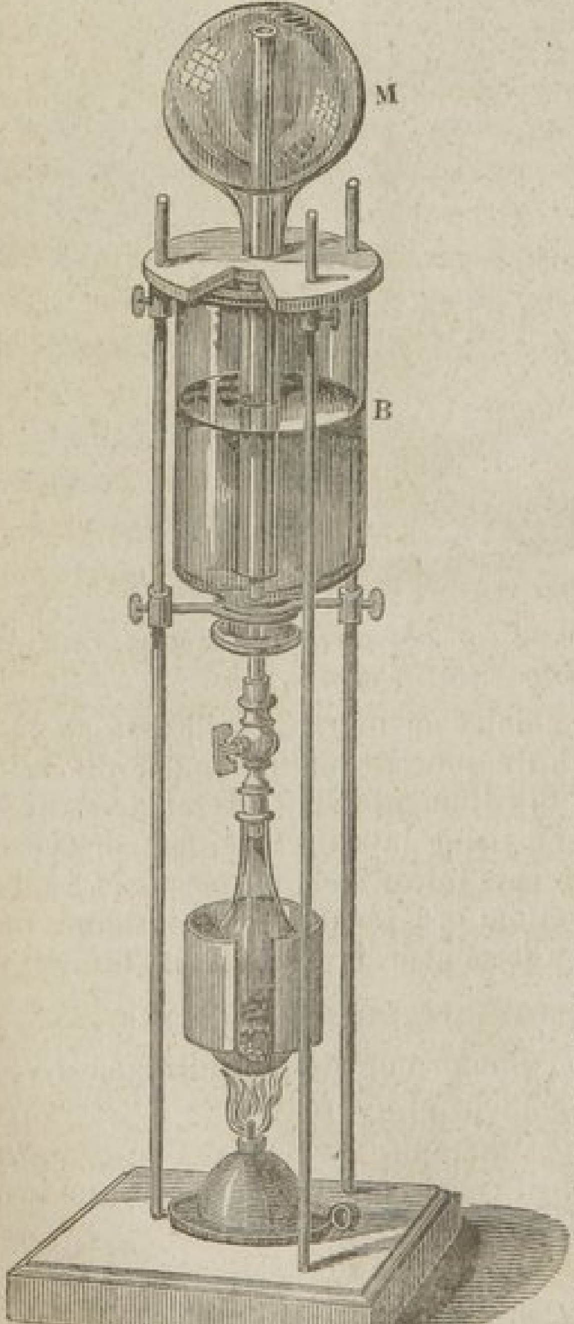
EXPERIMENTAL ILLUSTRATIONS.

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.

INFERENCE.

It would be anomalous for an amalgam, to arise from a union of mercury with any substance not metallic. It may therefore be inferred, that ammonia is a gaseous alloy of hydrogen and nitrogen—that these, if obtained in the solid state, would be metallic.

155.—APPARATUS *for showing conveniently the Absorption of Ammonia by water, and the Influence of this Alkali on vegetable Colours.*



The gas is evolved as in the preceding experiments. The flask, containing the lime and sal ammoniac, is luted to a cock, from which a tube proceeds vertically through the axis of an open-necked inverted bell glass, B. The tube also passes up through a long necked matrass, M, which is inverted so as to receive it.

The inverted bell is supplied with water coloured with Brazil wood, or any other colouring matter changeable by alkalies.

These arrangements being completed, the alkaline gas rises through the tube to the highest part of the bulb of the matrass, which situation it assumes, in consequence of its natural levity, and the expansion arising from the heat employed to extricate it. Of course the atmospheric air sinks before it, and is finally expelled. Whenever this takes place, which may be known, as bubbles will then cease to rise through the water, on account of the rapid absorption of the ammonia, the cock must be closed. The coloured water then rises through the neck of the matrass, slowly, until it reaches the bulb, but afterwards rushes up rapidly, sustaining, at the same time, the change of colour which the alkali is known to produce.

COMPOUNDS OF NITROGEN WITH CHLORINE AND WITH IODINE.

Neither chlorine nor iodine combine 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°, pursuant to Mr. Brande's directions.

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.

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 is given in commerce.

Properties of Sulphur.

Is is insipid and inodorous, unless when burning—electric by friction—cracks from the warmth of the hand. At 180° (F.), it evaporates slowly, melts at 225°—thickens between 350° and 400°. At 560 it takes fire, if exposed to the air. In close vessels, it sublimes at 600. The flowers which it forms in condensing, appear crystalline, when viewed with the microscope. It may be obtained in crystals, by pouring out the liquid part of a fused mass, after the exterior surface has congealed.

Sulphur is soluble in boiling oil of turpentine. It combines with metals, earths, and alkalies, forming compounds called sulphurets. An acid precipitates it from solutions of alkaline, or earthy sulphurets. It forms with oxygen the sulphurous, hypo-sulphurous, sulphuric, and hypo-sulphuric acids.

Equivalents of Sulphur and its compounds.

The atomic equivalent of sulphur is		2.
One atom of sulphur,	With one atom of oxygen, forms hypo-sulphurous acid, equivalent	3.
	With two atoms of oxygen, forms sulphurous acid, equivalent	4.
	With three atoms of oxygen, forms sulphuric acid, equivalent	5.
Two atoms of sulphur,	With five atoms of oxygen, form hypo-sulphuric acid, equivalent	9.
One atom of sulphur.	With one atom of hydrogen, forms sulphuretted hydrogen, equivalent	2.125
Two atoms of sulphur, with one of hydrogen, are supposed to form bi-sulphuretted hydrogen, equivalent		4.125

156.—EXPERIMENTAL ILLUSTRATIONS.

Sulphur exhibited in flowers, and in rolls, also crystallized, as above mentioned.

Combustion of Dutch gold leaf, of an iron bar, and of iron wire by sulphur. Hydrate of potash converted into a sulphuret, by the vapour of sulphur, emitted in a jet from the touch-hole of a red hot gun barrel.

157.—THE COMBUSTION OF IRON, BY A JET OF VAPORIZED SULPHUR, ILLUSTRATED.

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, a jet of ignited sulphureous vapour 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 proto-sulphuret. Hydrate of potash, exposed to the jet, fuses into a sulphuret of a fine red colour.

OF THE NOMENCLATURE OF THE COMPOUNDS OF SULPHUR AND SOME OTHER COMBUSTIBLES.

The compounds of sulphur, phosphorus, carbon, and hydrogen, are not designated by the termination employed in the case of oxygen, chlorine, iodine, &c.

Without any adequate reason, as it appears to me, the English and American chemists generally distinguish the former as combustibles, the latter as supporters of combustion. Consequently the nomenclature used in these, is made to accord with the termination in *ide*, assigned by the Lavoisierian school, to compounds of oxygen, which are not acids. The compounds of the class, considered as combustibles, are distinguished by the termination *uret*, as sulphuret, phosphuret, carburet, and hydroguret.

The French chemists distinguish the compounds of chlorine, iodine, &c., by a termination in *ure*, and the same term is extended to the combustibles above mentioned. Hence chlorure, iodure, carbure, sulphure, and phosphure.

When a sulphuret contains two atoms of sulphur, it is called a bi-sulphuret, and the same monosyllable is applied to convey an analogous idea in the case of bi-phosphuret, and bi-hydroguret. The last word should be shortened, I conceive, into bhydroguret, in pronunciation, at least.

COMPOUNDS OF SULPHUR WITH OXYGEN.

OF HYPO-SULPHUROUS ACID.

This acid exists only in combination with salifiable bases, and of these, no useful application has been made. I shall defer any attempt to explain the method in which hypo-sulphites are produced, until I have treated of sulphurous acid.

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 gas, intolerable to the organs of respiration, deleterious to life, and incapable of supporting combustion. Thirty-three measures of it are absorbed by one measure of water. It bleaches silk and wool, and unlike other acids, whitens litmus. For the purpose of illustration, an alkaline solution, or pure water, may be conveniently impregnated with sulphurous acid, by means of the apparatus described in the following article.

158.—APPARATUS FOR INHALING THE FUMES OF BURNING SUBSTANCES, AND CAUSING THEM TO PASS INTO LIQUIDS.

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 SULPHITES, AND HYPO-SULPHITES.

Agreeably to the received nomenclature, see page 152, the compounds of sulphurous acid are called sulphites.

These salts have long been known to be convertible into sulphates, by the addition of oxygen. It has been recently discovered, that, when sulphites, or sulphurous acid, are deoxidized, hypo-sulphurous acid is produced, which combines either with the substance which absorbs the oxygen, or the base of the sulphite.

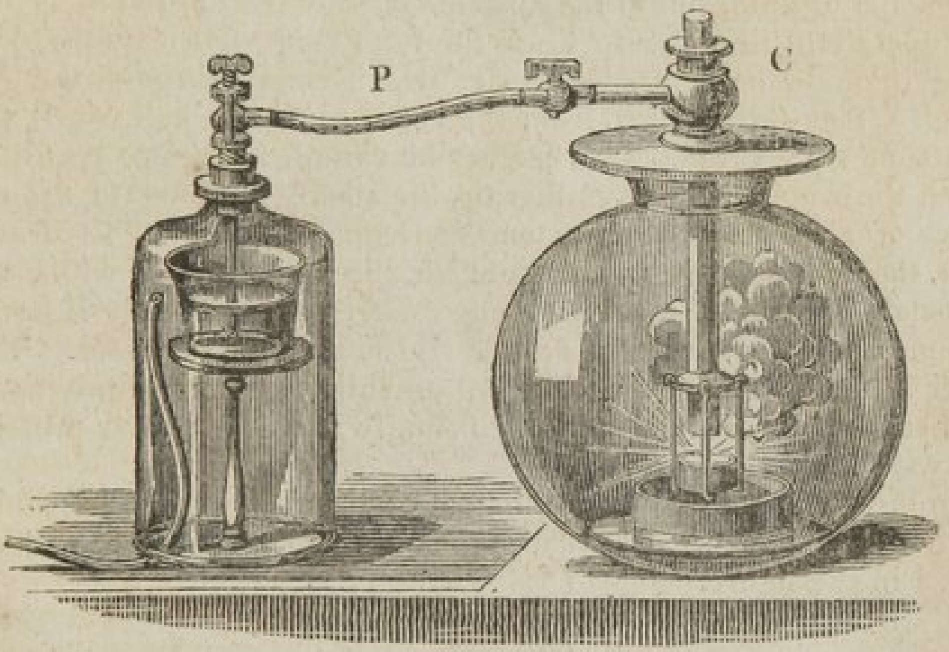
Sulphites are rarely met with. They are known by having the smell of sulphurous acid gas, especially when heated.

OF SULPHURIC ACID.

Means of obtaining Sulphuric Acid.

This acid may be obtained, by burning sulphur and nitre, in chambers lined with lead, or by the old process of distilling copperas, or green vitriol; whence the almost obsolete name, oil of vitriol. It is best purified by distillation.

159.—PRODUCTION OF SULPHURIC ACID ILLUSTRATED.



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 plate of lead. 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 with the water of a tumbler, supported within the bell glass, as in 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 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. 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 muriate of barytes.

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.

RATIONALE.

Three atoms of nitrate of potash, by giving up all their oxygen, produce five atoms of sulphuric acid, of which three unite with the potash of the decomposed nitrate, leaving two at liberty to act upon portions of nitrate as yet undecomposed. Thus two atoms of nitric acid are liberated, the nitrogen of which, yielding up six atoms of oxygen to the sulphur, two atoms of sulphuric acid, and two atoms of nitric oxide, are produced. The sulphuric acid decomposing more nitrate, more nitric acid, sulphuric acid, and nitric oxide, are evolved; and this process being repeated, the one part of the nitrate may, with the aid of the sulphur, be made to yield nitric oxide, by the total deoxydizement of nitrogen in another comparatively very small portion of the same salt.

The nitric oxide is converted into nitrous acid, by combining with the oxygen of the air. Taking from this acid a proportion of its oxygen, and reducing it to the state of nitric oxide, the sulphurous acid formed by the combustion of a part of the sulphur with the oxygen of the air, is converted into sulphuric acid which is absorbed by the water. Meanwhile the nitric oxide resulting from the decomposition of the nitrous acid regenerates this acid, by uniting with the oxygen of the air, and is of course enabled to change another portion of sulphurous acid into sulphuric acid.

According to Sir Humphry Davy, nitrous acid, and sulphurous acid, with a small proportion of water, form a crystalline compound; which by a larger proportion of water, is decomposed into sulphuric acid, and nitric oxide gas.

Properties of Sulphuric Acid.

It is a liquid oleaginous in its consistency—caustic, when concentrated—intensely acid, when dilute.—It heats greatly, when mixed with water, especially when to 73 parts of acid, 27 parts of water are added. Hot water explodes with it as with a melted metal. Its strength is reduced by the absorption of moisture, when exposed to the air.

OF CHLORIDE AND IODIDE OF SULPHUR.

When sulphur in a state of inflammation is lowered into gaseous chlorine, the combustion continues, being supported by the chlorine. Either in this way, or more slowly, without inflaming the sulphur, a chloride of sulphur may be produced, which is a reddish brown liquid, very volatile at ordinary temperatures, and of which the smell and taste are very disagreeable. By admixture with water, it is converted into sulphurous and muriatic acids.

When iodine is heated with sulphur, a solid iodide results, which is decomposed by a higher temperature.

OF THE COMPOUNDS OF SULPHUR WITH HYDROGEN.

OF SULPHURETTED HYDROGEN.

Means of obtaining Sulphuretted Hydrogen.

This gas is most easily obtained from sulphuret of iron, by diluted sulphuric acid.

160.—SELF REGULATING RESERVOIR OF SULPHURETTED HYDROGEN.

The best apparatus for the generation of sulphuretted hydrogen, is that already described, 120. It is only necessary to substitute the sulphuret of iron for zinc, and the method of operating with the self-regulating reservoir of hydrogen, will answer in the case of the gas now under consideration.

Of the Properties of Sulphuretted Hydrogen.

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—combines with earths and alkalies, forming hydro-sulphurets, and has, therefore, some attributes of acidity. It is found in some native mineral waters. 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.

Sulphuretted hydrogen decomposes all metallic solutions, unless those of iron, nickel, cobalt, manganese, titanium, and molybdenum, in consequence of the attraction between hydrogen, and either oxygen or chlorine, and between sulphur and the metals. Atmospheric air is said to be rendered deleterious to life by the addition of $\frac{1}{250}$ of this gas.

161.—EXPERIMENTAL ILLUSTRATIONS.

Method of extricating sulphuretted hydrogen gas 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.

162.—SYMPATHETIC PICTURE.

The original of this figure was drawn of a gigantic size, by Mr. Wm. A. Mason, 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.

163.—A CONVENIENT METHOD OF IMPREGNATING LIQUIDS WITH SULPHURETTED HYDROGEN.

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 sulphuretted hydrogen: 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 SELENIUM.

In 1818, Berzelius discovered this substance in a deposition, principally consisting of sulphur, which took place in the chambers for manufacturing sulphuric acid, at Fahlun in Sweden.

It has since been found in the volcanic rocks of the Lipari isles, and in several varieties of sulphur—also in union with copper, silver, cobalt, and lead.

Properties of Selenium.

Selenium is solid, tasteless, inodorous, fragile like glass, and easy to pulverize. It is little disposed to crystallize, a bad conductor of heat and electricity, and is not electric by friction. Fused and cooled rapidly, it assumes the appearance of an opaque mass, of a shining dark brown, with a leaden hue, and fracture, and an aspect both vitreous and metallic. Selenium softens at a boiling heat, fuses at a temperature a little higher, and at the heat of boiling mercury is converted into a yellow vapour, which condenses into opaque drops, having a metallic appearance. Heated before the blowpipe, it tinges the flame of an azure blue, and exhales a smell of horse-radish, so powerful, that $\frac{1}{50}$th of a grain will be perceived throughout a large apartment.

Selenium forms an oxide and an acid, also a liquid chloride. With hydrogen, it forms a gaseous compound, analogous to sulphuretted hydrogen. It seems, as already mentioned, to lie between sulphur and the metals in its properties, but is most analogous to sulphur.

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 made to enter some water. Phosphorus distils into the water in tears.

Agreeably to another process, the phosphate of soda (which is to 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. In the air it melts and inflames at about 110° F. At 550 it boils, and from a retort filled with hydrogen, the beak entering some water, may be distilled, and thus purified.

Hydrogen is evolved from phosphorus by electro-chemical action; but is present as an impurity, not as a constituent. Phosphorus is susceptible of a slow, and of a quick combustion, producing phosphorous and phosphoric acids. Phosphorus forms a compound with sulphur, which is spontaneously inflammable. The equivalent of phosphorus is 1.5.

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, as already described. In order to determine the quantity of oxygen in the air, we have only to ascertain the ratio between the quantity absorbed, and the quantity included.

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, (127,) 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.

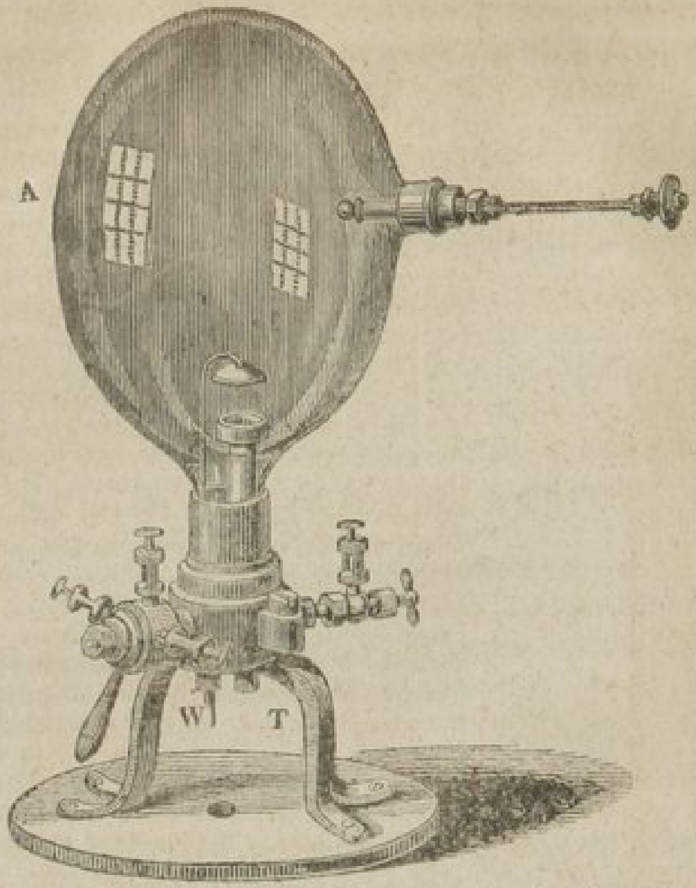
165.—BAROMETER GAGE EUDIOMETER, BY PHOSPHORUS.

By combining the principle of the apparatus for the combustion of phosphorus in oxygen, page 109, with that of the barometer gage eudiometer, 128, I have been enabled to construct a eudiometer for phosphorus, which appears to me much more perfect than those heretofore contrived.

A hollow glass spheroid, A, of which the vertical diameter is 11 inches, the horizontal diameter 9 inches, is cemented into a brass socket which screws into the same place as the socket of the receiver of the eudiometer above mentioned. In lieu of the igniting wires employed in that instrument, a cup, containing phosphorus, is supported by, and closes the upper end of a tube, T. This tube is soldered into the axis of a brass plug, which screws in at the bottom of the brass casting, which at top receives the socket of the spheroid. The phosphorus, being ignited by means of a hot iron passed up through the tube, the oxygen of the air included in the spheroid, is condensed, and the deficit ascertained by the gage.

It will be recollected that the gage of the barometer gage eudiometer is graduated into 450 degrees. It is expedient to commence this experiment with the mercury at fifty degrees, which leaves 450 parts in the spheroid, and allows room for the expansion which takes place in the beginning of the process.

I have made several experiments with this apparatus, and find the results to harmonize with each other, and with those obtained by my other instruments.



Upon the wire, W, which passes through the stuffing box into the cavity of the spheroid, a copper hood is supported, which is just large enough to cover the cap containing the phosphorus. By this contrivance, the phosphorus may be secluded from the air, until its exposure becomes desirable.

COMPOUNDS OF PHOSPHORUS WITH OXYGEN.

OF HYPO-PHOSPHOROUS ACID.

This acid is said to consist of two atoms of phosphorus, and one atom of oxygen.

OF PHOSPHOROUS ACID.

Means of obtaining Phosphorous Acid.

It is produced during the slow combustion which phosphorus spontaneously undergoes in the air, but is then contaminated by phosphoric acid. It is better procured by passing vaporized phosphorus over corrosive sublimate heated in a tube. Chloride of phosphorus results, which, by reaction with water, produces muriatic and phosphorous acids. The muriatic acid being most volatile, may be separated by heat.

Of the Properties of Phosphorous Acid.

It is distinguished from phosphoric acid, by its odious smell, and susceptibility of volatilization.

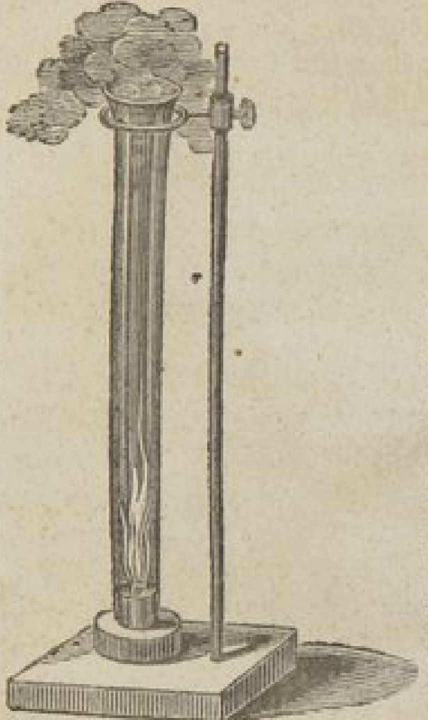
It consists of one atom of phosphorus, and one of oxygen. Consequently its equivalent is 2.5.

OF PHOSPHORIC ACID.

Means of obtaining Phosphoric Acid.

It is obtained, not only, as abovementioned, by the combustion of phosphorus, or decomposition of bones, but better by adding phosphorus, gradually, to heated nitric acid.

166.—REACTION OF PHOSPHORUS WITH NITRIC 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 a few pieces of phosphorus, about as large as peas, be thrown in, 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.

The residual nitric acid will be found intermingled with phosphoric acid.

Of the Properties of Phosphoric Acid.

Though composed of volatile ingredients, per se, phosphoric acid is one of the most fixed and unalterable acids by heat. Evaporated to dryness, and fused, it forms a glass. It is soluble in water—is not odorous. It is supposed to consist of two atoms of oxygen, with one atom of phosphorus. Its equivalent is therefore 3.5.

COMPOUNDS OF PHOSPHORUS WITH HYDROGEN.

One volume, or one atom, of phosphorus, with one volume, or one atom, of hydrogen, condensed into one volume, forms hydroguret of phosphorus, or phosphuretted hydrogen, equivalent - - - - - -	1.625
With an additional volume, or atom, of hydrogen, condensed into the same space, it forms bi-hydroguret of phosphorus, or sub-phosphuretted hydrogen, equivalent -	1.75

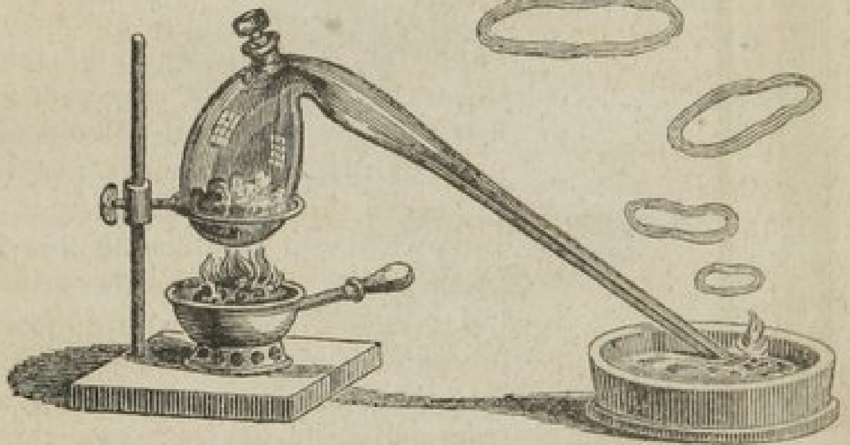
Another compound is alleged to exist, consisting of 4 atoms of hydrogen, with 3 of phosphorus.

Phosphuretted hydrogen is principally remarkable for the property of burning, or detonating, on meeting with the air, or with oxygen gas. Subphosphuretted hydrogen appears luminous in a place otherwise dark, but does not take fire.

The easiest process for evolving hydrogen in combination with phosphorus, is to add some phosphorus to the materials for generating hydrogen, as already described, 119. By using about 3 parts of sulphuric acid, to five of water, a heat, above that of boiling water, is produced. Under these circumstances, a portion of the phosphorus is dissolved by the hydrogen.

The process to which I have usually resorted for the purpose of obtaining this gas, is described in the following article.

167.—GENERATION OF PHOSPHURETTED HYDROGEN.



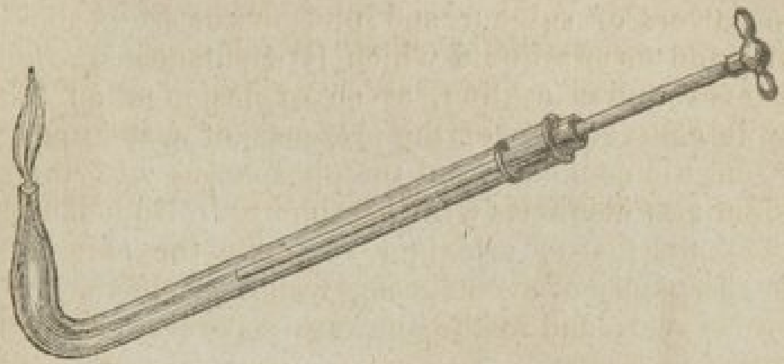
After filling a half pint tubulated retort with a solution of caustic potash, displace about two-thirds of the solution by introducing hydrogen gas. This may be easily effected by closing with the finger the orifice of the beak, depressing it into a portion of the alkaline solution, and allowing the hydrogen to rise into it from the pipe of a self-regulating reservoir, 120.

The tubulure of the retort is, meanwhile, closed with a cork which is now to be removed, so long only as necessary to introduce about 50 grains of phosphorus. The retort is then to be supported over a chauffer of coals, the orifice of the beak being under water or mercury.

The affinity of the alkali for the oxygen of the water, and phosphorus (in the form of phosphoric acid) co-operating with the affinity between the phosphorus and oxygen, causes the alkali, phosphorus, and oxygen, to unite into the compound called phosphate of potash. The hydrogen of the water being evolved in the gaseous form, dissolves at the same time a portion of phosphorus, which renders it spontaneously inflammable; so that 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, so that when the bubbles succeed each other quickly, a series of them may be seen in the air simultaneously.

The same phenomenon may be produced by the action of phosphuret of lime upon water, in which case the lime performs the part that has been above ascribed, to the potash.

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 THE COMPOUNDS OF PHOSPHORUS WITH CHLORINE AND IODINE.

There are two chlorides of phosphorus—a chloride and a bi-chloride. The latter is solid, and consists of one atom of phosphorus, and two atoms of chlorine—the former is a liquid, consisting of one atom of phosphorus, and one of chlorine. The bi-chloride produces, with water, muriatic and phosphoric acids—while the chloride, or proto-chloride, produces muriatic and phosphorous acids, with the same liquid. The bi-chloride having two atoms of chlorine, requires two atoms of hydrogen, and of course liberates two atoms of oxygen from the water, to act on one atom of phosphorus.

The production of the bi-chloride, by the spontaneous combustion of phosphorus with chlorine, has been already illustrated, 112.

Iodine enters into combustion with phosphorus, forming an iodide of phosphorus which decomposes water, producing hydriodic and phosphoric acids, and is mainly interesting as it serves to complete the analogy between chlorine, iodine, and their compounds.

COMPOUNDS OF PHOSPHORUS WITH SULPHUR AND SELENIUM.

When flowers of sulphur and phosphorus are heated together, they unite and form a liquid which is spontaneously inflammable. The process requires caution, as an explosion often takes place, probably in consequence of the presence of water, and the heat arising from the combustion of the phosphorus with the sulphur.

Selenium also combines with phosphorus. Both the phosphuret of sulphur, and that of selenium, resemble the chlorides and iodides, in the power of decomposing water, producing in both cases phosphorous acid; and in the one case selenuretted, in the other sulphuretted hydrogen.

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 rays 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, 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.

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, by igniting large quantities of wood, so covered with earth, that the access of air may at first be controlled, and afterwards prevented.

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 metals, it is the best conductor of electricity; and 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.

Carbon combines with oxygen, hydrogen, nitrogen, and sulphur, and as lately ascertained by Faraday, with chlorine: with which, however, it cannot be made to enter into combustion, even by the intense ignition of the voltaic pile.

The atomic weight, or equivalent, of carbon, is .75.

COMPOUNDS OF CARBON WITH OXYGEN.

There are two gaseous compounds of carbon with oxygen, carbonic oxide, and carbonic acid. It has lately been alleged that these, by their union, form a third solid acid compound, which has long been known under the name of oxalic acid.

OF THE GASEOUS OXIDE OF CARBON,

OR OF CARBONIC OXIDE.

Means of obtaining Carbonic Oxide.

It may be obtained by calcining whiting with iron filings, in a gun barrel, at a white heat.

Properties and Composition of Carbonic Oxide.

It is a gas, highly deleterious to life, and incapable of supporting combustion.

Carbonic oxide consists of one volume, or one atom, of vapour of carbon, equivalent - - - - -	0.75
And ½ volume, or one atom, of oxygen, equivalent -	1.00
Condensed into one volume, equivalent	1.75

169.—EXPERIMENTAL ILLUSTRATIONS.

Carbonic oxide gas evolved 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; also the subsequent absorption of the resulting carbonic acid by lime water.

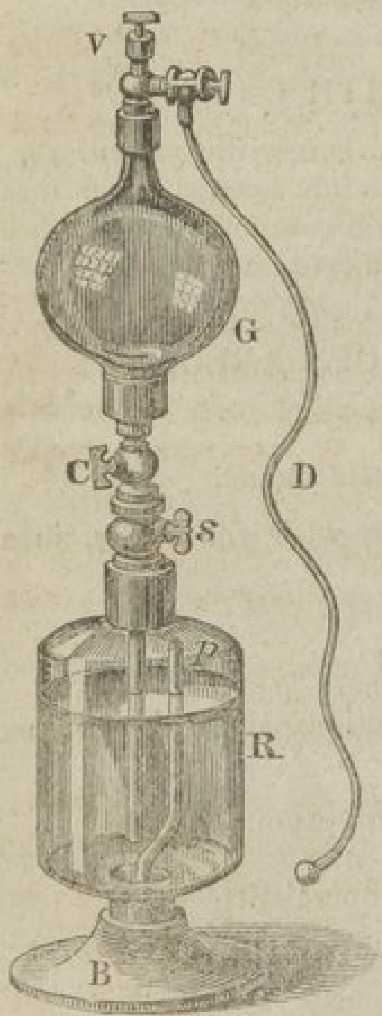
EUDIOMETRICAL ANALYSIS OF THE GASEOUS COMPOUNDS OF CARBON.

The method of detecting the presence, and ascertaining the quantity of carbonic acid, is the same as that already described in article 148, exchanging nitric oxide for carbonic acid, and the solution of iron for lime water. Henry recommends chlorine as a mean of removing olefiant gas. The quantity of carbon present, is easily ascertained by exploding these gases with oxygen, as described, 122, but better, by the mercurial sliding rod eudiometer, of which I shall give an engraving and description in the appendix.

170.—OF THE USE OF THE CARBONICOMETER.

A mixture of oxygen with carbonic oxide, or carburetted hydrogen, may be exploded in the barometer gage eudiometer. Any ensuing deficit will be seen by the effect upon the gage.

The quantity of carbonic acid produced, may be ascertained by means of the instrument described in the following article.



The apparatus here represented, is one which I have contrived for withdrawing a known portion of residual air from the barometer gage eudiometer, in order to wash it with lime water.

P is a pipe which causes a communication between the upper part of the receiver, R, and the cavity under the hollow pedestal, B. The lower orifice of this pipe, where it enters the cavity of the pedestal, is covered by a valve opening downwards. The receiver is surmounted by a brass cap, into which, as well as into the socket in the pedestal, it is cemented air tight. In the axis of this receiver, and descending nearly to the bottom, may be seen a tube, which is soldered into a perforation communicating with the bore of the cock, C, so as to establish a communication between the receiver, and the globe, G.

The globe is surmounted by a valve cock, V, furnished with a gallows and screw, so that a leaden pipe, D, terminated by a brass knob, duly perforated, may be joined to it, air tight, without difficulty. Hence if the pipe be annexed, at the other end, to the cock of the barometer gage eudiometer, a communication betwen the inside of the receiver of this instrument, and the globe, G, may be easily opened or suspended at pleasure.

The screw, S, serves to open, or close, a perforation which communicates with the cavity of the receiver.

Suppose the receiver, R, to be occupied by lime water, as represented in the figure. Place the pedestal, B, over the hole in the air pump plate, which the rim of the pedestal is ground to fit. On working the pump, the air of the receiver, above the lime water, is drawn out through the valve at the bottom of the pipe, *p*. Of course the air in the globe follows it, through the pipe, which leads from it into the receiver. Having exhausted the globe and receiver, if the screw, S, be so loosened as to allow the atmosphere to enter the receiver, and press upon the surface of the lime water while the globe remains exhausted, the lime water will of course rise into, and fill the globe. Should the receiver, under these circumstances, be again exhausted, while by means of the flexible pipe, D, a communication with the barometer gage eudiometer is effected, the pressure of the gas in the eudiometer being greater than that of the rare medium of the exhausted receiver, R, it follows that this gas will press into the globe, and cause a portion of the lime water to descend into the receiver. In this way, suppose 100 measures, by the barometer gage, taken from the eudiometer. The valve cock may then be closed, and the screw, S, relaxed so as to admit the atmosphere. The lime water will rise into the globe, until the pressure of the gas therein be nearly equal to that of the atmosphere. By agitating the globe, the carbonic acid will combine with the lime in the water. When this object is effected, the residual gas may be allowed to re-enter the eudiometer, where the quantity of it may be measured, and consequently the extent of the absorption known. It is not necessary that the apparatus should remain upon the air pump plate during the whole process. By means of the valve which covers the perforation in the pedestal, in which the pipe, P, is inserted, the exhaustion may be sustained, during the removal of the receiver from the air pump, to any part of the laboratory, where it may be convenient to connect it with the eudiometer.

OF CHLORO-CARBONIC ACID, A COMPOUND OF CHLORINE AND CARBONIC OXIDE.

When equal volumes of the gaseous substances, above mentioned, are exposed to the rays of the sun, a gaseous acid compound is formed, to which the name of chloro-carbonic acid has been given.

Properties of Chloro-Carbonic Acid.

It is colourless—is exceedingly offensive to the eyes, and to the organs of respiration. It reddens litmus paper, and with ammonia forms a white salt. When received in water, a reciprocal decomposition ensues, and muriatic and carbonic acids are produced. It consists of one atom of chlorine, and one atom of carbonic oxide.

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, causes 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.

Its production, by the combustion of charcoal with oxygen gas, has already been illustrated.

It may be obtained, from any carbonate, by heat or by acids. It is usually procured for the manufacture of mineral water, by the superior affinity of sulphuric acid for the lime, in marble. Excepting that it is more costly, muriatic acid is preferable, for this purpose, as the muriate of lime, being very soluble, does not, like the sulphate, clog the vessels. A mixture of about three parts of sulphuric acid, with four of salt, by weight, answers better than sulphuric acid alone, as it is essentially a solution of sulphate of soda, and muriatic acid.

Carbonic acid is evolved copiously during the vinous fermentation.

The self regulating apparatus for hydrogen, 120, may be employed for carbonic acid gas, substituting lumps of marble, or chalk, for zinc.

On the Properties of Carbonic Acid.

Under ordinary circumstances it is a permanent gas, but has been rendered liquid by very great pressure. 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, 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.

COMPOSITION.

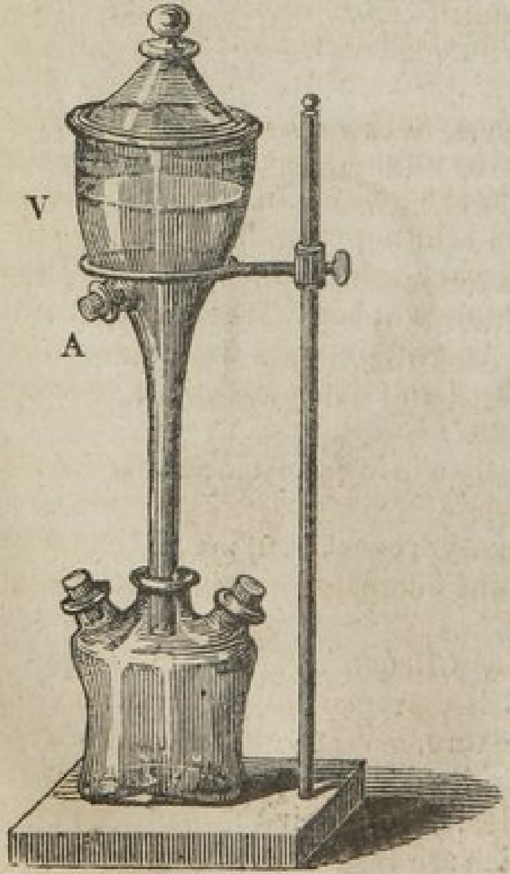
Carbonic acid consists of one volume, or one atom, of carbon, equivalent - - - - - - -	0.75
And one volume, or two atoms, of oxygen, equivalent -	2.00
Condensed into one volume, equivalent -	2.75

171.—EXPERIMENTAL ILLUSTRATIONS.

Evolution of the gas shown—also its property of extinguishing a candle.—Its difference from nitrogen, 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.

172.—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 deep orange coloured nitric 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.

The movements of the carbonic acid gas will thus be recognized, 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.

That wells are so often fatal to those who enter them, is owing to the tendency of carbonic acid towards the lowest accessible cavities. 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 spirit of wine, or 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.

173.—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 a self regulating reservoir, like that which has been described 120, 121, as suitable for generating either hydrogen or carbonic acid.

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 the vessel, to the bottom, while the other is conveniently situated for filling a goblet.

OF THE COMPOUNDS OF CARBON WITH HYDROGEN.

Carbon and hydrogen are in opposite extremes, as respects their susceptibility of the aëriform 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.

The existence of two gaseous, of two liquid, and one solid compound of hydrogen with carbon, has been well ascertained.

The binary compound has long been known under the name of olefiant gas. It is alleged to consist of two volumes, or two atoms, of carbon vapour, and two volumes, or two atoms, of hydrogen, condensed into one volume.

Another gaseous product, which is evolved from the mud of stagnant waters, in hot weather, consists of two volumes, or two atoms, of hydrogen, united with one volume, or one atom, of carbon vapour, condensed into one volume.

This gas has been known by the name of carburetted hydrogen; but this appellation appears now to be due to olefiant gas, as the elements exist in this, in the ratio of equality. Dr. Thomson proposes to call the latter hydroguret, the former, bi-hydroguret of carbon. These names are more rational than pleasing, especially if we are not allowed to shorten the latter into bhydroguret, as I have proposed in treating of nomenclature, page 161.

In the gas obtained from oil, in the vapour of sulphuric ether, and in that of naphtha, three other aëriform compounds of carbon with hydrogen, are alleged to exist, (one a gas, the other two, vapours) in which the elements are in the same proportion as in olefiant gas, but under different degrees of condensation.

The liquid compounds were obtained by Mr. Faraday, from a substance which condenses from oil gas, when compressed. One of them is colourless and transparent, and smells like oil gas, with a slight odour of almonds. Its specific gravity is 0.85. The specific gravity of the other is 0.627, so that it is the lightest liquid known.

The first mentioned liquid is a bi-carburet of hydrogen; the last contains the same number of atoms of each element, so that it does not differ in its composition from olefiant gas. It is alleged to exist in the vapour of sulphuric ether.

The solid compound above alluded to, is a crystalline substance called naphthaline, obtained during the distillation of naphtha from tar. It crystallizes in the neck of the retort, in white crystalline plates. It appears to consist of three atoms of carbon, and two of hydrogen.

Properties of the Compounds of Carbon with Hydrogen.

Generically, these substances are distinguished by inflammability and volatility.

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. In the vaporous or liquid form, they are highly stimulating.

Means of obtaining the Gaseous Compounds of Carbon with Hydrogen.

They are procured by the destructive distillation of bituminous coal, wood, oil, tar, and other inflammable substances.

Olefiant gas is obtained, purest, by passing alcohol through an ignited porcelain tube; or, by distilling one part of alcohol, with four parts of sulphuric acid. Bihydroguret of carbon is alleged to be evolved, nearly pure, from the mud of stagnant waters in summer.

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 an uncontaminated brilliancy.

174.—EXPERIMENTAL ILLUSTRATIONS.

Cork, cotton seed, caoutchouc, nuts, introduced in small quantities into a gun barrel, of which the but-end has been heated to a bright red heat. A brilliant jet of flame proceeds from the touch-hole. Inflammation of gas evolved by distillation from bituminous coal or oil. Also of olefiant gas. Olefiant gas, mixed with oxygen gas, and exploded in a sliding rod eudiometer. Residue renders lime water milky.

175.—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. It is made to pass into large gas holders, called gasometers. This name was bestowed by Lavoisier on a similar apparatus, which was employed to measure, as well as to contain gas, but has been improperly extended to such as can be used only for the last mentioned purpose. Agreeably to present acceptation, a gasometer is essentially nothing more than two vessels, one inverted, and suspended, by a rope, within the other, containing water to confine the gas. The rope passes over a pulley, and is fastened to a counter weight. There are usually two pipes, which proceed from the outside, through the bottom of the lower vessel, and rise above the surface of the water. Through one of these, the gas is introduced into the gasometer; by the other, together with its ramifications, the gas is conveyed to the burners.

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.

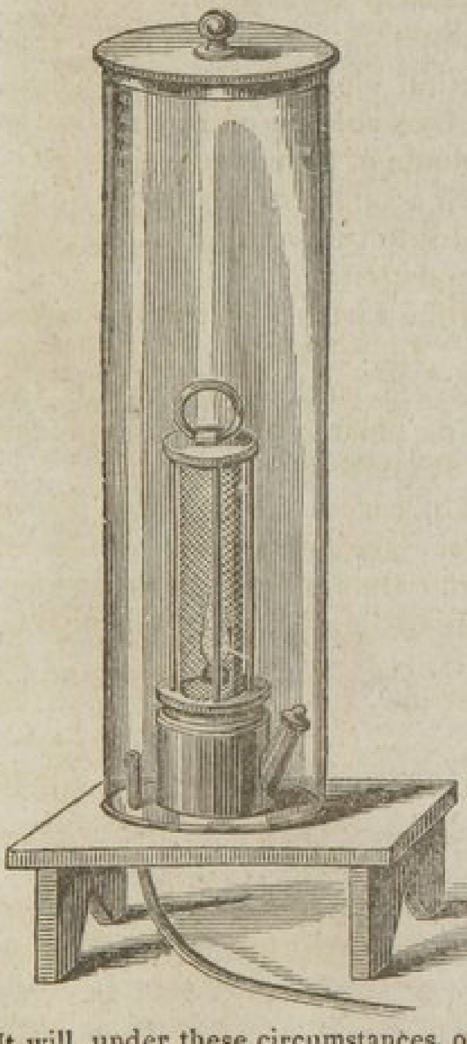
It is only necessary to exchange the communication with the self-regulating reservoir of carbonic acid gas, for a similar communication with a reservoir of olefiant gas, and the copper vessel being first exhausted of air, to condense the gas into it. The syphon used for the efflux of the impregnated 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.

176.—SAFETY LAMP.

Coal mines are liable to be infested with a species of carburetted hydrogen gas, called by the miners fire-damp. 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 the 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 easily be 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 this 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.

COMPOUNDS OF CHLORINE WITH OLEFIANT GAS: ALSO WITH CARBON.

Olefiant gas received its name from its condensing with chlorine gas, into a liquid of an oleaginous consistency. On exposure to chlorine gas and the solar rays, this liquid yields a perchloride of carbon; which, by passing over quartz, in an ignited glass tube, yields a proto-chloride. A sub-chloride of carbon has also been accidentally produced.

OF BI-CARBURET OF NITROGEN, OR CYANOGEN.

Means of obtaining Cyanogen.

Distil bi-cyanide of mercury, in a coated glass tube, at a heat as nearly approaching to redness, as the glass will bear. The tube must have a smaller one adapted to it, to convey the gas under the bells, in the mercurial pneumatic cistern.

Properties and Composition of Cyanogen.

It is a true gas, but may be rendered liquid by pressure. It is characterized by burning with a beautiful violet flame. Its weight to common air, is as 9 to 5 nearly. One volume of water absorbs four and a half volumes—and one volume of pure alcohol, twenty-three volumes. When detonated with a sufficient quantity of oxygen, a volume of this gas is converted into two volumes of carbonic acid, and one of nitrogen, without condensation.

It is absorbed by alkalies, and alkaline earths. With hydrogen it forms prussic or hydrocyanic acid. In relation to the galvanic poles, it is electro-negative. An instance is thus afforded of the adventitious character of this species of polarity, since carbon and nitrogen, the elements of cyanogen, are both electro-positive.

Cyanogen consists of two volumes of carbon vapour, and one of nitrogen, condensed into one volume. Hence, as in the case of these gases, equivalents in volume and atomic weights are represented by the same numbers, the composition of cyanogen must be

two atoms of carbon, equivalent to $.75 \times 2 =$ -	1.50
And one atom of nitrogen, equivalent to - -	1.75
Hence the equivalent of cyanogen is -	3.25

177.—EXPERIMENTAL ILLUSTRATIONS.

Cyanogen evolved, agreeably to the process above mentioned, and its flame exhibited—also mixed with oxygen gas, and exploded.

OF PRUSSIC OR HYDROCYANIC ACID, A COMPOUND OF CYANOGEN WITH HYDROGEN.

When potash is ignited, in contact with animal matter, cyanogen is formed by the union of carbon and nitrogen, and combines with the potassium, of the potash, with which it constitutes a cyanide. The cyanide, thus created, being dissolved, and sulphate of iron added, a complicated reaction ensues. The oxygen, of the water, and the sulphuric acid, take the potassium from the cyanogen, which combines with the hydrogen of the water, and the oxide of iron forming a prussiate or hydrocyanate of iron. At the same time, a cyanide of iron is produced, and unites with the prussiate of iron—making what has been called a ferro-cyanate, or ferro-prussiate, also called Prussian blue. When this compound is boiled with potash, the cyanide of iron, and hydrocyanic acid, unite with the alkali, forming a ferro-prussiate, or ferro-cyanate of potash.

Boiled with red oxide of mercury, Prussian blue cedes its cyanogen to the mercury, forming a bi-cyanide, analogous to the bi-chloride of the same metal.

When bi-cyanide of mercury is distilled with muriatic acid, the cyanogen combines with the hydrogen of this acid, and forms Prussic or hydrocyanic acid, which passes over, while the chlorine of the muriatic acid, forms a bi-chloride with the metal, and remains in the retort.

To make Prussic acid of a strength sufficient for medical purposes, one pound of muriatic acid, diluted with six pints of water, should be added to a pound of the bi-cyanide—after which, six pints of the dilute Prussic acid may be brought over by distillation.

It may be more easily obtained by impregnating with sulphuretted hydrogen, see article 163, a solution, containing 60 grains of bi-cyanide of mercury, for every ounce of water. The hydrogen unites with the cyanogen, while the sulphur precipitates with the metal. Any excess of the sulphuretted hydrogen, is easily removed by the carbonate of lead.

The acid may be procured, in its most concentrated form, by exposing the bi-cyanide, in crystals, in a tube, to sulphuretted hydrogen, and employing a receiver, surrounded by salt and snow, to condense the vapour evolved.

Of the Properties of Hydrocyanic Acid.

Hydrocyanic acid is far more volatile than ether, as it boils at 70° F. and evaporates so rapidly, that one portion becomes frozen, by the loss of the caloric which the other absorbs, in passing into the aëriform state. Its specific gravity is .7058, being nearly the same as that of sulphuric ether.—A drop, allowed to fall on the eye, or on the tongue, of a small animal, kills it instantly. The consequences are equally deleterious, when the fumes are applied to the nose.

COMPOSITION.

Hydrocyanic acid consists of one volume, or one atom, of cyanogen, and one volume, or one atom, of hydrogen.

Its equivalent is - - - - - - 3.375

EXPERIMENTAL ILLUSTRATIONS.

Evolution of Prussic, or hydrocyanic acid, in the concentrated form, and in a state of dilution.

COMPOUNDS OF CYANOGEN WITH OXYGEN, CHLORINE, AND SULPHUR.

Cyanogen forms binary compounds with oxygen and with chlorine; both of which are acids. The compound formed with oxygen is called cyanic acid, that formed with chlorine, chloro-cyanic acid.

It has been lately ascertained that the acid discovered in fulminating mercury and silver, and called fulminic, contains the same elements, and in the same proportion, as cyanic acid.

Cyanogen unites also with sulphur and hydrogen, forming a triple compound, called sulpho-cyanic acid.

OF BI-SULPHURET OF CARBON.

It is obtained by passing sulphur in vapour, over pieces of charcoal, intensely ignited in a porcelain tube.

Properties of Bi-sulphuret of Carbon.

It is colourless and transparent—acrid—pungent to the taste—caustic—somewhat aromatic, smells nauseously, and is very inflammable, volatile, and difficult to freeze. Its most remarkable property is that of producing intense cold by its evaporation.

OF SILICON, OR SILICIUM.

Means of obtaining Silicon.

By heating 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.

Properties of Silicon.

It is of a dark nut brown colour, without the least trace of metallic lustre; a nonconductor of electricity; incombustible in the air, or in oxygen gas; infusible by the blowpipe. It is not liable to be dissolved, or oxydized, either by sulphuric, nitric, muriatic, or fluoric acids; but is soluble in a mixture of nitric and fluoric acids. When heated nearly 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. With fluorine it forms a gas, with oxygen, silex, or silicic acid.

Silicon appears to be an elementary substance, of which the equivalent is 1.

OF THE COMPOUND OF SILICON, OR SILICIUM, WITH OXYGEN, CALLED SILEX, SILICA, OR SILICIC ACID.

Some of the observations which were made as introductory to the subject of ammonia, seem to be applicable to the case of silex. The properties of this substance being analogous to those of the class called earths, it was heretofore treated of as an earth. Latterly, the earths, being generally found to be metallic oxides, they have been treated of, under the head of metals. The radical of silex has been generally allowed to accompany them, with the name silicium; which, by its termination, implies a metallic nature. Yet as a nonconductor of electricity, the substance thus designated, is obviously less metallic than carbon, to which otherwise, it is most nearly allied.

In common with Dr. Thomson, Sir H. Davy, and some other chemists, I conceive the radical of silex to be much more analogous to carbon and boron, than to the metals: I therefore treat of it in this place, under the name given to it by those whose opinions I have adopted.

The congeries called earth, was, until within the last century, considered as one of four principles, which were supposed to be the only elements of the creation. Silex constitutes the earth of flints, of sand, of rock crystal, and generally of all the earthy, or stony matter, which mineralogists recognise under the generic name of quartz. It is by far the most abundant of all the substances, which have been classed under the name of earth, and probably, excepting oxygen, abounds more than any other substance in the creation.

The earths have been distinguished into earths proper, and alkaline earths. It is among the former that silex has been placed, as its qualities are the inverse of alkaline.

Means of obtaining Silex, or 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. This solution being poured into an acid, the silex, slightly contaminated by potash, is precipitated.

Rock crystal is silex nearly pure. If quenched in water, after being heated to incandescence, it is easily pulverized.

Properties of Silex.

Pure silex is white, tasteless, and inodorous. It is insoluble, excepting when nascent, which principally distinguishes it from other acids.

COMPOSITION.

One atom of silicon, equivalent	1.
With one atom of oxygen, equivalent	1.
Forms one atom of silex, equivalent	2.

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 silex 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 piece of thick 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 pass through, glass.

By gradually making up fires 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 Ruperts' 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.

EXPERIMENTAL ILLUSTRATIONS.

Prince Rupert's Drops exhibited; also the phenomenon of their explosion in consequence of a slight fracture. Glass tube fractured by a slight scratch.

OF BORON.

Means of obtaining Boron.

By the addition of sulphuric acid, to a saturated solution of borax in water, shining crystalline plates are precipitated, consisting of boracic acid. When these are exposed to the action of a powerful voltaic series, or allowed to react with potassium, the oxygen of the acid is absorbed, and a substance is evolved, to which the name of boron has been given.

Properties of Boron.

Boron is dark olive coloured, tasteless, inodorous, a nonconductor of electricity, and insoluble either in water, alcohol, ether, or oils. Its specific gravity is 2 nearly. When heated in the air to 600 F. it takes fire, and, by uniting with oxygen, regenerates boracic acid.

OF THE COMPOUND OF BORON WITH OXYGEN, CALLED BORACIC ACID.

Means of Procuring Boracic 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 boracic acid may be liberated in crystals, as above described, by the superior affinity of sulphuric acid for the soda.

Boron, in its habitudes, seems to lie between phosphorus and carbon. In its susceptibility of volatilization, infusibility, and the temperature requisite for its combustion, it is most allied to carbon: yet boracic acid, is more analogous to phosphoric, than to carbonic acid. Both phosphoric and boracic acids, are capable of being reduced to a vitreous state, bearing a white heat, without being volatilized, while the acid of carbon, is naturally aëriform.

Boracic acid, and especially the biborate of soda, are of great use in blow-pipe assays, as fluxes; and in soldering, as the means of protecting metallic surfaces, from oxidation.

EXPERIMENTAL ILLUSTRATIONS.

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 COMPOUNDS OF FLUORINE, WITH HYDROGEN, SILICON, AND BORON.

Fluorine was cursorily noticed, page 114. As the theoretic grounds upon which its existence is assumed, cannot be elucidated without a reference to the compounds which it forms with silicon and boron, I deferred treating of it until now, when the student has been made acquainted with those substances.

OF FLUORIC ACID, A SUPPOSED COMPOUND OF FLUORINE WITH HYDROGEN.

It is supposed that fluorine exists in nature in union with the alkaline and earthy metalloids, 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 considered as a fluoride of calcium.

Means of obtaining Fluoric Acid.

When fluor spar is pulverized and heated, in a leaden retort, with twice its weight of sulphuric acid, fluoric acid passes over in the form of a very volatile acid vapour, which 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.

Properties of Fluoric Acid.

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 more easily preserved.

EXPERIMENTAL ILLUSTRATIONS.

Powdered fluor, 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 fluoric acid upon glass.

OF FLUORIDE OF SILICON, OR FLUO-SILICIC ACID GAS, USUALLY CALLED SILICATED FLUORIC ACID:

A SUPPOSED COMPOUND OF FLUORINE WITH SILICON.

Means of obtaining Fluo-silicic Acid Gas.

The only difference between the process above described for fluoric acid, and that for fluo-silicic acid gas, is, that in the latter case, a glass retort, or matrass, may be used, and that one-half of the weight of the fluor in powdered glass, must be added to the materials. The product being gaseous and absorbable by water, is received in bell glasses over mercury. The apparatus which I employ for fluo-silicic acid, is precisely the same as that described under the head of ammonia, 153, 154.

Properties of Fluo-silicic Acid.

It is a gas permanent over mercury. In its odour, in the fumes which it produces, when mingled with the air, in consequence of combining with moisture, this acid is so like muriatic acid, that there is a difficulty in distinguishing it, from that gas, until it is received in water; but when subjected to this test, a characteristic phenomenon ensues.

The water is immediately covered with a white gelatinous matter, which, according to Berzelius, when well washed and heated, is pure silex. One third of the whole quantity, which the gas is capable of yielding, is thus deposited. The rest of the ingredients, are dissolved in the water.

EXPERIMENTAL ILLUSTRATIONS.

Production of fluo-silicic acid, shown; also, its absorption by water, and the precipitation of silicious matter, as above described.

DECOMPOSITION OF FLUO-SILICIC ACID GAS, BY POTASSIUM.

The evolution of silicon from this gas, by potassium, might be accomplished by means of the barometer gage eudiometer; exchanging phosphorus for potassium, and fluo-silicic acid gas, for atmospheric air. The method of exhausting the vessel, and supplying it with the gas, would be the same as that described in article 128.

OF FLUORIDE OF BORON, OR, FLUO-BORIC ACID, A SUPPOSED COMPOUND OF FLUORINE WITH BORON.

It is obtained by distilling fluor spar, in powder, with dry boracic acid, in the proportion of one part of the acid, to two parts of the fluor, in an iron tube, at a strong heat; or the same materials may be subjected to heat in a glass retort, with twelve parts of sulphuric acid. Fluo-boric acid gas is produced, and may be collected over mercury.

Properties of Fluoride, of Boron, or Fluo-boric Acid.

It is a gas analogous to fluoride of silicon, but attracts moisture more intensely. Water absorbs 700 times its bulk, becoming nearly as heavy, and corrosive of organic matter, as concentrated sulphuric acid. In this state, it appears to consist of the same elements as fluoric and boracic acids;—but, as it does not corrode glass, there must be an intimate union between the fluorine and boron.

Equivalents of Fluorine and its Compounds.

An atom of fluorine is equivalent to 2.25, and with one atom of hydrogen, forms fluoric acid, equivalent, 2.375. With one atom of silicon, it forms fluo-silicic acid gas, equivalent, 3.25—also, with two atoms of boron it forms fluo-boric acid, equivalent 4.25. Fluor spar consists of one atom of calcium, equivalent 2.5, and one atom fluorine, and of course is equivalent to 4.75.

OF THE DIFFERENT OPINIONS WHICH HAVE BEEN ADVANCED RESPECTING THE COMPOSITION OF FLUORIC ACID.

Different opinions have been held respecting the nature of fluoric acid, analogous to those which existed on the subject of muriatic acid.

According to one opinion, the acid in question is a compound of oxygen, with an unknown radical; and Derbyshire spar is a fluate of lime; being a compound of lime (oxide of calcium) with fluoric acid, which is liberated in the process above mentioned for evolving it, by the superior affinity of sulphuric acid for the lime. If liberated in contact with silicic acid, silicated fluoric acid gas is evolved. Exchanging silicic for boracic acid, the process being otherwise the same, fluo-boric acid gas is produced.

When fluo-silicic acid is received in water, it separates into a soluble compound containing an excess of fluoric acid, and into an insoluble compound, consisting of silicic acid.

When fluo-boric acid gas is received in water, a solution of both acids is obtained, in which they exist in a state of combination.

Agreeably to the other doctrine, fluor spar is a compound of fluorine and calcium (the metal of lime), which being subjected to sulphuric acid, water is decomposed. The acid, oxygen, and calcium, form sulphate of lime; while the fluorine and hydrogen pass over as fluoric acid vapour. When silicic acid is present, its oxygen unites with the hydrogen of the fluoric acid, while the fluorine and silicon form a gaseous fluoride. By a similar exchange of principles, a gaseous compound of fluorine and boron results, when boracic acid is brought into contact with the fluoric acid, at the time of its liberation. When either fluoride is received in water, fluoric acid is regenerated by the hydrogen of that liquid, while in the one case, silicic acid, in the other, boracic acid, is regenerated by the oxygen. In the latter instance, both acids being soluble, a compound acid solution is created, in which, however, the acids display a powerful reciprocal attraction for each other, and a stronger attraction for water, than either, separately; in the former case one of the acids is partially precipitated, while the remainder of this acid, combining with the whole of the other acid, is dissolved.

From the manner in which I have treated of fluorine, it will be evident that I am a convert to the doctrine last mentioned, which we owe to Mr. Ampere, and Sir H. Davy. It appears to me, however, that the compound of fluorine with boron, being a gaseous acid, analogous to muriatic acid, liquid fluo-boric acid, should be deemed a compound of that gas with water, or with hydrogen and oxygen separately, without any preliminary disunion of the fluorine and boron.

One of the greatest objections to the other doctrine is, that it involves the anomaly of energetic affinities existing between acids; but both hypotheses are burdened with this anomaly, if liquid fluo-boric acid be a compound of fluoric and boracic acids, produced by the union of the hydrogen of the water with fluorine, and of the oxygen, with boron.

The imperfect state of our knowledge respecting fluorine, arises from the impossibility of isolating it, in consequence of the activity with which it would assail any substance that could be employed to evolve or contain it.

In addition to this the insupportable influence, of its liquid compounds, upon the organs of respiration, renders any accurate examination of the phenomena produced by them, when subjected to any process, extremely difficult. Yet, notwithstanding these obstacles, fluoric acid was subjected by Sir H. Davy to wires, proceeding from the poles of a Voltaic series. He ascertained that hydrogen was evolved from the negative wire, while the positive wire was corroded, and covered by a chocolate coloured substance, suspected to be fluorine, or fluoride of platina.

OF ZIRCONIUM, OR ZIRCONION.

In a stone which had been designated as the Jargon or Zircon of Ceylon, a substance was discovered by Klaproth, in 1789, which possessed all the generic characteristics of an earth, while some of its properties were such, as to distinguish it as a distinct species. To this earth, the name of zirconia was given. There is a compound, in which zirconia has been supposed to exist in combination with fluoric acid, and potash, called the fluate of zirconia and potash. When this compound, carefully dried, is heated with potassium in a tube of glass or iron, by means of a spirit lamp, zirconium, the radical of zirconia, is evolved.

Properties of Zirconium, or Zirconion.

Zirconium, obtained by the process above mentioned, is a black powder, which, being a non-conductor of electricity, and being deficient in metallic lustre, is, by Thenard, judiciously as I conceive, esteemed as non-metallic, and as deserving to be associated with carbon, silicon, and boron. Agreeably to this classification, its name must be zirconion, as the termination in *um* is appropriated to metals. By the combustion of zirconion with oxygen, zirconia is regenerated.

OF THE RECIPROCAL ACTION OF ACIDS.

It was stated, in treating of acidity and alkalinity, that acids do not usually combine with acids. I used the qualifying word *usually*, because, agreeably to the opinion heretofore generally received, and which is now entertained by many chemists (see page 192), fluo-silicic and fluo-boric acids, especially when united with water, are to be considered as chemical compounds; the former of fluoric acid, and silicic acid, the latter of fluoric acid, and boracic acid. Viewing them as acids, in one of which silicon is the radical, in the other boron, while fluorine is the acidifying principle in both, they do not form an exception to the rule, that acids do not combine with each other.

OF NITRO-MURIATIC ACID.

Nitro-muriatic acid is produced by the admixture of muriatic, and nitric acids. 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, nitro-muriatic acid 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 either chlorides or muriates.

The most striking and useful property of nitro-muriatic acid, is that of dissolving gold, whence it was formerly called by chemists, and is still called by some artists, aqua regia, (i. e. royal water,) as gold was considered the king of metals. There are some other metals of which it is peculiarly the solvent. Platina, especially, deserves to be mentioned as among those which it dissolves. See pages, 237, 239.

183.—EXPERIMENTAL ILLUSTRATION.

Some gold leaf is placed in two glass vessels. Nitric acid being poured into one, and muriatic acid, into the other, the gold is not acted upon; but when the contents of the two vessels are united, the gold disappears.

184.—METHOD OF ASCERTAINING THE SPECIFIC GRAVITIES OF THE GASES.

I mentioned, page 88, 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 airpump, 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, 16. 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, in stead of preponderating decidedly, as when air was allowed to enter; unless the balance be very delicate, the additional weight, arising from the admission of the hydrogen, will scarcely be 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 85. 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, 125, 126, 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, R, 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.

A MODIFICATION OF THE PROCESS FOR ASCERTAINING THE SPECIFIC GRAVITY OF THE GASES.

The principal difficulty in weighing the gases accurately, arises from the small proportion which the weight, of any gas, can have, to that of any receiver, which can sustain the unbalanced atmospheric pressure, consequent to exhaustion. It has been already mentioned that the accession of weight, produced in an exhausted glass globe by filling it with hydrogen, cannot be detected by an ordinary balance. This led me to adopt another mode of manipulation, which I shall proceed to describe and explain.

The weight of a bladder is exactly the same, however large or small the quantity of atmospheric air which it may include, provided the air which may be within it, be under no greater compression, than that without. Hence, if by means of a volumeter, we introduce a known quantity of any other gas, 100 cubic inches for instance, whatever the bladder gains or loses in weight, will be the difference between the weight of the gas introduced, and that of a like volume of air. If the gas be lighter, we must deduct the weight necessary to restore the equilibrium from 30.5 grains, which is the weight of 100 cubic inches of air. The remainder will be the weight of 100 cubic inches of the gas. A varnished silk bag might be preferable to a bladder.

The accuracy of this process may always be subjected to trial, by ascertaining whether the weight of the bag or bladder employed, is the same when nearly void, as when containing a volume of atmospheric air, equal to the volume of gas, which it is intended to weigh. When a bladder is used, it must be dry; as otherwise the loss of moisture, during the experiment, may influence the result.

It must be evident that this process is predicated upon the idea, that the gravity of atmospheric air, has been already determined with a sufficient degree of accuracy.

As there is no method by which a bag, or bladder, can be exhausted of air, so that a portion will not remain between its folds; neither nitric oxide, nor phosphuretted hydrogen could be weighed, by the process last mentioned, unless the residual air were previously washed out by the gas to be weighed, by hydrogen, or some other gas with which they exercise no chemical reaction. A portion of nitric oxide might be introduced, and then expelled as a mean of getting rid of oxygen.

Another process suggested.

I will take this opportunity of suggesting, that the comparative gravities of the gases might be found, by means of two bodies, counterpoised, as represented in article 96, by ascertaining the rarefaction or condensation of each gas, which would make the bodies equiponderate in it, as if it were atmospheric air. In that case, the smaller body should be of platina, which of all bodies is the heaviest in proportion to its bulk; and the larger should be of glass, as thin as would be competent to sustain the requisite changes of pressure; since I know of no body, equally firm, and impervious, which would be as light in proportion to its bulk. The changes of density being effected by the airpump or condenser, might be measured by means of a barometer gage.

SPECIFIC GRAVITIES OF THE GASES.

	Sp. gravity at 60 degrees.	Weight of 100 cubic inches in grains.
Air	1	30.5
Oxygen	$1.111\dot{1}$	$33.888\dot{8}$
Chlorine	2.5	76.25
Protoxide of chlorine	$2.444\dot{4}$	$74.555\dot{5}$
Hydrogen	$0.069\dot{4}$	2.1180
Steam	0.625	19.0620
Muriatic acid	$1.2847\dot{2}$	39.1839
Nitrogen	0.9722	$29.652\dot{7}$
Nitrous oxide	$1.527\dot{7}$	$46.597\dot{2}$
Nitric oxide	1.04166	31.7708
Ammonia	$0.5902\dot{7}$	$18.003\dot{5}$
Sulphurous acid	$2.222\dot{2}$	$67.777\dot{7}$
Sulphuretted hydrogen	$1.180\dot{5}$	36.0069
Carbonic oxide	$0.972\dot{2}$	$29.652\dot{7}$
Carbonic acid	$1.527\dot{7}$	$46.597\dot{2}$
Carburetted hydrogen (*light*)	$0.555\dot{5}$	$16.944\dot{4}$
Olefiant gas	$0.972\dot{2}$	$29.652\dot{7}$
Cyanogen	$1.805\dot{5}$	$55.069\dot{4}$
Chloro-carbonic acid	$3.472\dot{2}$	105.9020
Fluo-silicic acid	$3.611\dot{1}$	110.1385

OF METALS.

In Thenard's Traité de Chimie, we find 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		
Platina	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	1808
Osmium	Smithson Tennant	1803
Cerium	Hisinger and Berzelius	1804
Potassium	Sir H. Davy	1807
Sodium		
Barium		
Strontium		
Calcium		
Cadmium	Stromeyer	1818
Lithium	Arfwedson	1818

By the same distinguished chemist, metals are divided into six sections, founded on their habitudes with oxygen.

The first section comprises the supposed metals of the earths, magnesia, glucina, yttria, alumine. These earths have not been reduced to the metallic state. The existence in them of metallic radicals is inferred, not proved.

The second section comprises calcium, strontium, barium, lithium, sodium, and potassium. These absorb oxygen* at the highest temperatures, and decompose water at ordinary temperatures, uniting with its oxygen, and disengaging its hydrogen.

The third section comprises five metals—manganese, zinc, iron, tin, and cadmium. These absorb oxygen at the highest temperatures, yet do not decompose water, unless aided by a temperature above redness.

The fourth section comprises fifteen metals—arsenic, molybdenum, chromium, tungsten, columbium, antimony, uranium, cerium, cobalt, titanium, bismuth, copper, tellurium, nickel, and lead. These metals absorb oxygen at high temperatures, but do not decompose water, either with or without heat.

The five metals first mentioned, among the fifteen which belong to this list, are distinguished as acidifiable; the rest as oxidizeable, simply, excepting antimony and titanium, which are represented as doubtful or intermediate in their nature.

The fifth section comprises metals, which can absorb oxygen only at a certain degree of heat, and which do not decompose water. In this section there are but two metals, mercury and osmium. Their oxides are consequently reduced at elevated temperatures.

The sixth section contains six metals, silver, palladium, rhodium, platina, gold, and iridium, which, per se, neither absorb oxygen, nor decompose water at any temperature; and when oxidized by the agency of acids, or chlorine, are reduced to the metallic state, by a heat below redness.

Not only are the six sections arranged in the order of the affinity of the metals for oxygen, but their precedency, in this respect, is allowed to determine the order in which they are severally mentioned in each section, and that in which they are afterwards treated of individually.

Thenard designates the metals of the first section, as the metals of the earths, or earthy metals; those of the second section, as metals of the alkalies, or alkaline metals.

The grounds of these distinctions have been suggested as introductory to the subject of ammonia, page 154, and that of silex, page 187.

It does not appear to me that the metallic nature of the radicals of the three first mentioned earths, is sufficiently established to justify their classification among metals. Until of late, the radicals of silica and zirconia were placed under the first section, by the same author. He has now removed them from it. Alumine, yttria, and glucina, of which the radicals are allowed to remain in the class, associated with that of magnesia, are more analogous to silica and zirconia than to magnesia, which is, at the same time, decidedly analogous to the oxides of the second section, and especially to lime.

I think it probable that the radicals of alumine, yttria, and glu-

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* I would say retain oxygen.

cina, will be found intermediate in character, between metallic and non-metallic combustibles; yet that I may not be out of fashion, I shall treat of them as metals.

I will venture, however, to divide the two first sections, of Thenard, into three.

In the first, I will place metals of earths proper, or those which are not alkaline.

In the second, metals of alkaline earths.

In the third, metals of the alkalies.

As he designates the metals of the second section as alkaline, it appears to me, that the metallic radical, of magnesia, ought to be among them, as the properties of this earth, are decidedly, though feebly, alkaline.

Generic Characteristics of the Metals.

Metals have, when newly cut, 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 sulphurets; and all are susceptible of solidity and fluidity, and probably of the aëriform state. Mercury and arsenic are easily volatilized: and gold, silver, and platina, though very difficult to burn or volatilize, are nevertheless dissipated and oxidized, 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 property of hardening by being suddenly refrigerated from a red heat.

The metals remarkable for permanency of lustre, are—gold, platina, silver, and palladium. Those principally remarkable for malleability, are—gold, silver, platina, copper, palladium, iron, tin, lead, and nickel. Among these, iron and platina only, can be advantageously hammered at a very high temperature.

The metals distinguished for elasticity, are—iron, copper, and silver. It is a quality which appears dependent on the approximation of their particles, and expulsion of their caloric by the hammer, rollers, or wire-drawing. Iron, in the state of steel, when duly tempered, is pre-eminent for this property.

The metals remarkable for ductility, are—gold, iron, (either as iron, or steel,) silver, copper, platina, 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, nickel, and cobalt. Those susceptible of the welding process, are, iron and platina. Iron only, is capable of uniting with carbon, silicon, or aluminum, and hardening, consequently, by quick refrigeration. Gold and platina 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.

The perfect metals are those which, like gold, silver, platina, and palladium, possess ductility and malleability, and which are not tarnished by exposure to the air, or oxidized by the highest heats of the air furnace, or forge.

All the metals have a specific gravity greater than five, if we except those of the earths and alkalies comprised in the first and second sections of Thenard.

OF THE ANNEALING PROCESS IN THE CASE OF METALS.

Malleability, ductility, and toughness, in substances 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, and more dense, until they acquire a certain maximum of density. This being attained, they are fractured, if the hammering be not suspended. 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 AMALGAMS.

These are the compounds of mercury with other metals.

OF THE SUPPOSED METALS OF THE EARTHS PROPER—ALUMINUM, YTTRIUM, AND GLUCINUM.

The existence of the substances designated by the appellations above mentioned, rests on some experiments of Sir H. Davy, in which their earths, while heated to incandescence, were exposed to vaporized potassium.

I here give, in his own words, the account of his experiments and observations made in the case of alumine, to which those made in the case of glucina and yttria, were analogous. "By passing potassium in vapour, through alumine heated to whiteness, the greatest part of the potassium became converted into potassa, which formed a coherent mass with that part of the alumine not decompounded, and in this mass there were numerous gray particles, having the metallic lustre, and which became white when heated in the air, and which slowly effervesced in water. In a case in which a similar experiment was made, a strong red heat only being applied to the alumine, a mass was obtained, which took fire spontaneously, by exposure to air, and which effervesced violently in water, and which probably contained the basis of alumine united to potassium."

OF ALUMINE OR ALUMINA, THE SUPPOSED OXIDE OF ALUMINUM.

Of the Means of obtaining Alumine.

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.

By adding ammonia to a solution of alum, alumine precipitates, and when washed and dried, is nearly pure.

Of the Properties of Alumine.

It is white, soft to the touch, adherent to the tongue, inodorous, insipid, and infusible in the furnace. It is plastic when moistened, soluble in alkalies and acids, and combines with colouring matters, forming the precipitates called lakes. It is the only earth that 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. The specific gravity of alumine, is 2. Its equivalent is 2.25.

185.—EXPERIMENTAL ILLUSTRATION.

Alumine precipitated from a solution of alum, by an alkali.

OF GLUCINA, THE SUPPOSED OXIDE OF GLUCINUM.

This earth is white, insipid, infusible by the forge fire, fusible by the compound blowpipe, insoluble in water, capable of combining with carbonic acid at ordinary temperatures, and of a specific gravity of 2.967.

Glucina exists only in two kinds of gems, the emerald, comprehending the beryl and aqua-marine, and the euclase. In consequence of the peculiar sweetness of its salts, it was named glucine, or glucina, from γλυκυς, sweet.

OF YTTRIA, OR OXIDE OF YTTRIUM.

The description given of this earth, by Thenard, accords exactly with that given of glucina, excepting that the specific gravity of yttria is not mentioned.

This earth has been found only in three Swedish minerals—gadolinite, yttro-tantalite, and yttro-cerite.

OF THE METALS OF THE ALKALINE EARTHS.

MAGNESIUM, CALCIUM, STRONTIUM, AND BARIUM.

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, combined with the divellent attractions of wires, proceeding from the different poles of a voltaic series.

A paste made of the earth to be decomposed, either pure, or in the state of sulphate or carbonate, was formed into a small cup, into 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 above mentioned, to an extent still less satisfactory than strontium or barium. It is alleged to have appeared brighter and whiter than those metals.

The existence of magnesium, as a metal, seems to rest on a basis of observation, even narrower than that of calcium, as it was found to act upon the glass of the tube, before the whole of the mercury could be distilled from it.

OF MAGNESIA, OR OXIDE OF MAGNESIUM.

Means of obtaining Magnesia.

This earth may be precipitated from a solution of Epsom salt, by adding a solution of potash, or soda.

Of the Properties of Magnesia.

Magnesia is white, and has a feeble alkaline taste. It is nearly insoluble in pure water, but dissolves, to a considerable extent, in water containing carbonic acid, forming a soluble super-carbonate.

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 operated upon with the compound blowpipe. The specific gravity of magnesia is 2.3, and its equivalent is 2.5.

186.—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.

Means of obtaining Lime.

This oxide exists largely in nature, in combination with carbonic acid, forming all the well known varieties of marble and limestone. Some kinds of white marble, especially that of Carrara, so celebrated on account of its employment in statuary, consist 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.

Of the Properties of Lime.

The colour, taste, and smell, of this earth, are well exemplified in the best kinds of quicklime, in which it exists nearly pure. During the process of slaking, quicklime 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. Though lime is precipitated by carbonic acid, in the state of carbonate, water, impregnated with this acid, dissolves the carbonate—hence limestone water. Oxalic acid is the best test for lime. This earth was first fused by me. The specific gravity of lime is 2.3, and its equivalent is 2.5.

187.—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 lime.

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.

Carbonate of barytes, or the sulphuret, (obtained by intensely igniting sulphate of barytes with charcoal) is to be exposed to the action of nitric acid, in a quantity sufficient to saturate it. The solution must be filtered, and evaporated, and then deprived of water and acid, by an intense heat, in a platina or porcelain crucible.

Like the carbonates of potash and soda, those of barytes and strontites, cannot be decomposed, per se, by heat. The addition of carbonaceous matter enables us to decompose them, as it changes the carbonic acid to 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 caustic and more soluble in water. It is dark gray at first, but absorbs water and becomes white. Its aqueous solution is rendered milky by carbonic acid, and by combining with the same principle, becomes covered with a pellicle of carbonate, when exposed to the atmosphere. From its solution in boiling water, barytes crystallizes, on cooling. Ignited intensely, and exposed to a current of oxygen gas, it absorbs the oxygen, and passes to the state of deutoxide. Its solutions are the best tests for sulphuric acid, and reciprocally, sulphuric acid is the best test for barytes. This earth is poisonous. The specific gravity of barytes is 4. Its equivalent is 9.75.

188.—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 in the case of the alkalies.

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—also by its being more soluble in boiling water, and less so in cold.

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 6.5.

189.—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 barytic or strontitic water is added to oxygenated water, the deutoxides of those metals 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 liquid muriatic 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 muriatic 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 water held double the quantity essential to it as a protoxide of hydrogen.

OF THE METALS OF THE ALKALIES.

The discovery of potassium and sodium was made by Sir Humphrey 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 both iron and 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 ignition.

190.—EXPERIMENTAL ILLUSTRATIONS.

The inflammation of potassium upon water, and ice, exhibited,—the regeneration of the alkali, demonstrated by the usual tests. The decomposition of potash, by iron card teeth, heated to incandescence.

OF POTASH, OR POTASSA, AND SODA, THE PROTOXIDES OF POTASSIUM AND SODIUM.

Means of obtaining Potash and Soda.

A ley obtained by the lixiviation of the ashes of inland plants, especially wood, boiled down, yields the potashes of commerce. Potashes, ignited, lixiviated, and evaporated 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. The ebullition being discontinued, as soon as the alcohol has escaped, crystals are obtained. After fusion at a red heat, the alkali contains about 20 per cent. of water, of which, per se, it cannot be deprived by heat. It is therefore called a hydrate.

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 muriate of soda, and sulphate of soda.

Soda is purified, and procured in the state of hydrate, or in crystals, by a process analogous to that above described, for its kindred alkali.

Properties of Potash and Soda.

Potash and soda, 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, forming with them compounds, 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 most active. Common caustic is an impure hydrate of this alkali.

Potash is distinguished from soda, by forming a less soluble salt, with tartaric acid, and giving a yellow precipitate with muriate of platina.

191.—EXPERIMENTAL ILLUSTRATIONS.

Characteristic changes produced in vegetable infusions, as in a previous illustration, 151.

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, muriate of platina being poured, a light yellow precipitate distinguishes the potash.

OF THE DEUTOXIDES OF POTASSIUM AND SODIUM.

These compounds are formed when potassium and sodium are heated in an excess of oxygen gas. They are converted into hydrated protoxides by water, and are easily decomposed by substances in general, which have an affinity for oxygen. No useful application has been made of these deutoxides.

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.

OF LITHIA, THE PROTOXIDE OF LITHIUM.

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 muriate and phosphate of lithia differ from those of potash and soda; the muriate of lithia being deliquescent, and soluble in alcohol, and the phosphate insoluble in water.

OF THE COMPOUNDS FORMED BY THE METALS OF THE EARTHS AND ALKALIES WITH CHLORINE.

For aluminum, yttrium, and glucinum, chlorine has not sufficient affinity to expel the oxygen from their oxides, and it is only in the state of oxides that it has been in the power of chemists to subject them to the trial. Silicon, the only radical of the earths proper, which has been isolated, enters into combustion with chlorine, forming a liquid chloride. The oxides of magnesium, calcium, barium, strontium, potassium, and sodium, when heated in the gas, are converted into chlorides, the oxygen being expelled. Potassium and sodium, the only metals of the second section of Thenard, with which the experiment has been made, burn actively in chlorine.

The chlorides of the metals of the alkalies, and alkaline earths, are all very soluble, and some of them deliquescent. When in solution, they contain the same elements as if they were muriates, and are therefore considered as such by a majority of chemists.

The difference between a chloride in solution, and a muriate, is rendered evident, by setting down the ingredients agreeably to both suppositions, as follows.

$$\underbrace{\underbrace{\text{Hydrogen, chlorine.}}_{\text{Muriatic acid.}} \qquad \underbrace{\text{Oxygen, metal.}}_{\text{Oxide.}}}_{\text{Muriate.}}$$

$$\underbrace{\underbrace{\text{Hydrogen, oxygen.}}_{\text{Water.}} \qquad \underbrace{\text{Chlorine, metal.}}_{\text{Chloride.}}}_{\text{Dissolved Chloride.}}$$

GENERIC CHARACTER OF MURIATES, OR SOLUBLE CHLORIDES.

They precipitate solutions of silver, lead, or black oxide of mercury. When concentrated, they give off muriatic acid gas, by the affusion of sulphuric acid. They are not generally decomposable by heat. Muriate of magnesia is the only important exception. 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.

OF THE COMPOUNDS FORMED BY THE METALS OF THE EARTHS AND ALKALIES, WITH IODINE.

On this subject, it will be sufficient for the student to know that there is a great analogy between the habitudes of iodine and chlorine, in combining with the metals of the earths and alkalies. It expels the oxygen from the protoxides of potassium, and sodium, but not from those of barium, strontium, and calcium.

Iodides, when dissolved in water, are supposed to be converted into hydriodates, by the union of hydrogen with the iodine, and of oxygen with the metal.

OF THE COMPOUNDS FORMED BY THE METALS OF THE EARTHS AND ALKALIES, WITH SULPHUR.

The reaction of sulphur with the alkaline metals, is very analogous to that of chlorine, as it combines with them, expelling the oxygen from them when in the state of oxides.

When either of the alkaline metals is heated to fusion, in contact with sulphur, in a close vessel filled with hydrogen or nitrogen, a true combustion ensues, and a sulphuret is produced. A like compound may be obtained by passing sulphur in vapour, over a portion of the hydrate of potash or soda, heated in a glass tube; or by exposing either of these substances to a jet of vaporized sulphur, emitted from the touch-hole of a red hot gun barrel, as already described, 157.

When the sulphates of any of the earths, or alkalies, are heated with charcoal, or exposed, in a state of ignition, to a current of hydrogen gas, they are converted into sulphurets. The oxygen of the acid and oxide, forming water with the hydrogen, the sulphur of the acid remains in combination with the metal.

The sulphurets of the metals of the earths and alkalies, form solutions with water, in which case a change seems to take place, resembling that which has been alleged to ensue during the solution of chlorides and iodides. Water is decomposed, its oxygen combines with the metals, its hydrogen with the sulphur in excess. The oxide, and the super-sulphuretted hydrogen uniting, form a sulphuretted hydro-sulphuret, or hydroguretted sulphuret. Meanwhile, another portion of the water is decomposed by another portion of the sulphur, so that sulphurous and hypo-sulphurous acids are produced, and a portion of free sulphuretted hydrogen, which escapes. The quantity of free sulphuretted hydrogen is probably increased, by the expulsion of this gas from the hydro-sulphurets, in consequence of the superior affinity of the acids generated by the oxygen, of the water, or the air, for the metallic oxide.

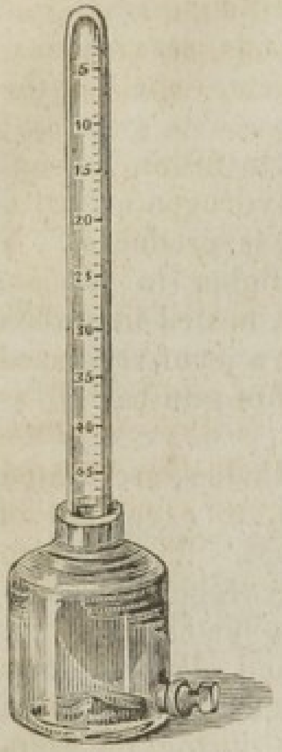
192.—APPLICATION OF SULPHURETS IN EUDIOMETRY.

The aqueous solutions of the sulphurets called sulphuretted hydro-sulphurets, or hydroguretted sulphurets, are capable of absorbing oxygen from the air. This property has induced the employment of them in eudiometry.

The same processes will answer in using these liquids, as in employing the solution of nitric oxide in sulphate, or muriate, of iron, 148.

A eudiometer, contrived by Dr. Hope, by means of which the sulphurets may be employed in the analysis of atmospheric air, is described in the following article.

EUDIOMETER OF DR. HOPE.



This eudiometer consists of a graduated glass tube, sealed at one end, and at the other fitted, by grinding, into the mouth of a tubulated glass bottle, so as to be air tight. Manipulation, with this instrument, is very simple. The tube is filled with gas, the bottle with the liquid which is to act upon the gas. The tube being, under these circumstances, inserted into the mouth of the bottle, by inverting both, the contained gas is made to pass into the bottle. Agitation is next to be resorted to, and time allowed for the absorption to be completed. In the interim, the tubulure is to be occasionally opened under water, by removing a ground stopple with which it is furnished. The gas absorbed, is consequently replaced by water.

Finally, the stopple must be removed, the tube being previously depressed into water, till this liquid is as high on the outside as within. The graduation being at the same time inspected, the deficit produced by the absorption of oxygen, is ascertained.

OF THE COMPOUNDS FORMED BY THE METALS OF THE EARTHS AND ALKALIES, WITH PHOSPHORUS.

As respects their habitudes with the metals of the earths and alkalies, there is the greatest analogy between sulphur, and phosphorus.

The action of the phosphurets upon water, is, however, much more active than that of the sulphurets, and the evolution of sulphuretted hydrogen, in the one case, is consequently much less abundant than that of phosphuretted hydrogen in the other. This, however, results, in part, from the affinity of sulphuretted hydrogen for the metallic oxides, with which it enters into combination, so as to require an acid for its expulsion.

OF THE COMPOUNDS FORMED BY THE METALS OF THE EARTHS AND ALKALIES WITH SELENIUM.

In its combinations with the metals, of the earths and alkalies, selenium is quite analogous to sulphur.

Definition of the terms Metalloid and Metal Proper.

The metals of the earths and alkalies have heretofore been called metalloids by some chemists, to distinguish them from the rest, which have been designated as metals proper. Having found these appellations useful, I shall continue to employ them.

OF THE METALS OF THE THIRD SECTION OF THENARD.

The metals placed under this section, are those which do not decompose water at a lower temperature than that of redness; which absorb oxygen either at low or at high temperatures; and of which the oxides, although irreducible by heat merely, at any temperature, are reducible by the Voltaic series, or by being heated with various combustibles. Manganese, zinc, iron, tin, and cadmium, are the only metals whose qualities coincide with this description.

MANGANESE.

Manganese exists in nature principally in the state of a black tritoxide; rarely in that of phosphate, sometimes in the state of sulphuret. 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. 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 sub-oxide, a protoxide, a deutoxide, and tritoxide, it forms two acids, the manganous and manganesic acids. The salts of the latter detonate with combustibles.

When the black oxide (tritoxide) is fused with potash, a compound results, of which the aqueous solution becomes successively blue, red, and violet; and finally, colourless—hence the compound has been called Chameleon mineral.

The colours appear to be produced by various degrees of oxygenation.

OF ZINC.

This metal exists in nature in five states. In that of oxide, sulphate, silicate, carbonate, and sulphuret. Either as a silicate or carbonate, it is known in mineralogy under the name of calamine; its sulphuret is called blende.

Means of obtaining Zinc.

Zinc is obtained from its oxide, by calcining it with charcoal. It may be purified by sublimation in a stone-ware retort.

Properties of Zinc.

Zinc is brilliant, and of a white colour, slightly tinctured with a leaden hue. 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. Its structure is strikingly crystalline. By exposure to the atmosphere it is slightly oxidized, but at a white heat burns rapidly, giving off fumes of oxide.

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 muriatic acid.

Zinc is soluble in nitric and muriatic acids, being oxidized by the water in the one case—in the other at the expense of a portion of the nitric acid. It forms a chloride when subjected, in a divided state, to chlorine gas. This chloride has been called from its consistency, butter of zinc.

The equivalent for zinc is 4.25. It forms but one oxide, whose equivalent is 5.25, as it contains only one atom of oxygen.

193.—EXPERIMENTAL ILLUSTRATIONS.

Zinc subjected to diluted sulphuric, and diluted muriatic acids, 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.

OF IRON.

This metal is found abundantly in nature, principally in union either with sulphur or oxygen.

Large masses of iron alloyed with nickel or cobalt, or with both of these metals, have fallen from the sky to the earth, at different times, and in various countries. Besides these metallic masses, a great number of stones, called meteorolites, on account of their origin, have fallen to the earth from regions unknown. In these iron always exists in the state of black oxide, and likewise in that of metallic globules resembling the meteoric iron, above mentioned, in composition.

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 probably the most universal colouring matter.

Means of obtaining Iron.

It is obtained usually from its oxides, as they are susceptible of decomposition by being heated with charcoal: the oxygen and carbon passing off in the form of carbonic oxide or acid. There is no profitable mode of separating this metal from sulphur.

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. Few metals are more speedily oxidized by the joint agency of air and moisture.

The protoxide is formed during the solution of the metal, in diluted sulphuric, or muriatic, acid. When these solutions are exposed to the air, they change from a green to a red colour, in consequence of the absorption of oxygen by the iron which is thus peroxidized.

The scales called finery cinder, which fly off during the forging of incandescent iron, consist of two atoms of protoxide and one of peroxide. The oxide formed by subjecting iron, at a red heat, to steam, is also a compound of the two oxides, but the proportions are reversed.

The native magnetic oxide of the mineralogists, is, according to Thenard, the same as that obtained when iron is oxidized by steam. It is probable, however, that the other compound exemplified by finery cinder, also exists in nature among the substances designated as the magnetic, or black oxide of iron.

Water combines with the oxides of iron, forming hydrates. Ochre is a hydrate of the peroxide, mixed with earthy matter.

The green muriate of iron evaporated to dryness, forms a protochloride. The per-chloride is formed by the combustion of iron in chlorine gas.

Nitric acid oxidizes iron, and dissolves the oxide, as in the case of other metals.

Acetic acid causes iron to absorb oxygen slowly, and dissolves the oxide as produced.

The protoxide of iron combines with carbonic acid, and is soluble in water impregnated with this gas.

Iron, probably in the state of protoxide, is soluble in water: for when copper, or silver, disks are alternated with this metal, in pure water, a chalybeate taste is acquired; and a precipitate of red oxide soon appears. The solution of oxidized iron, and precipitation of the red oxide, may be observed also, in the Yellow Springs, and other chalybeate waters, where iron is in solution, without any adequate assistance from carbonic acid.

There are two native sulphurets of iron, a proto-sulphuret and a bi-sulphuret. The former only is magnetic, but the latter may be rendered magnetic by roasting, or exposure before the blowpipe, by which it loses one half of its sulphur, and passes to the state of proto-sulphuret. It is the proto-sulphuret which is formed by the combustion of iron with sulphur. Iron filings and flowers of sulphur, moistened with water, after some time take fire. When heated together without moisture, they incorporate with the appearance of combustion.

Iron, at a welding heat, if touched with a roll of brimstone, falls instantly in drops of melted proto-sulphuret; and iron wire burns brilliantly, when exposed to a jet of vaporized sulphur, as it issues from the touch-hole of a red hot gun barrel, as already described, 157.

Iron combines with phosphorus. The presence of this substance in a small proportion, renders it brittle while red hot.

With carbon, iron combines in various proportions, forming steel, cast iron, and plumbago. Plumbago consists of carbon, combined with about five per cent. of iron. It is very difficult of fusion and combustion. It was first fused, in 1802, by means of the compound blowpipe. The finest kind is seen in the best English pencils. Plumbago of an inferior kind, is used as a material for crucibles and small furnaces.

Cast iron contains not only carbon, but silicon, and probably sometimes calcium. It is purified by long continued fusion, frequent stirring, and subsequent hammering.

Pure malleable iron, thus obtained, is converted into steel, by being heated in contact with charcoal, in ovens, without access of air. The process is called cementation. The bars are blistered by the operation, as they are seen in commerce. Broken up, and then welded, they form shear steel. Fused, they form cast steel. It has lately been advanced, that silicon is an ingredient in steel, more necessary than carbon, and that wootz, or Indian steel, owes its excellence to aluminum, as well as silicon.

Iron is equivalent to 3.5, and its protoxide, consequently, is equal to 4.5. The oxygen in the peroxide is the same as if two atoms of iron $= 7$ were united with three atoms of oxygen; of course, its number would be ten, but it is usually represented as consisting of one atom of iron, and $1\frac{1}{2}$ atoms of oxygen, or $3.5 + 1.5 = 5$. Either mode of representing these equivalents, will answer in practice, but the latter is inconsistent with the atomic theory, agreeably to which, there can be no half atoms.

Of the Tests for Iron.

Iron, in the state of red oxide, is precipitated, purple or ink-coloured, by infusion of galls or other astringent vegetables; brown, by succinates, or salts formed by the acid of amber, and blue, by the ferro-prussiate of potash. It has been alleged, however, that the iron in Prussian blue is partly in the state of peroxide, partly in that of protoxide, as the colour would be too intense, so as to approximate to blackness, if the metal were all peroxidized. See page 135.

There are four principal classes of ferruginous minerals, magnetic black oxides, and red oxides not magnetic; magnetic sulphurets, and bi-sulphurets not magnetic. Hence the ores of iron, if not obedient to the magnet, generally become so, after exposure on carbon to the blowpipe, by which the excess of oxygen, or sulphur, which destroys the magnetic power, is expelled.

194.—EXPERIMENTAL ILLUSTRATIONS.

Iron, dissolved by muriatic and sulphuric acids. Red and black oxides of iron, exhibited, and their solutions, precipitated by galls, and by ferro-prussiate of potash. Effects of muriate of tin, on the colour of the precipitates. Iron burned in oxygen gas, also by sulphur, and by galvanism. Ores rendered magnetic by the blowpipe.

OF TIN.

This metal is found in the state of oxide, and in that of sulphuret. The sulphuret is rare, and contains much copper. The ore of tin, which is the principal source of the metal, is a deutoxide, 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.

Properties of Tin.

The colour and lustre of this metal, may be seen in utensils newly made of tinned iron. Tin tarnishes slightly by exposure to the air. It is very malleable and ductile. Tinfoil is $\frac{1}{1000}$th of an inch thick. 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.

Tin forms two oxides and two chlorides. The bi-chloride is a very singular fuming liquid. A small quantity of water congeals it; but a larger restores its fluidity. This chloride has long been known, by the name of the fuming liquor of Libavius. The protoxide of tin is soluble in diluted nitric acid. In strong acid it becomes peroxidized, and in that state is not soluble. Boiling sulphuric acid, whether strong, or weak, converts this metal into a protoxide, and dissolves it. Solutions of the nitrate, or sulphate, absorb oxygen, and deposite the peroxide in a state of sub-sulphate, or sub-nitrate. Muriatic acid is its proper solvent, and the compound produced, is usually considered as the muriate of the protoxide. This solution absorbs oxygen, and deoxidizes oxides in other solutions. Hence it destroys the colour of ink and of Prussian blue. It is always acid.

Nitro-muriatic acid dissolves tin with violence, producing much heat, and forming a bi-chloride in solution. Tartaric acid dissolves tin. Either brass, or copper, is tinned slightly when boiled with powdered, or leaf tin, and cream of tartar. When cleaned and immersed in melted tin, with addition of oil, or rosin, to prevent oxidizement, they become covered with a coat of the fused metal.

Tin forms two sulphurets. The bi-sulphuret is of a golden colour, and was known formerly as aurum musivum.

The equivalent for tin is	7.25
That of its protoxide	8.25
of its peroxide	9.25
of its proto-chloride	11.75
The bi-chloride is probably	16.25

Although the fuming liquor of Libavius appears to contain an excess of chlorine.

195.—EXPERIMENTAL ILLUSTRATIONS.

Exhibition of ingots of tin, and of tinfoil, also the fuming liquor of Libavius. Reaction of nitric acid, or nitrate of copper with tin powder. Solution of tin, by muriatic acid, and effect of the muriate thus obtained, on other metallic solutions. Discolouration of ink and Prussian blue.

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.

Means of obtaining Cadmium.

A solution of the ore in sulphuric acid, being impregnated with sulphuretted hydrogen, the cadmium precipitates in the state of sulphuret, mixed with a little sulphuret of zinc.

When these sulphurets are subjected to liquid muriatic acid, water is decomposed; the oxygen and acid unite with the metals, while the hydrogen and sulphur escape. Carbonate of ammonia being added to the resulting muriates of cadmium and zinc, a carbonate of cadmium is alone precipitated. From this, the metal may be obtained by means of heat and charcoal.

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 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.

OF THE METALS OF THE FOURTH SECTION.

The metals of this section are capable of retaining oxygen at high temperatures, but do not decompose water at any temperature.

OF ARSENIC.

This metal is found in nature in combination with oxygen, sulphur, and various metals.

Means of obtaining Arsenic.

Arsenic is sold in commerce under the name of cobalt. As it is very attractive of oxygen, and in the state, in which it bears this name, full of crevices, it is 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 catch 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 above the part heated to redness.

According to Thenard, arsenic may be sublimed in a glass retort, filled with nitrogen, and heated by a spirit lamp.

Properties of Arsenic.

Exposed before the blowpipe, arsenic is distinguished by burning before it fuses, and emitting copious white fumes, which have the odour of garlic. Such fumes are easily produced by projecting a portion of the metal upon a hot iron.

According to the opinion of Berzelius, which is adopted by Thenard, the black matter into which arsenic is converted, by exposure to the air, is a protoxide, and the fumes yielded by the combustion of the metal, consist of the deutoxide. These fumes, condensed as they are evolved, on a large scale, during some metallurgic operations, constitute the white arsenic of the shops. By Henry, and many other chemists, white arsenic is considered as the protoxide—and they deem the black matter, into which arsenic is converted by the action of the air, as a mixture of white arsenic with metallic arsenic. This conclusion appears irreconcilable with the fact, 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.

There is also another combination of arsenic with oxygen, obtained by deflagrating the metal with nitre, or by digesting it with nitro-muriatic acid. In the compound thus procured, the oxidizement is admitted to be at a maximum. The white oxide of arsenic, and the peroxide, are also called arsenious, and arsenic acids, as they combine with alkalies, and do not combine with acids.

Fowler's solution is made, by boiling pearlash on the white oxide. It is an arsenite of potash. An arseniate is obtained by deflagrating white oxide with nitre.

When arsenic is exposed to chlorine gas, or distilled with corrosive sublimate, a liquid chloride is produced, which is very analogous to the bi-chlorides of tin and antimony, in its properties.

Arsenic is found in nature in combination with sulphur, in different proportions. The compound, containing the least sulphur, is of a fine red colour, and is called realgar—the other sulphuret is yellow, and is called orpiment. The former consists of one atom of arsenic, and one atom of sulphur; the latter, of two of the metal, and three of sulphur.

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, and forms a pigment called Scheele's green. The arsenite of silver is yellow—the arseniate, brick red.

The equivalent of arsenic is - - - -	4.75
Of arsenious acid, which contains two atoms of oxygen, the equivalent is - - - - - -	6.75
Of arsenic acid, which contains three atoms of oxygen	7.75

The black oxide, or protoxide, probably consists of one atom of metal, and one atom of oxygen.

196.—ARSENURETTED HYDROGEN.

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 arseniuretted 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 muriatic acid. This gas is extremely poisonous.

OF THE SOLID COMPOUND OF ARSENIC WITH 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.

OF THE MEANS OF DETECTING ARSENIC IN FOOD OR DRINK, OR IN THE CONTENTS OF A STOMACH, IN CASES WHERE POISONING IS SUSPECTED.

The presence of arsenic is most satisfactorily proved, by evolving it in the metallic state. This may be effected by subjecting any mixture, or mass, supposed to contain it to heat, with powdered charcoal, in a glass tube. The arsenic will sublime in crystals. The addition of soap, recommended by some chemists, I find unnecessary and disadvantageous, as it soils the crystals. Lampblack is liable to the same objection. I consider the ammoniacal nitrate of silver, as decidedly the best test, either for arsenious or arsenic acid. With the former, it produces a very copious precipitate of a bright yellow colour, with the latter, a brick red precipitate.

Wherever arsenic is much intermingled with other matter, as it must usually be, when in a solution obtained from the contents of the stomach of a person supposed to be poisoned, I should prefer to evaporate the whole to dryness, at a heat below that of boiling water, and then to digest the mass in strong nitric acid, until this acid is all decomposed or expelled. By these means the organic matter will be entirely destroyed, and the arsenic will be converted into arsenic acid. Besides the advantage of having removed the vegetable and animal matter, which would affect the colour of the precipitate, it seems to me that the arseniate of silver is less liable than the arsenite to be confounded with other precipitates.

Mr. Smithson's plan of deflagrating any matter supposed to contain arsenic, with nitrate of potash, and testing with a solution of silver, seems to me an excellent one. He recommends that acetic acid be used to saturate any alkali which may be liberated by the heat. A drop of arsenious matter, of which not more than $\frac{1}{80}$th may be arsenious acid, by fusion with nitrate of potash in a platina spoon, gives decided indication of arsenic acid with nitrate of silver.

197.—EXPERIMENTAL ILLUSTRATIONS.

Habitudes of arsenic, as obtained by sublimation, in its metallic crystalline form, contrasted with those of zinc, antimony, and bismuth. White oxide, and its solutions, exhibited: also, Fowler's solution, or arsenite of potash. To large vessels of clear water, measured quantities of arsenic in solution are added, and detected by various tests. Combustion of arseniuretted hydrogen displayed.

OF MOLYBDENUM.

This metal is only found in the state of sulphuret, resembling plumbago, or united with oxygen and lead in the state of molybdate of lead. From the sulphuret, 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, yet even its colour is doubtful.

OF CHROMIUM, OR CHROME.

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 their colour, that this metal was discovered by Vauquelin. A compound of oxide of chromium and iron, called incorrectly, chromate of iron, is found plentifully in this country. The oxide of chromium is reduced with very great difficulty when heated with charcoal.

Chromium is a brittle metal, of a grayish white colour, and very difficult to fuse. Its specific gravity is 5.9. Its equivalent is 3.5. It forms with oxygen a protoxide, a deutoxide, and an acid.

The protoxide of chromium is green, and communicates a fine green colour to its compounds, whether natural or artificial.

The well known green of the emerald is produced by the oxide of chromium. Chromic acid is ruby red, and it communicates this colour 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.

198.—EXPERIMENTAL ILLUSTRATIONS.

Solutions of silver, mercury, and lead, precipitated by chromate of potash.

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, with considerable brilliancy. Its specific gravity is 17.6. It is extremely difficult to fuse, and has not been applied to any useful purpose.

OF COLUMBIUM.

A metal discovered by Hachett, 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 yttro-tantalite; 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 the usual means, intense heat, and charcoal; also by heating fluo-columbate of potass (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 ANTIMONY.

Antimony sometimes occurs in nature, in the metallic state, but exists abundantly in the state of sulphuret. It is in fact the sulphuret that is called antimony in commerce, the metal being designated as the regulus of antimony.

Means of obtaining Antimony.

Metallic antimony may be obtained by mingling the sulphuret with two-thirds of its weight of bi-tartrate of potash, and one-third of its weight of nitre, and deflagrating the mixture in a red hot crucible. The metal being oxidized, and sulphur acidified, by the oxygen of the nitre, the resulting oxide of antimony is reduced by the carbon of the tartaric acid. Charcoal intimately intermingled with either sub-carbonate of potash, or soda, may be used instead of the bi-tartrate.

Antimony, thus obtained, is not quite pure. To render it so, it may be dissolved in nitro-muriatic acid, precipitated by water in the state of an oxide, and revived by ignition with bi-tartrate of potash.

Properties of Antimony.

Antimony is brittle, and displays a crystalline structure. When newly fractured, it is of a very fine 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.

There has been much discordancy among chemists, respecting the oxides of antimony. The most satisfactory information respecting them, appears to me to be that afforded by Dr. Thomson, in his Principles of Chemistry. Agreeably to his experiments and deductions, there are three oxides of antimony; a protoxide, which consists of one atom of metal, with one atom of oxygen; a deutoxide, consisting of two atoms of metal, with three of oxygen; and a peroxide, consisting of one atom of metal, with two of oxygen. According to the same author,

The equivalent	Of antimony is - -	5.5
	Of its protoxide - -	6.5
	Of its peroxide - -	7.5

The equivalent of its deutoxide may be assumed as equal to 14 or 7, accordingly as it may be estimated, to consist of two atoms of metal, with three of oxygen, or one atom of metal, with one and a half atoms of oxygen.

When the solution, obtained by boiling the sulphuret in muriatic acid, is poured into water, a white curdy matter precipitates, which is a sub-muriate of the protoxide. On digesting this salt with a dilute alkaline solution, the protoxide is obtained in purity. This oxide may also be produced, by adding carbonate of potash or soda, to a solution of tartar emetic.

It is the protoxide of antimony only, which forms salts with acids, and which is efficacious medicinally.

The deutoxide of antimony is formed when either the protoxide, the peroxide, or metallic antimony, is exposed to a red heat with access of air. It sublimes, and upon being refrigerated, condenses in crystals of a silvery whiteness, formerly called argentine flowers of antimony. This oxide is less fusible than the protoxide, but is more volatile. It is quite insoluble in water, and has but little affinity for acids. As it combines with alkalies, it has been called antimonious acid, by Berzelius. From its union with alkalies, it is separated, as a hydrate, by acids, and in this state reddens litmus, and is soluble in muriatic acid.

The peroxide of antimony, may be obtained by digesting the metal in nitric acid, or by dissolving it in nitro-muriatic acid, and pouring the solution into water. When newly procured, it is a hydrate, and reddens litmus. As it does not form definite compounds with acids, while it forms salts with alkalies, it is correctly, as I conceive, called by Berzelius, antimonic acid, and its salts antimoniates.

When antimonic acid, or peroxide of antimony, obtained, as above described, in the state of a hydrate, is exposed to a temperature of 500° or 600° F., it is deprived of water, and rendered insoluble in muriatic acid.

The reaction which ensues between antimony and chlorine, has been illustrated by means of an appropriate apparatus, 113. The fumes which filled the vessel, after the combustion, consisted of proto-chloride of antimony, which may also be obtained by distilling one part of antimony, with two parts and a half of corrosive sublimate, by weight.

This chloride, from its consistency and fusibility, has been called butter of antimony. It is deliquescent, and may be decomposed, by a certain quantity of water, into a muriate of the protoxide. If the muriatic acid, of this muriate, be much diluted with water, the whole of the protoxide precipitates.

The per-chloride is generated by subjecting antimony, while heated, to a current of dry chlorine. In its susceptibility of decomposition by water, this chloride resembles the proto-chloride. It is a transparent volatile liquid, having a very powerful and disagreeable odour, and producing thick fumes in the air. This liquid chloride, by the addition of water, or by a spontaneous absorption of humidity from the air, is converted into a crystalline mass, which, by a further supply of water, deposites hydrated antimonic acid.

The existence of a compound of two atoms of antimony, with one of chlorine, which he calls a di-chloride, is alleged by Dr. Thomson.

The sulphuret of antimony may be formed, by fusing antimony with sulphur.

When sulphuret of antimony is boiled, with an aqueous solution of potash, a liquid is obtained, which, on cooling, yields a reddish brown precipitate. This has long been known under the name of kermes mineral. After the precipitation of the kermes, an acid causes a further precipitation. The compound thus procured, is called, in Pharmacy, the golden sulphur of antimony.

According to Thomson, kermes mineral contains, of antimony, sulphur, oxygen, and hydrogen, each one atom—that is,

Antimony - - - -	5.5
Sulphur - - - - -	2.
Oxygen - - - - -	1.
Hydrogen - - - -	.125

He alleges, reasonably, that as it comprises the elements of one atom of sulphuret of antimony, and one atom of water, it may be considered either as a hydrated sulphuret, or hydro-sulphuretted oxide. In the golden sulphur of antimony, there is probably one atom of sulphur more than in the kermes.

The bi-sulphuret of antimony has been formed by the action of sulphuretted hydrogen upon the peroxide. A golden sulphur, or sulphuret, prepared by boiling sulphuret of antimony with sulphur, and a solution of potash, is alleged to be the bi-sulphuret.

There is a definite native compound, of one atom of protoxide of antimony, with two atoms of sulphuret, which has been distinguished in mineralogy as red antimony. The glass, the liver, and crocus, of antimony, resemble this compound in composition.

199.—EXPERIMENTAL ILLUSTRATIONS.

Antimony and its sulphuret exhibited and exposed to the blowpipe; also the crystals and solution of tartar emetic. Kermes mineral, and golden sulphur of antimony, exhibited. Antimony subjected to acids. Kermes precipitated from a solution of tartar emetic, by sulphuretted hydrogen.

OF URANIUM.

Uranium is a very rare production in nature, and has scarcely been obtained in sufficient quantities for an adequate observation of its properties. It is stated to have the metallic lustre, and to be of 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 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.

Cobalt is brittle, of a reddish-gray colour, and feeble lustre. Its specific gravity is 8.5 nearly. It requires a high temperature for its fusion.

OF TITANIUM.

This metal, like many others, is only interesting as an item, in the stock of 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 an oxide, by Mr. Gregor, in a mineral called menaccanite. 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 or nitro-muriatic acid, but were oxidized by being heated with nitre.

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 sulphuret.

Means of obtaining Bismuth.

According to Cleaveland, the ore which contains it, in its native metallic state, is the only one which is explored. It is obtained by throwing the ore upon a fire of wood, under which a hole is made to receive the metal, and protect it from oxidizement.

Bismuth, as known in commerce, is nearly pure.

Properties of Bismuth.

Its fracture is crystalline, like that of zinc, or antimony, but a peculiar tint of red distinguishes it. It is pre-eminent for the facility and regularity with which it crystallizes. Its specific gravity is 9.82. It is usually considered as unmalleable; yet, according to Dr. Turner, it may be hammered into plates while warm.

Excepting mercury, tin, potassium and sodium, it is the most fusible metal. Its fusing point is 476° (F.). It is oxidized, when kept in fusion in the air.

Subjected to sulphuric acid, bismuth is partly dissolved, and partly converted into an insoluble oxide.

In nitric acid it dissolves completely. When the neutral nitrate of bismuth is poured into water, the whole of the metal precipitates, in the state of a hydrated sub-nitrate, which is of a fine white colour, and has been called magistery of bismuth. If muriatic 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 sulphuretted hydrogen.

Bismuth, when subjected, in a divided state, to chlorine gas, takes fire, and forms a chloride.

Most of the metals may be alloyed with bismuth. Eight parts of this metal, with five of lead, and three of tin, form a compound fusible in boiling water.

Bismuth is sometimes added to "soft solder," which usually consists only, of tin and lead, to render it more fusible.

200.—EXPERIMENTAL ILLUSTRATIONS.

Bismuth, and its oxide, exhibited. Its hue, and habitudes with the blowpipe, compared with those of zinc, antimony, and arsenic.

OF COPPER.

Copper is occasionally found in nature, in the metallic state, also in the states of oxide, carbonate and sulphuret.

Means of obtaining Copper.

It is obtained principally from the sulphuret. 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 muriatic acid, and subsequent precipitation by a bright plate of iron.

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. Its specific gravity is nearly 9. It is very malleable, and ductile, and is next to iron in tenacity.

It fuses at a white heat. By exposure to air and moisture, it sustains a slight oxidizement. At a red heat it is oxidized rapidly, being converted into a red protoxide, which scales off, if it be afterwards hammered. By further calcination, it is reduced to the state of a black deutoxide. The precipitate from nitrate of copper, by potash, being exposed to a red heat, forms the deutoxide.

Thenard mentions that a peroxide of copper may be obtained, by mixing, with oxygenated water, a weak solution of the deutoxide, in nitric acid.

Copper, in thin leaves, takes fire in chlorine, and forms two chlorides—a fixed proto-chloride, and a volatile per-chloride. The per-chloride, when dry, is of a faint yellow colour; but if moistened, becomes green. Hence it acts as a sympathetic ink, which is invisible until breathed upon, or otherwise made humid.

Hydriodic acid precipitates copper from its solutions, in the state of an insoluble iodide.

Nitric acid, which should be of the specific gravity of 1.2, peroxidizes 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, 130.

Sulphuric acid, boiled on copper, peroxidizes and dissolves it, as nitric acid does, without heat. The sulphate, resulting, forms the blue crystals, called, in commerce, blue vitriol.

Carbonate of copper is produced, when copper is precipitated from its solutions by alkaline carbonates. It accumulates upon copper, when exposed to moist air. It is found native, in various forms, remarkable for beauty.

Alkalies combine with the peroxide of copper, and with the salts of this metal. Ammonia, especially, dissolves the peroxide, producing a very beautiful blue solution. The changes which ensue from the addition of this alkali, in excess, to a solution of the peroxide in an acid, were adduced to illustrate the fifth case of affinity, page 12.

Cuprum ammoniatum is made, by triturating sulphate of copper, with sub-carbonate of ammonia.

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 equivalent for copper is usually assumed as 4, but may be 8.

Of the Means of detecting Copper, in solution.

The blade of a knife, or any bright piece of iron, or steel, is a very delicate test for copper, in solution, as a film of the metal will be precipitated upon the iron, and communicate to it the appearance of copper. Ammonia, when added in excess, produces a blue colour, as already mentioned, in water containing a very minute quantity of copper; but the ferro-cyanate of potash is far more efficient. I have ascertained that it requires twice as much copper to produce a blue tinge with ammonia, as to produce the appropriate hue of the ferro-cyanate of copper, which is a peculiar rich reddish brown.

201.—EXPERIMENTAL ILLUSTRATIONS.

Solution of copper in nitric acid, and its precipitation by iron. Effect of ammonia; also of ferro-cyanate of potash.

202.—APPARATUS FOR THE COMBUSTION, OF METALLIC LEAVES, IN CHLORINE.

The ends of a glass cock are severally cemented into the perforated necks of two bell glasses, A, B, one of them smaller than the other, and surmounting it in an inverted position. The brass plate which covers the orifice of the upper bell, is so fitted to it, as to form an air tight juncture, and is furnished with a cock terminating in a gallows and screw, for attaching a leaden pipe proceeding from an air pump. A hook is soldered to the lower surface of the plate, from which some leaves of Dutch gold* are suspended. Suppose the lower bell to be filled with chlorine over the hydropneumatic cistern, the upper one exhausted by the air pump. On turning the cock, the chlorine will rush into the upper bell, and cause the instantaneous combustion of the included leaf metal. Afterwards the upper bell will be replete with the fumes of the resulting chlorides, of the metallic matter of the alloy.

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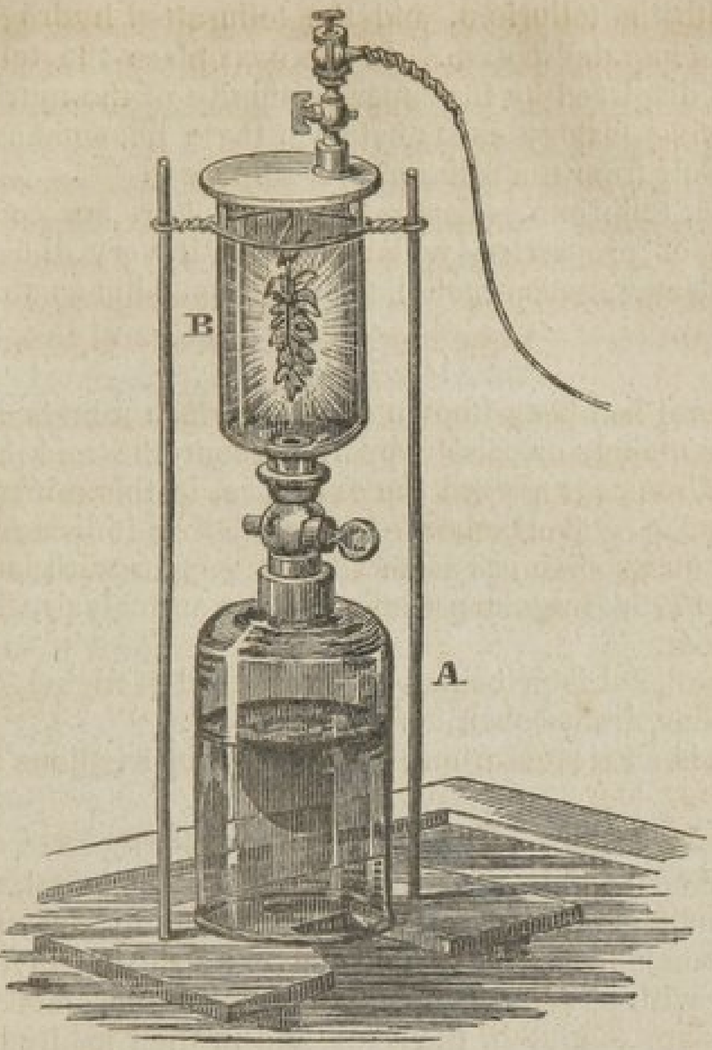
* An alloy of copper.



OF TELLURIUM.

Tellurium is a metal which has been found only in the veins of auriferous silver, in the mines of Transylvania.

This metal is brilliant, and 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.

Tellurium combines with chlorine in one proportion, and with hydrogen in two proportions; of which one is solid, the other gaseous. The solid compound is obtained, by means of the Voltaic series, in the same way as that formed by arsenic with hydrogen. The other, which is called telluretted hydrogen, is procured by subjecting an alloy of tellurium and potassium, successively, to water and muriatic acid. In the first instance, water is decomposed; the oxygen unites with the potassium, while the hydrogen unites with the tellurium, and the telluretted hydrogen combines with the generated potash. In the next place the telluretted hydrogen is displaced by the superior affinity of the muriatic acid.

A striking analogy exists between these phenomena, and those which result from the solution of a sulphuret.

Arsenic, tellurium, selenium, and sulphur, are connected by a gradation of properties, which renders it very difficult to define the boundary between metallic and non-metallic combustibles.

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 arseniuret of nickel, but contains, also, sulphur, iron, cobalt, and copper.

Nickel is extricated from this mineral, by a tedious and intricate process.

Properties of Nickel.

The colour of this metal is white. It is magnetic—difficult of fusion—malleable—and not easily oxidized by the air. If sufficiently abundant, nickel would be very valuable in the arts. It combines with oxygen, chlorine, iodine, 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 LEAD.

Lead is found in nature in union with sulphur and oxygen, and likewise united severally with the chromic, sulphuric, phosphoric, molybdic, carbonic, and arsenic acids.

Means of obtaining Lead.

Lead is obtained chiefly from the sulphuret, called galena, in mineralogy, which is by far the most abundant of its ores. In order to liberate the lead from galena, it is only necessary to heat it with charcoal, so as to expel the sulphur, and prevent the oxidizement of the metal. This process may be performed in the small way, by means of the blowpipe.

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. Leaden tubes and vessels, are not easily injured by moisture, or acid fumes.

Two oxides of lead are usually met with in commerce. One is the protoxide, being yellow, and called massicot, or when vitrified, litharge; the other, called minium, or, from its colour, red lead, is a mixture of protoxide with deutoxide.

A peroxide of lead, of a puce colour, is obtained by exposing red lead, suspended in water, in an impregnating apparatus, to chlorine gas, or by digesting it with nitric acid.

Lead is oxidized and dissolved, when subjected to nitric acid. Neither sulphuric, nor muriatic acid, has any action on it, when cold. Sulphuric acid, when boiling and concentrated, oxidizes, and combines with it, forming an insoluble sulphate.

Lead is also oxidized and dissolved by acetic acid, and forms a soluble acetate, and a sub-acetate. The acetate is called in commerce, sugar 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.

Chlorine combines with lead, but the resulting chloride being fixed and insoluble, protects the metal from further erosion. Hence the utility of leaden vessels, in manufacturing chlorine in the large way.

Lead is equivalent to - - -	13
Its protoxide to - - - -	14
And its peroxide to - - - -	15

An oxide, which Dr. Thomson calls the deutoxide, is alleged by him to consist of 2 atoms of metal, united with three atoms of oxygen; and of which the equivalent is 29: or, considering it as a compound of one atom of lead, and $1\frac{1}{2}$ atoms of oxygen, its equivalent is 14.5.

Of the Tests for Lead.

Lead may be precipitated from its solutions by sulphates, chromates, phosphates, and muriates; and its presence, in very small quantity, demonstrated by sulphuretted hydrogen.

203.—EXPERIMENTAL ILLUSTRATIONS.

Solution of lead in nitric acid. Its solutions precipitated by sulphates, muriates, phosphates, and chromates. Also by sulphuretted hydrogen. Precipitation of carbonate of lead, from the sub-acetate, by the carbonic acid of the breath. Galena decomposed by the blowpipe flame.

METALS OF THE FIFTH SECTION.

Metals of this section absorb oxygen at moderate temperatures, but do not retain it at a high degree of heat. They do not decompose water at any temperature.

Mercury and osmium, are the only metals comprised under this head.

OF MERCURY.

This well known metal, is found, in nature, in the metallic state, pure, and amalgamated with silver; also in the states of sulphuret and of chloride.

Means of obtaining Mercury.

It is obtained principally from the sulphuret, by distillation from iron filings, or lime, which detain the sulphur.

Of the Properties of Mercury.

It is the only metal which is fluid at the ordinary temperatures of the atmosphere. In colour and brilliancy, it resembles and rivals silver. Its specific gravity is 13.6 nearly.

At —39° F. it freezes into a malleable solid, and boils at about 660° of the same scale. It forms two oxides, two chlorides, and two sulphurets. The protoxide is black—the deutoxide, red. The black oxide may be made by mechanical agitation, without heat—the red, by long exposure to heat, the air having free access in both cases. The red oxide is usually obtained by expelling the acid from the nitrate by heat. When thus produced, it is said to retain some nitrogen. It is decomposed at the temperature at which mercury boils.

When nitric acid, whether cold or hot, is poured upon mercury, one portion of the acid is decomposed, imparting oxygen to the metal. The oxide, thus formed, is 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 deutoxide predominates. Usually, more or less of each oxide is formed. The crystals of the nitrate of the black oxide are white; those of the nitrate of the red oxide, yellowish.

No reaction arises from adding cold sulphuric acid to mercury; but when it is boiled on mercury, the phenomena are similar 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.

Each oxide of mercury forms three salts with nitric acid; a sub, a super, and neutral nitrate. The neutral nitrates of mercury, subjected to water, yield insoluble sub-nitrates, and soluble super-nitrates.

When washed with hot water, the sulphate of the deutoxide yields a yellow compound, which has been known under the name of turpeth mineral.*

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* Thenard informs us that this substance is a sub-sulphate, and that a very acid sulphate is dissolved by the water employed in producing it. Dr. Thomson alleges that turpeth mineral is a neutral sulphate, consisting of one atom of deutoxide and one atom of acid. He describes a bi-per-sulphate as consisting of one atom of deutoxide, and two atoms of acid. He does not explain the extrication of the turpeth by washing, nor state what compound the water takes up. The only way

With a solution of muriate of soda, the nitrate of the protoxide, gives a precipitate of proto-chloride of mercury.

Under the same circumstances, the nitrate of the deutoxide produces the bi-chloride, or corrosive sublimate, which remains 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 proto-chloride, the deutoxide, the deuto-chloride, or bi-chloride.

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 bi-sulphate of the deutoxide of mercury produces these results, when sublimed with certain compounds of chlorine, as common salt for instance. Corrosive sublimate is thus procured; and by trituration with mercury, a second sublimation, and washing in water, acidulated with muriatic acid, may be converted into calomel: or the bi-sulphate, triturated with a further portion of the metal, being converted into proto-sulphate; by sublimation with common salt, yields calomel directly.

Chlorine does not combine with mercury in the indirect mode, above mentioned, only. A jet of chlorine burns spontaneously in mercurial vapour, forming a bi-chloride. 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. In proportion as chlorine predominates, corrosive sublimate is formed; and, reversing the proportions, calomel.

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. With the muriates of ammonia, potash, soda, barytes, and magnesia, it forms very soluble compounds. These solutions, and those by ether and alcohol, undergo no change from light. A yellow hydrated deutoxide is produced, by solutions of the alkaline oxides with corrosive sublimate. This chloride has a most nauseous metallic taste, and is a virulent poison.

Calomel is also white and crystalline, but usually much more compact than corrosive sublimate. It is tasteless and insoluble, is blackened by alkalies, and presents a yellowish streak, when scratched.

Pure ammonia occasions a white precipitate from the solution of the deuto-chloride, called, in the pharmacopœias, hydrargyrum precipitatum album. This is now considered as a compound, of

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in which I can reconcile the phenomena, with the composition of the mercurial sulphates, as stated by him, is, by assuming that the dry mass, which yields the turpeth by washing, is a mixture of the bi-sulphate with neutral sulphate; and that the former is dissolved by the water, while the latter remains.

one atom of peroxide of mercury, with one atom of muriate of ammonia.

Heated together, mercury and iodine combine, forming either protiodide, or deutiodide, or both. Iodides are also produced from the nitrates, in the wet way, by the addition of the alkaline iodides in solution, as chlorides are, by addition of alkaline chlorides under like circumstances. The protiodide precipitates—the deutiodide does not.

The production of a bi-cyanide of mercury, by the union of this metal with cyanogen, has been noticed, under the head of hydrocyanic acid, page 185. This compound is also called prussiate or cyanuret of mercury.

The proto-sulphuret of mercury may be produced, by impregnating a dilute solution of the proto-nitrate, with sulphuretted hydrogen. This is a binary compound.

The bi-sulphuret is formed by the fusion of five or six parts of mercury, with one of sulphur, by weight, and subliming the compound in close vessels. This sulphuret is called artificial cinnabar; and when pulverized, is known under the name of vermillion. It does not differ essentially from native cinnabar, which is the most prolific ore of mercury. The bi-sulphuret may also be obtained, by pouring a solution of corrosive sublimate into an excess of hydro-sulphuret of ammonia.

Equal parts, by weight, of mercury and sulphur, triturated together, form Ethiops mineral, which is now considered as a compound of bi-sulphuret of mercury, and sulphur.

Cinnabar has been formed, also, by triturating the black sulphuret, with a solution of caustic potash.

Sulphuretted hydrogen deoxidizes the mercury, in mercurial salts, and precipitates it as a sulphuret. It is precipitated from its solution, in nitric acid, by borates, arsenites, arseniates, chromates, and phosphates. Albumen produces a precipitate with corrosive sublimate, and is considered both as a test, and as an antidote for it.

All metals combine with mercury, directly or indirectly. The 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 platina, and still more so with iron; owing, probably, to the great difference in fusibility.

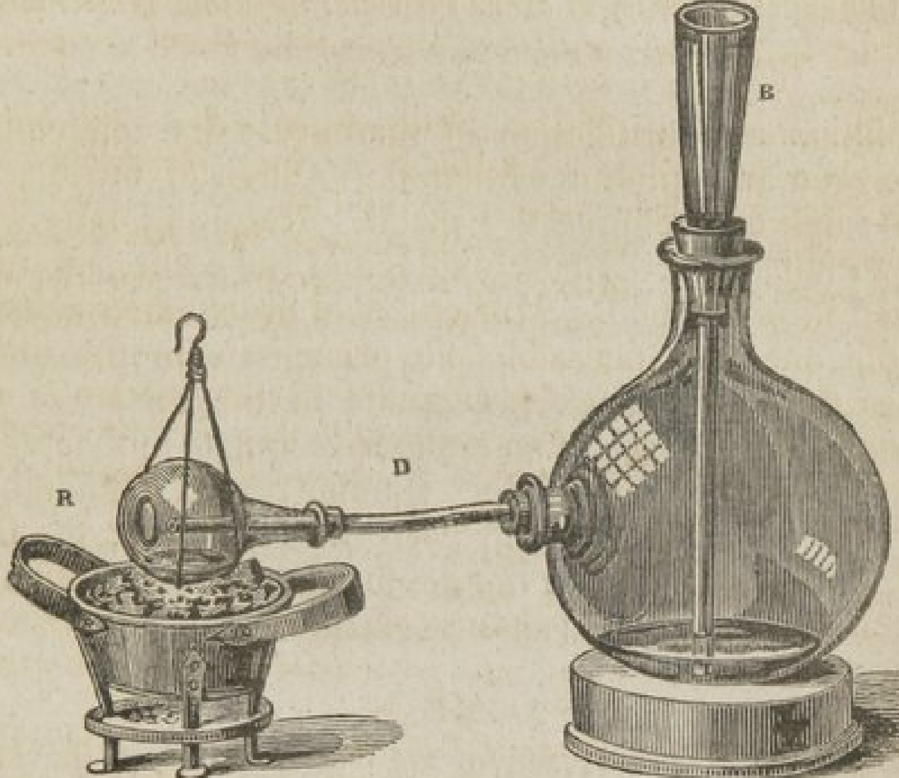
Mercurial compounds are all volatilizable by heat; and mercurial salts, when moistened and rubbed on copper, cover it with a film of mercury.

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 its compounds, with oxygen, chlorine, and sulphur, are as follows:—

Mercury,	- - - - equivalent to	25.
Protoxide,	1 atom mercury with 1 atom oxygen -	26.
Peroxide,	1 ,, ,, 2 atoms ,, -	27.
Proto-chloride,	1 ,, ,, 1 atom chlorine -	29.5
Per-chloride,	1 ,, ,, 2 atoms ,, -	34.
Proto-sulphuret,	1 ,, ,, 1 atom sulphur -	27.
Per-sulphuret,	1 ,, ,, 2 atoms ,, -	29.

204.—COMBUSTION OF CHLORINE WITH MERCURY.



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 liquid muriatic 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 duly supplied with salt and manganese, and a glass funnel with a cock, being fastened into the tubulure; as much diluted sulphuric 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.

205.—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. Muriatic 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 deutoxide. Similar results obtained, by adding them to calomel and corrosive sublimate; the first giving the black, the last the deutoxide. Inflammation of chlorine with mercurial vapour. Explosion of fulminating mercury.

OF OSMIUM.

Although mercury and osmium are treated of under the same head, in consequence of a coincidence in chemical properties, it would be impossible for two substances to be at greater extremes, as respects their utility in the arts, or the extent to which they have been objects of scientific investigation.

In the year 1803, osmium was discovered by Tennant, among the native grains of platina, alloyed with another metal called iridium.

We are told that osmium is a solid metal, of a grayish-black colour, which 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.

When heated to the temperature of about 144, it has the property, in common with platina, of inducing the combustion of hydrogen with oxygen.

OF THE METALS OF THE SIXTH SECTION.

The metals of this section are silver, gold, platina, palladium, rhodium, and iridium.

They are incapable of decomposing water; and at temperatures lower than those produced by the hydro-oxygen blowpipe, electricity, or galvanism, are not susceptible of oxidizement. Their oxides are, per se, easily reducible by heat.*

I shall so far pursue an order different from that adopted by Thenard, as to treat of silver, gold, and platina, before the other metals of this section.

OF SILVER.

Silver exists in nature, nearly pure, and likewise alloyed with gold, antimony, arsenic, or mercury. It is found also in the states of chloride, iodide, sulphuret, and carbonate; and in the ores of lead.

Means of obtaining Silver.

In consequence of its fusibility, and insusceptibility of oxidizement, it is easily disengaged by heat, and the oxygen of the air, from all other impurities, excepting metals of the same section, of which gold is alone likely to be united with it. The method of separating it from gold, will be mentioned subsequently.

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, when washed, yield pure silver by heat. The residual solution may be decomposed by copper, and the precipitate redissolved and crystallized by evaporation. 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 fusion to render it pure.

Properties of Silver.

Excepting steel, silver is susceptible of the highest degree of metallic brilliancy; 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 in 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 another. In fact, this acid is its proper solvent.

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* I deviate from the description of the metals of this section, given by Thenard, (see page 198) not only on account of the fact that I believe them to be oxidizeable by the means above mentioned, but also, because the more I have considered it, the less I have been satisfied with the employment of the word absorb, to convey an idea of the union of metals with oxygen, as presented to them in the gaseous state. It appears to me that absorption can be alleged to take place, only in cases where a fluid enters the interstices of a mass. An atom cannot absorb an atom, still less can it absorb a gaseous atom, since that atom ceases to be gaseous, at the moment the alleged absorption takes place.

I am aware, however, that these objections may be valid against the use of the word *absorb* in English, and yet not hold good against the French, *absorber*, which may have a meaning with which I am unacquainted.

Sulphuric acid has no reaction with silver, when cold. 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 unites with chlorine, when heated in it, or presented to it in solution. The chloride of silver is one of the most insoluble combinations. Hence silver is not soluble in nitro-muriatic acid, and hence soluble chlorides yield a precipitate, when solutions of this metal are added to them; for in any mixture, those substances will usually unite, which, when united, are the least soluble. Gravity, unbalanced by attraction for the solvent, aids in precipitating them.

Chloride of silver is soluble in liquid ammonia. It may be decomposed by hydrogen, if evolved in contact with it, 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 tin, or zinc, or 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.

Nitrate of silver, fused, forms lunar caustic. The fused chloride forms horn silver, or luna cornea.

Silver combines with iodine and sulphur. It forms several fulminating compounds.

The equivalent of silver is 13.75. It forms one oxide, and one chloride, of which the equivalents are of course 14.75, and 18.25.

A sub-oxide of silver is said to exist.

206.—EXPERIMENTAL ILLUSTRATIONS.

Oxidizement and solution of silver, in nitric acid, exemplified: also its precipitation by muriates, phosphates, chromates, arsenites, arseniates, copper, and mercury. Detonation of fulminating silver.

OF GOLD.

Means of obtaining Gold.

Gold is occasionally found in nature, nearly pure. It is not liable, like other metals, to be degraded by a union with oxygen or sulphur. The precipitate obtained from a solution of gold coin, in nitro-muriatic acid, by green sulphate of iron, is pure gold. This metal is also purified by exposure to heat and air, or 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.

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.

Gold fuses at a low white heat, but requires the temperature produced by the compound blowpipe, or galvanism, or the explosive power of electricity, to volatilize or oxidize it. Its not being liable to injury from exposure, is due to its weak affinity for oxygen or sulphur.

Respecting the oxides of gold, there is much obscurity. The purple powder, into which gold is dissipated by an electric discharge, is generally considered as an oxide; yet some chemists consider it as metallic gold in a state of minute division.

According to Berzelius, the protoxide may be obtained, by decomposing the proto-chloride by a solution of pure potash.

By Pelletier, we are informed, that the deutoxide is best procured by digesting the muriate of gold with magnesia, washing the precipitate with water, and removing the excess of the earth by pure nitric acid. This oxide is prone to unite with alkalies, rather than with acids. With ammonia it forms a compound, which has been called the aurate of ammonia, as the gold, in uniting with this alkali, is supposed to act as an acid. It is also called fulminating gold, because it explodes by friction or percussion.

Neither sulphuric, nor nitric acid, has any action on gold. With the oxides, they combine, but the compounds, thus formed, are not crystallizable.

It has been already stated, that 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 nitro-muriatic acid. The dissolved chloride, or muriate of gold, yields triple salts with the alkalies.

Sulphuretted hydrogen precipitates gold in the state of a sulphuret, which may be dissolved by liquid alkaline sulphurets.

When a solution of muriate of gold, is mixed with sulphuric ether, the ether takes the metal from the acid, and dissolves it. If iron or steel be moistened with this ethereal solution, 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. Muriate of tin, or tinfoil, furnishes a purple precipitate. Hence tin, especially in the state of muriate of the protoxide, or dissolved proto-chloride, is the best test for gold.

Gold combines with almost all the metals, and amalgamates eagerly with mercury.

The equivalent for gold is 25.

207.—EXPERIMENTAL ILLUSTRATIONS.

Gold dissolved by nitro-muriatic acid, and precipitated by sulphate of iron, or by muriate 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 CUPELLATION, QUARTATION, AND PARTING.

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 metals of the sixth class, should any be present, can remain upon the cupel in the metallic state. This stage of the process is indicated by the brightness of 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 metals of the sixth class 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 exposure to 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 nitro-muriatic acid, 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.

208.—EXPERIMENTAL ILLUSTRATIONS.

Exhibition of an assay furnace and muffle: also of a cupel. Fusion of silver, with lead, upon the cupel, by the compound blowpipe.

OF PLATINA, OR PLATINUM.

Means of obtaining Platina.

This metal, in the crude state, of its native grains, as it comes from South America, may be dissolved in nitro-muriatic acid. A solution of sal ammoniac being added, an orange coloured precipitate results, of ammoniacal muriate of platina. Ignition develops 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.

Properties of Platina.

The colour of this metal is intermediate between that of silver, and steel. Its specific gravity is 21.5. It is the heaviest body in nature, being about twice as heavy as lead, and nearly three times as heavy as iron. A cubic inch weighs nearly a pound. 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 very analogous to gold, being, like that metal, detected by muriate or proto-chloride 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. With mercury it amalgamates by trituration, when in a divided state, as obtained by igniting the ammoniacal muriate.

The equivalent of platina is 12. It forms two oxides, one containing one atom, the other two atoms, of oxygen. The latter, only, has been isolated.

The existence of an oxide, consisting of two atoms of metal, and three atoms of oxygen, has been rendered probable.

209.—EXPERIMENTAL ILLUSTRATIONS.

Platina exhibited, in the state of native grains, and in that of larger masses. Precipitated from its solution, by muriate of ammonia, and muriate of tin. A precipitate produced in salts of potash, by muriate of platina, distinguishes them from salts of soda. Combustion of platina with tinfoil.

OF PALLADIUM.

Besides osmium, of which I have already treated, three other metals are found, either in union with, or accompanying the native grains of platina.

When the assemblage of metallic particles, of which these grains, as found in commerce, usually form a part, is digested in nitro-muriatic acid, the platina, together with the palladium, rhodium, copper, and lead, is dissolved; while a black powder is left, consisting of osmium and iridium.

On adding to the solution thus obtained, a proper quantity of cyanide of mercury, dissolved in water, either before or after the precipitation of the platina, by muriate of ammonia, a cyanide of palladium precipitates, from which, metallic palladium may be liberated by a red heat.

Palladium resembles platina 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. It is soluble in nitric acid.

OF RHODIUM.

By immersing a thin plate of iron or zinc in the solution made of the crude grains of platina, as above described, after the greater part of the platina has been precipitated, rhodium, together with small portions of platina, copper, and lead, is thrown down. By means of nitric acid, the lead and copper being removed, the rhodium and platina are re-dissolved in nitro-muriatic acid, and the solution, with a due addition of muriate of soda, evaporated to dryness. Soda-muriates of platina and rhodium, are left. The former is removed by alcohol, in which the latter is insoluble. The residual salt, of rhodium, is then dissolved in water, and the metal precipitated by zinc.

Rhodium requires the strongest heats of the wind furnace, or forge, to fuse it. After fusion, it displays a metallic whiteness and lustre.*

Its salts are generally either red or yellow. It is named from its muriate, which is rose red.

OF IRIDIUM.

The black grains which remain after the reaction of nitro-muriatic acid, with crude platina, by being repeatedly ignited with soda, and afterward digested in muriatic acid, yield two solutions, one alkaline, the other acid. From the alkaline solution, when neutralized, oxide of osmium is obtained, by distillation. It passes over with the water, and remains dissolved in this liquid. By

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* The hue which we call white, in metals, is not strictly white, and is evidently peculiar to them. Hence I consider its existence as tending to demonstrate the presence of a metal, no less than the metallic lustre.

agitation with mercury, an amalgam is formed, which by heat, yields metallic osmium.

The acid solution, above mentioned, contains iridium; and being first heated to expel any excess of acid, and afterwards evaporated, affords crystals, from which, the metal may be obtained by exposure to the temperature of ignition.

Iridium is said to be the most infusible 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 THE COMPOUNDS FORMED BY ACIDS WITH METALLIC OXIDES.

The word salt is, by chemists in general, employed to designate the compound, formed by an acid, with an oxide. Agreeably to this acceptation, chloride of sodium, which is pre-eminently saline, and the parent of the idea of salt, is not a salt; while marble, alabaster, and the sulphates of barytes and strontites, which mankind, in general, consider as rocks, and stones, are all salts.

It does not appear to me correct, to give to an ordinary word a meaning so foreign to that which common sense, when uninfluenced by theory, would assign to it.

I have already endeavoured, page 152, to attach a chemical meaning to the word, consistent with established usage.

OF THE CHLORATES,

Or Salts formed by the union of Chloric Acid with Metallic Oxides.

Means of obtaining the Alkaline Chlorates.

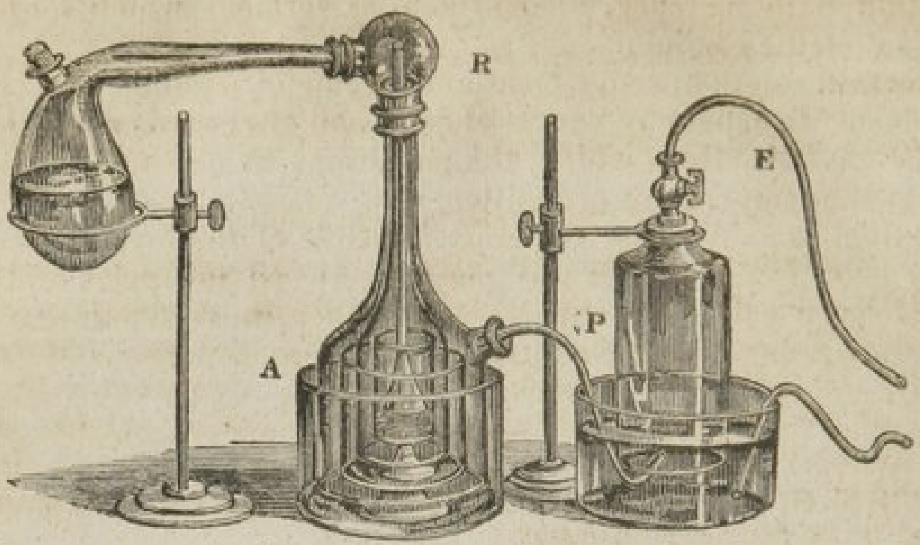
When chlorine is passed into an alkaline solution, water is decomposed. The hydrogen unites with one portion of chlorine, and, with a portion of alkali, forms a muriate; while the oxygen combines with another portion of the chlorine, and another portion of alkali, producing a chlorate.

The chlorate of potash is much less soluble than the muriate. Hence, when these salts are formed, their separation spontaneously ensues, the former precipitating in brilliant crystalline plates.

An apparatus which I use in this process, is described in the following article.

210.—APPARATUS FOR PROMOTING THE ABSORPTION OF SUBSTANCES FROM THE GASEOUS STATE.

The apparatus, which I am about to describe, was contrived by me at Williamsburg, in 1818. It obviates the necessity of having many junctures to make tight, every time the apparatus is put into operation, as in the case of Woulfe's bottles, and other apparatus for promoting the absorption, by liquids, of substances presented to them in the gaseous state.



After my apparatus has been once put together, there is no juncture to be made in order to employ it, excepting that of the retort with the neck of the receiver, R. The other junctures will serve for any length of time, during which, the glass may remain unbroken.

Suppose the three concentric jars, of which A is the outer one, to be supplied with the liquid to be impregnated, the bells and trumpet shaped tube being situated as the figure represents them; also that a cork has been perforated for the reception of the beak of the retort, and inserted into the mouth of the receiver, R. In order to put the apparatus in operation, it will then only be necessary to introduce into the retort the generating materials, fasten the beak into the mouth of the receiver, and apply heat, if requisite. On inspecting the figure, it will be sufficiently evident, that any gas, generated in the retort, must pass into the receiver. Having, in this, deposited any accompanying vapour, the gas must proceed by the trumpet shaped tube, until it reaches the liquid in the innermost jar. If it be not all absorbed, in this jar, it must escape through the liquid in it, and reach another portion of the liquid between the innermost jar and the next one. If not absorbed by this portion of the liquid, with a sufficient degree of rapidity, it must depress it, until its surface coincide with the narrow part of the stem, which supports the jar. Of course, the pressure and the surface, exposed for impregnation, will be very much increased. Should the supply of gas still exceed the absorption, the excess, after filling the inner bell glass, will escape to the next bell glass, and depress the liquid, in the outer jar, exactly in the same manner as described with respect to the intermediate jar. The degree, of this depression, will depend on the depth to which the recurved pipe, P, is sunk in the adjoining vessel; for as soon as the pressure within is sufficient to displace a column of water equal to that in this tube, an escape of the gas must take place from its orifice.

The bell glass, over the recurved tube, being previously filled with water, may be employed to catch the excess of gas, while by the syphon, the water descending from the bell is conveyed into another vessel, so as to be productive of no inconvenience.

By extending the pipe, E, proceeding from the top of the bell glass, any gas, which is not absorbed, may be conducted into a bladder, or under a large vessel, filled with water, and inverted over the pneumatic cistern.

The chlorate of potash may be obtained, by means of the apparatus above described, by introducing a solution of pearlash into the three jars, and supplying the retort with the materials for liberating chlorine. During this process, the carbonic acid liberated from one portion of the pearlash combines with another. Hence the chlorate of potash, in precipitating, is accompanied by the bi-carbonate, as well as other matters which may accidentally exist in union with the alkali. From the precipitate thus formed, pure crystals, of the chlorate, may be conveniently obtained, by means of the apparatus described in article 217.

The chlorates of barytes and strontites may be formed in the same way as the alkaline chlorates, the solutions of the earths being assisted during their impregnation by heat; but it is preferable to resort to the following process. To a concentrated solution of chlorate of potash, in hot water, add fluo-silicic acid, in a slight excess, and expose the mixture to the fire. The potash forms with the acid a fluo-silicate, which is chiefly precipitated. The liquor is then filtered, and the chloric acid saturated with the earth. By these means, all the fluo-silicate is precipitated. The solution being again filtered, crystals of the chlorate in question are procured.

From the chlorate of barytes, pure chloric acid may be obtained by precipitating the barytes, carefully by sulphuric acid.

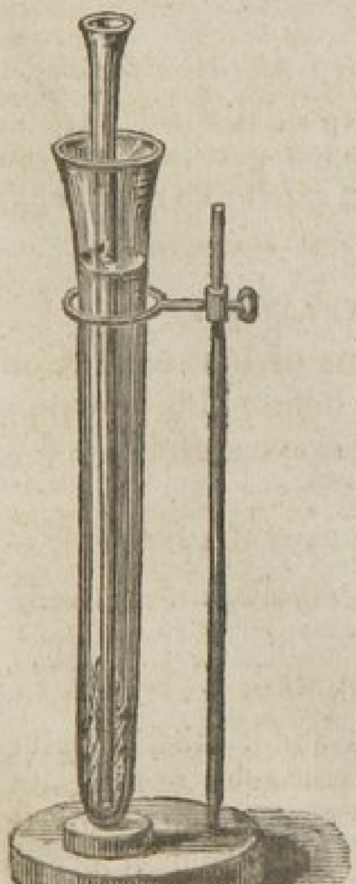
General Properties of the Chlorates.

The chlorates resemble the nitrates, in deflagrating with combustibles; but the residuum which they leave, is always a chloride, and the deflagration is more powerful, and more easily effected. If chlorate of potash be triturated, in contact with sulphur, or phosphorus, an explosion ensues. Salts, of this class, give up their oxygen, simply by being heated. They are almost all soluble in water. The chlorate, of the protoxide of mercury, is said to be sparingly soluble.

The chlorates are not of much use in the arts, but the facts ascertained, and the phenomena exhibited by means of them, are highly interesting. The properties of the chlorates are most conveniently illustrated by the chlorate of potash, to which, reference has been made in several instances in this compendium, 73, 114, 115.

Priming, for percussion gun locks, has been made by mingling the chlorate of potash with combustibles: in like manner, matches, to be ignited by sulphuric acid, have been contrived. For the former purpose, cyanate of mercury is preferable, see page 247.

211.—IGNITION OF PHOSPHORUS BY CHLORATE OF POTASH AND SULPHURIC ACID, UNDER WATER.



Let there be two tubes, one within another, as here represented; the larger one, closed at the lower end, and containing water; the other open at both ends; the upper orifice funnel-shaped, and the bore about one-eighth of an inch in diameter. Allow some very small pieces of phosphorus, and a few crystals of chlorate of potash to fall down to the bottom of the large tube. Then, into the smaller tube, pour some sulphuric acid; so that, without being much diluted, it may descend upon the chlorate and phosphorus. A vivid ignition ensues in despite of the water which surrounds the agents by which the fire is produced.

EXPLANATION.

The sulphuric acid, uniting with the potash of the chlorate, liberates peroxide of chlorine; which, coming into contact with the phosphorus, cause its combustion, although surrounded by water.

212.—EXPERIMENTAL ILLUSTRATIONS.

Ignition of phosphorus with chlorate of potash, by percussion. Explosion of sulphur, mixed with the chlorate, by trituration.

OF THE MURIATES OR SOLUBLE CHLORIDES.

For the composition and general character of the muriates, see pages 207, and 208.

OF THE NITRATES,

Or Salts consisting of Nitric Acid and Metallic Oxides.

This class of salts is distinguished by deflagrating with charcoal and other combustibles. When the combustible is acidifiable, it is always found afterwards in union with the potash. Thus, in the case of charcoal, a carbonate is left. In the case of sulphur, a sulphate. In the case of arsenic, an arseniate.

The nitrates, when dry, on being subjected to concentrated sulphuric acid, emit fumes of nitric acid. When added to muriatic acid, they enable it to act upon gold leaf.

213.—EXPERIMENTAL ILLUSTRATIONS.

Deflagration of a nitrate upon charcoal. A nitrate added to muriatic acid containing gold leaf. Decomposition of a nitrate by heat.

OF THE SULPHATES,

Or Salts formed by Sulphuric Acid with Metallic Oxides.

Their solutions all yield precipitates, with solutions of barytes. Heated in contact with charcoal, or hydrogen gas, they are converted into sulphurets, which, if moistened, smell like rotten eggs. They are almost all insoluble in alcohol.

214.—EXPERIMENTAL ILLUSTRATIONS.

Precipitation of sulphates by solutions of barytes. Conversion of a sulphate into a sulphuret, before the blowpipe, demonstrated by the subsequent effect upon metals.

OF HYDRO-SULPHURETS, OR HYDRO-SULPHATES,

Or compounds formed, by Sulphuretted Hydrogen, with Metallic Oxides.

Means of obtaining Hydro-Sulphurets.

They are obtained by saturating alkalies and earths, dissolved or suspended in water, with sulphuretted hydrogen.

For this purpose, Woulfe's apparatus, or that which forms the subject of the 140th illustration, or the more convenient process described under the head of sulphuretted hydrogen, 163, may be resorted to.

Of the Properties of the Hydro-Sulphurets of the Earths, and Alkalies.

The compounds produced by the union of sulphuretted hydrogen, with the earths and alkalies, are capable of forming solutions with water, which blacken the bottle, in which they are kept, if consisting of flint glass, by reviving the lead. They precipitate all solutions of metals proper; the acid solvent being attracted by the earth, or alkali, and the metal, and oxygen, by the sulphur and hydrogen. Hence arises the efficiency of the hydro-sulphurets, in detecting metallic poisons. Acids, generally, by combining with the alkali, or earth, are capable of disengaging the gas.

215.—EXPERIMENTAL ILLUSTRATIONS.

Hydro-sulphurets exhibited, and likewise their effects upon metallic solutions.

OF SULPHURETTED HYDRO-SULPHURETS.

They are said to exist always in solutions of sulphurets, and differ from simple hydro-sulphurets, only, in containing a double proportion of sulphur.

OF THE PHOSPHATES,

Or Compounds of Phosphoric Acid with Metallic Oxides.

Generic Character of the Phosphates.

The phosphates all give precipitates, with solutions of barytes, lime, lead, and silver. The precipitate with silver is yellow, and resembles that produced by the same metal with arsenious acid; yet the colour of the arsenite is deeper.

The phosphates are not decomposable by heat alone. The phosphates of the metals proper, may be decomposed by heat and charcoal; those of the earths and alkalies are susceptible only of a partial decomposition, by these means. The phosphates are all fusible, and excepting those of potash, soda, and ammonia, are nearly insoluble in water. They are soluble, generally, in nitric, muriatic, and acetic acids.

OF THE NITRITES AND HYPO-NITRITES, SULPHITES, HYPO-SULPHITES, AND HYPO-SULPHATES, PHOSPHITES AND HYPO-PHOSPHITES.

The composition of these salts must be evident from their names.

The nitrites, and sulphites, produce the well known fumes of their respective acids, by the affusion of sulphuric acid. The phosphites, thrown upon incandescent coals, produce a yellow flame. The hypo-sulphites evolve fumes of sulphurous acid, and yield sulphur by the same means. As the hypo-sulphates are produced only by peculiar management, it would be useless to burden the memory with details respecting the means of detecting them.

OF THE CARBONATES,

Or Compounds of Carbonic Acid with Metallic Oxides.

Generic Character of the Carbonates.

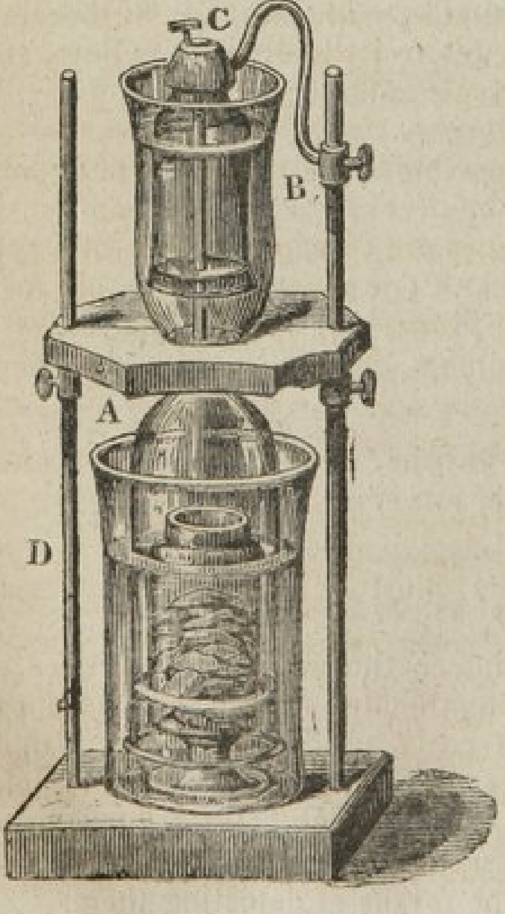
This class of salts is distinguished, by being susceptible of decomposition, with effervescence, by any of the liquid acids, excepting a few that are remarkably feeble; as, for instance, the hydrocyanic and the meconic.

All the alkaline carbonates are decomposable by heat, excepting those of potassium, sodium, barium, and, probably, that of lithium.

Each of the alkalies, potash, soda, and ammonia, forms with carbonic acid, three compounds, a *carbonate*, in which the ratio of alkali to acid is that of equality; a *bi-carbonate*, in which the ratio of alkali to acid is as one to two; and a *sesqui-carbonate*, in which it is as two to three. When saturated with it, they are more susceptible of crystallization, and are less nauseous to the taste.

The evolution of the acid, from the carbonates of lime, and ammonia, has been already exhibited. Its extrication from one alkali, and its absorption by another, may be effected by means of the apparatus described in the following article.

216.—APPARATUS FOR REGULATING THE SUPPLY OF A GAS, BY ITS ABSORPTION, AND BY MEANS OF WHICH, THE CARBONIC ACID MAY BE CONVENIENTLY TRANSFERRED FROM ONE CARBONATE, TO ANOTHER.



Two open-necked bell glasses, A, B, are joined neck to neck, so as to be inverted as respects each other. From the cavity of the lower one, a pipe leads up through the axis of the upper one. The lower bell, which is the largest, is situated within a large cylindrical vessel of glass, D, so as to include a jar, with a perforated stem or pedestal. Over the opening, in the pedestal, some irregular fragments of glass are laid, so as to furnish support to some carbonate of ammonia, subsequently introduced into the jar. Suppose the upper bell, B, to be supplied with a solution of pearlash, and another smaller bell glass, C, placed within it, so as to include the pipe proceeding from the bell, A, below. If, while the apparatus is thus situated, diluted nitric acid be poured into the cylindrical glass vessel, D, it will rise into the jar containing the carbonate, and cause it to give out carbonic acid gas. This gas will, at the same time, press with equal force upon the surface of the acid in the glass cylinder below, and upon that of the alkaline solution in the upper bell.

If the atmospheric air of the vessels be allowed first to escape by a hole at C, furnished with a screw, by means of which it may be closed or opened, so that the carbonic acid may reach the alkaline solution undiluted with air, it will of course be gradually absorbed, generating bi-carbonate of potash. Should the absorption thus arising, be too slow to take up the carbonic acid as fast as it is evolved by the reaction between the acid and the carbonate, the alkaline solution will be depressed within the bell glass, C. At the same time the pressure within the larger bell glass increasing proportionally, the height to which the acid reaches in the jar is diminished, and of course the reaction with the carbonate lessened, until the quantity of carbonic acid evolved by it, be commensurate with the absorption, by the solution in the upper part of the apparatus. Should the solution in the upper bell become saturated the depression of this solution, and consequently that of the acid, within the lower bell, must go so far, as that the acid no longer reaching any portion of the carbonate, the evolution of gas from it must cease.

OF THE HYDRO-CYANATES, CYANATES, BORATES, FLUATES, AND FLUO-BORATES.

Among these compounds, there are few which I deem it expedient to notice. The ferro-cyanate of potash, and the bi-borate of soda, have been adverted to in pages 185 and 189, and the former, as a test for iron or copper, pages 214, 220.

The fluate of ammonia is an excellent test for lime, as it produces an insoluble precipitate of fluoride of calcium, when added to solutions of the earth.

The cyanate (or fulminate) of mercury, has been lately employed as a priming in percussion gun locks, and is, I think, preferable to the powder made by mingling chlorate of potash with combustibles.

The fulminating power of this compound, has already been exhibited, 6. It is usually called fulminating mercury.

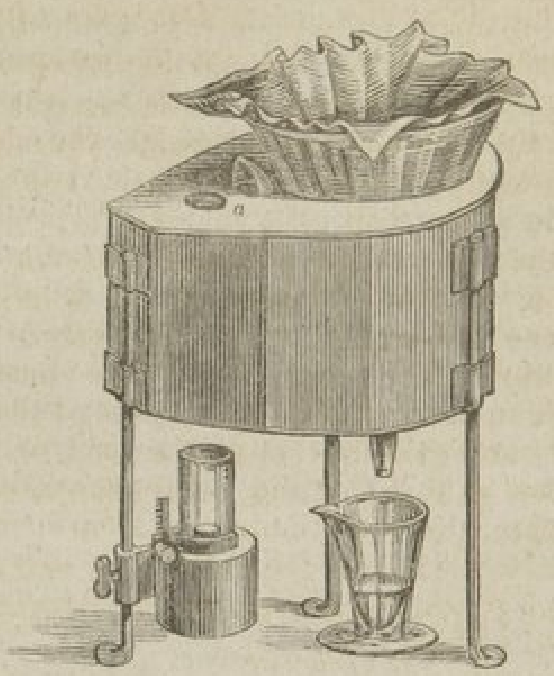
Means of obtaining Fulminating Mercury.

This compound may be obtained by the following process. Dissolve 100 grains of mercury with heat in a measured ounce and a half of nitric acid, of moderate strength; when cold, mix the solution with a measured ounce and a half of alcohol; apply heat till an effervescence takes place. When red fumes appear, check the action with water. The powder which precipitates, well washed with water, and afterwards dried at a gentle heat, will be the cyanate of mercury.

In giving an account of the production of bi-cyanide of mercury, I omitted to notice an apparatus by which that process is facilitated, as well as many others in which crystals are to be obtained by refrigeration.

I subjoin an engraving and description of the apparatus in question.

217.—FILTRATION FACILITATED BY HEAT.



In the case of solutions, which, being saturated at a boiling heat, are capable of yielding crystals on cooling; in order to remove feculent matter, it is often important to resort to filtration. Yet as, by the premises, such liquids yield crystals by refrigeration, unless they be kept hot, while on the filter, it soon becomes choked by crystalline particles. In order to preserve, under such circumstances, a proper temperature, I contrived the apparatus represented by this figure.

It consists of a case of tinned iron, which, on the side where it has the larger diameter, surrounds a cone of the same materials, shaped like the body of a common funnel. Towards the other side of the case, where it has the smallest diameter, a smaller and sharper cone is included, the position of which is the inverse of that first mentioned; so that the apex of the larger one, terminates below the bottom of the case, while that of the smaller rises through the top at *a*.

The cones are soldered into the case, so as to make with it water tight junctures, and so that they may be surrounded by any liquid which the case may contain. Supposing the case to be filled with boiling water, by means of an aperture left for that purpose, and that a lamp be placed under the little chimney formed by the smaller cone, it must be obvious that the temperature of ebullition may be supported in the water of the case, and in the larger cone of tinned iron which it surrounds. Consequently, if, within the latter, a glass funnel, containing a filtering paper, be placed, the temperature of any boiling liquid poured upon the filter, will be preserved with little diminution, until it passes through the filter, and falls into the vessel placed below to receive it.

In order to obtain prussiate, or bi-cyanide, of mercury, red precipitate is boiled in water with Prussian blue. The resulting solution contains the desired compound, and if passed through a filter surrounded by the heated cone as above described, yields, on cooling, cream coloured crystals, each in the form of a four-sided prism.

In separating the chlorate, from muriate of potash, this contrivance is very useful. It has been mentioned that these salts, as precipitated from the solution of pearlash, by the chlorine which produces them, are usually more or less contaminated by foreign matter. If, under these circumstances, a saturated solution of the mixed precipitate be made in boiling water, as soon as it passes the filter, the chlorate separates in crystalline plates of a silvery whiteness, which, during their subsidence, are beautifully iridescent. The principal difficulty in this operation, is to sustain the temperature of the solution till the liquid is filtered. This difficulty is obviated by the contrivance above represented and described.

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OF THE COMPOUNDS OF CHLORINE, WITH METALLIC OXIDES.

It may be proper, at this time, to notice another class of compounds produced by the reaction of chlorine with the alkalies, and earths, which are highly useful in bleaching, and as the means of disinfecting air.

It has been mentioned, page 207, that chlorine combines with potassium, sodium, barium, strontium, and magnesium, so that when their oxides are heated in the gas, oxygen is displaced, and chlorides are formed. Yet during the formation of the chlorates, in the process above described, a union takes place between a portion of the alkali and chlorine; so that a chloride is formed, not with the metal, but with the oxide; being, in the case of potash, a chloride of potash.

Hence the mother waters, of the chlorate of that alkali, has eminently the power of bleaching, which is not possessed by a solution of chlorate of potash.

A compound of chlorine with lime, analogous to the chloride of potash, constitutes the powder which is now the principal mean, of effecting the bleaching process.

The earth, in the state of pulverized hydrate, to which it is reduced by slaking, is exposed to chlorine without any farther intervention of water. The chlorine unites with the oxide of calcium, forming a triple compound.

The simultaneous presence of chlorine and oxygen, appears reciprocally to lessen their affinities for the calcium. Hence when colouring matter, or the matter of putrid exhalations, is presented to the chloride of lime, a reciprocal decomposition ensues. When carbonic acid is a component part of an effluvium, it unites with the lime, the chlorine at the same time combining with the hydrogen, which is the principal aëriform ingredient in all offensive effluvia.

Dr. Thomson considers the compound, obtained by saturating hydrate of lime with chlorine, as a di-chloride of lime, which implies that it consists of two atoms of oxide of calcium, and one of chlorine. He informs us, that when muriate of ammonia is introduced into a retort, containing di-chloride of lime made into a paste with water, gaseous nitrogen is evolved, with an "action so violent," that unless retarded by wrapping the muriate in blotting paper, it would be difficult to collect the whole of the gas.

The explanation of this result is evident. The lime and muriatic acid combine, liberating ammonia, and chlorine, in contact with each other. Consequently, the hydrogen of the ammonia unites with the chlorine, and the nitrogen is disengaged.

It would seem as if this were the most convenient process for procuring pure nitrogen.

EXPERIMENTAL ILLUSTRATIONS.

Production of di-chloride of lime. Its effects upon colouring matter. Evolution of nitrogen from muriate of ammonia.

[251]

ON 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. Ultimate analysis demonstrates between these, a difference, chiefly in the proportions of the hydrogen, oxygen, carbon, or nitrogen, of which they are constituted; while in their influence on vitality, they 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, analysed 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 alleged elements.

Those who have any acquaintance with modern chemistry, will not be so skeptical. When diamond is burned in one bell glass, and charcoal in another, in different portions of the same oxygen gas, and in lieu of the diamond and charcoal, carbonic acid gas is found in each vessel, who would hesitate to admit both substances to consist of carbon, because this element cannot be recovered in its crystalline form?

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 pyrolignous (acetic) acids: also carbonic oxide, with bituminous matter or essential oils, formed by the union of the hydrogen and carbon in different proportions, and which are more volatile in proportion as hydrogen predominates. By further ignition, the oils and bitumen, thus obtained, are converted into carburetted hydrogen—a deposition of carbon, being a necessary concomitant of the change. In proportion to the extent to which the hydrogen is rarefied by heat, its capacity to suspend the carbon is diminished.

When treating of carbon, page 180, I pointed out that while the hydrogen and nitrogen, cannot be obtained, per se, uncombined with caloric, charcoal can only, by the most intense galvanic ignition, be united with it to a sufficient degree to become aëriform.

The oxygen in the compound, by uniting with the hydrogen and carbon, gives rise to the water, and acetic and carbonic acids, and carbonic oxide.

It is evident that these results originate, from the superior volatility of the hydrogen and oxygen, which causes them to pass off into the aëriform state, with such portions of the carbon as they may, under these circumstances, retain.

The experiments of Sir James Hall, show that vegetable matter, subjected to great compression, as well as to heat, is converted into a bitumen, analogous to that of mineral coal.

Under these circumstances, the heat destroys the organic structure, but does not sever the constituents of many bodies, which would be otherwise partially dissipated. Exposed to heat, in the open 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.

The ratio of the quantity of water, carbonic acid, and other incombustibles, (afforded by a destructive distillation) to the inflammable matter, varies with the nature of the substance subjected to the process. Hence the employment of bituminous coal or oil, to evolve gas for the purpose of illumination, since these substances yield much carburetted hydrogen, and but little acid or water.

Of the Effects, upon Vegetable Matter, of Chlorine and Iodine, also of the Metalloids, and some of the more powerful Acids.

Chlorine and iodine act upon vegetable matter, from their affinity to one of its elements only; for carbon, they have little affinity—and exerting but a feeble attraction for oxygen, under any 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.

Iodine unites with starch without decomposing it, producing a deep blue.

The metals of the alkalies destroy vegetable matter, containing oxygen as an essential constituent, by combining with this principle, and liberating hydrogen. Fluoric, fluo-boric, and sulphuric acids, 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.

Muriatic 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 produces malic acid, first, and 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 oxide of the nitrate detains the acid, until the heat is adequate to produce a powerful reaction.

Vegetable Products incapable of existing in the Gaseous State.

It does not appear that any vegetable matter is capable of existing as a permanent gas. The volatility of scented or aromatic emanations, is, no doubt, like that of camphor or turpentine, due to a solution of the matter of these emanations, in atmospheric air.

Of the Influence of the Proportions of the Ultimate Elements upon the Qualities of the Substances which they constitute.

It is suggested by 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 (as is usual) 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 matter. To this, it may be added, that alkalinity, in vegetable principles, seems to require the presence of nitrogen.

OF VEGETABLE PRODUCTS,

Which are neither Acid, Alkaline, Oily, Resinous, nor Active.

OF EXTRACT.

In Henry's Chemistry, and other compilations, a substance is mentioned, under the name of extract; an appellation too vague to be given to any peculiar principle. It does not appear that any substance, bearing this appellation, has been well designated. By some chemists, the residuum, of an evaporated infusion of saffron, is considered as a specimen of extract.

OF GUM OR MUCILAGE.

The obvious properties of gum must be familiar to every body, as observed in the infusions of linseed, or gum arabic in water.

In this state it is called mucilage. Solubility in water, with insolubility in alcohol, is an essential characteristic of gum. In ether, it is also insoluble. It is neither sweet nor sour. By nitric acid, it is partially converted into mucic or saccolactic acid.

Gum is separated from water, in a thick curdy precipitate, by sub-acetate of lead; also by solutions of the peroxide of iron and mercury.

It causes the oxides of antimony and bismuth to remain in solution, when otherwise they would be precipitated by water, as subsalts.

Cerasin is an appellation given to a species of gum obtained from the cherry tree, or from the astragalus tragacantha. Of this species, gum tragacanth is a fair specimen.

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.

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, which is the uncrystallizable syrup of the sugar cane.

Thenard assumes that all substances are sugar, which are capable of the vinous fermentation. In this, it is evident that he errs. The greater part of the whiskey made in this country, is produced by the fermentation of unmalted grain, which consists principally of starch and gluten. The production of alcohol, from the potato, is a fact still more unfavourable to Thenard's definition of sugar, as that root consists chiefly of starch and water, with a very minute proportion of sugar, if any. 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 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. Sugar decomposes some metallic salts, reviving the metal, by abstracting the whole of the oxygen and acid, as in the instances of the muriate of gold, the nitrates of silver and mercury, and of the sulphate of copper. In others, it acts by removing a portion of the oxygen, only, as in the case of the acetate of the metal last mentioned. With protoxide of lead it forms an insoluble compound.

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—a violet, with still less, and remains colourless when the iodine is at a minimum.

It does not combine with cold water, but forms a viscid solution with hot water. It is acted upon, neither by alcohol nor ether. Boiled with diluted sulphuric acid, for about 36 hours, it 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, heated with it, yields malic or 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.

OF AMYDINE, OR AMYLINE.

According to Mr. Caventon. On exposing dry starch to a temperature a little above 212, it 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 starch; 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 amidine, supposing it to be generated, during the process above described, in which he obtained sugar. The blue colour produced by iodine, with starch, Mr. Caventon considers as the characteristic effect of amydine.

When starch is exposed to a temperature higher than is necessary to convert it into amidine, 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.

COMPOSITION OF GUM, SUGAR, AND STARCH.

The proportions in which hydrogen, oxygen, and carbon, exist in gum, starch, and sugar, 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 element.

In sugar, there is a small excess of carbon.

The composition of starch differs but little from that of gum or sugar.

OF GLUTEN.

The substance left, after washing away the starch from wheat flour, is called gluten. It is to destroy the gluten, that fermentation is required in the manufacture of starch.

Gluten is distinguished by its approaching more to the nature of animal matter, than other products of vegetation. Like animal substances, it yields ammonia by distillation, and of course contains nitrogen. It is to the presence of gluten in wheat flour, that its pre-eminence, in nutritive power, is attributed. By trituration with alcohol, it is capable of forming a kind of varnish.

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 gas. 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 in the oven, causes innumerable cavities, resembling those produced in the ordinary process of panification.

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 adds to the lightness of the bread, by its vaporization.

M. Taddei, an Italian chemist, has ascertained that gluten, when subjected to alcohol, is separated into two principles—one, soluble in that fluid, which he calls gliadine—the other insoluble, which he calls zimome.

It is alleged that zimome produces a fine blue colour, with gumguiacum, so as to be a test of its presence. This property is represented as deriving additional importance from the fact, that zimome always exists in good flour, while bad flour is more or less deficient of it.

OF CAOUTCHOUC.

Caoutchouc, or elastic gum, is a very singular substance—not only from its extraordinary mechanical properties, but from its insolubility, both in water and alcohol, and remaining untouched even by acids, unless aided by heat. Ether, and the volatile oils, dissolve it slowly. The oil of cajeput, is said to be its best solvent. Turpentine, repeatedly rectified, dissolves it, and forms, with it, an elastic varnish.

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.

It yields ammonia by distillation, and of course contains nitrogen. It becomes warm, when suddenly extended.

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 abovementioned, 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.

OF 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, is called tannin.

Tan, or tannin, abounds in the barks used by tanners. It predominates in nut-galls, combined with gallic acid; from which however, no satisfactory method of liberating it has been devised. It may be precipitated by muriate of tin, the alkalies, and lime water; but not pure. It is said to constitute one-half of terra japonica, or catechu; and is still purer in extract of rhatania.

Tannin is formed, artificially, by the action of nitric, and sulphuric acids, on various substances. The tests of its presence, are muriate of tin, or animal glue. In the one case, the oxide, in the other, the glue, forms with it an insoluble compound, which precipitates. See gallic acid, page 264.

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 VEGETABLE SUBSTANCES OF MINOR IMPORTANCE.

Besides the peculiar vegetable principles of which I have treated, there are others of a minor degree of importance—as, for instance:—Asparagin, from asparagus—Ulmin, from the elm—Inulin, from elecampane—Fungin, from mushrooms—Polycroite, from saffron—Hematin, from logwood—Medulin, from the pith of the sun-flower—Olivile, from the olive tree: also sarcocoll, which resembles gum in forming a mucilage with water, and yet is soluble in alcohol.

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, poppy seed, and rape seed. Being procured by expression, they contain mucilage. To the presence of this, Henry attributes their liability to become rancid. 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. They 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 compounds which they form with the fixed alkalies are well known, and pre-eminently useful. With soda, they 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 oil, 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, flax; and recently, inflammation has been discovered to arise from their admixture with ashes.

I stated above, that every fixed oil appears 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. Each of these, in the process of saponification, gives rise to an acid (the margaric or oleic) which, combining with the alkali, constitutes soap. The acid produced by stearin, is called margaric; that formed by elain, oleic. Another matter is at the same time liberated in small quantity, called the sweet principle of oils.

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 alleged by Huber, that bees who have access to nothing but sugar, can produce wax.

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.

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 any surface on which they may be dropped 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.

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.

Henry suggests that this absorption of oxygen accounts for the unhealthfulness of newly painted rooms. At this remark I am surprised, as the breathing of one person would consume more oxygen, than the paint of any common room.

It seems to me more rational to suppose, that the vapour which, by its escape, causes the hardening of the paint, carries off a portion of some matter which the paint contains. 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. Muriatic and other acids also dissolve this substance. Sulphuric acid and camphor, reciprocally decompose each other.

OF ARTIFICIAL CAMPHOR.

If 100 parts of oil of turpentine, refrigerated by snow and salt, be saturated with muriatic 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 is 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. It seems to be a combination of the acid gas with the volatile oil.

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.

OF RESINS.

According to 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, in 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.

219.—EXPERIMENTAL ILLUSTRATIONS.

A solution of gum precipitated by alcohol; a solution of resin by water.

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 aëriform state.

It has been suggested that the diamond is a product of vegetation, or the decomposition of vegetable matter.

Bitumen is, in its qualities, intermediate, between the extremes, being separable, by distillation, into a volatile oil and coal.

Petroleum is more fluid, lighter, and more inflammable than bitumen.

Amber is a singular fossil, which is supposed to owe its origin to vegetable matter. It is distinguished by burning with a peculiar odour, yielding succinic acid by sublimation; and by insolubility both in water and in alcohol. It resembles copal in its appearance, and in its properties.

The decomposition of the bituminous matter, in mineral coal, by ignition, yields carburetted hydrogen—as in the gas-light process.

OF VEGETABLE ACIDS.

There are about thirty vegetable acids, of which fifteen are the products, solely, of vegetation. Ten are produced both by nature and art. Five are, solely, the products of art, and therefore cannot be properly considered as vegetable elements.

The acids which are produced only by vegetation, are the benzoic, citric, fungic, gallic, igasuric, kinic, laccic, meconic, mellitic, moric, pectic, succinic, sulfo-synapic, and perhaps the tartaric, and the acid of the strychnos pseudo-kina.

The acids, produced both by nature and art, are the acetic, malic, margaric, oleic, and oxalic.

The acids which are produced by art, only, are the camphoric, ellagic, lampic, nanscic, pyro-citric, pyro-malic, pyro-mucic, pyro-tartaric, and suberic.

I deem it expedient to notice, particularly, but a few of the acids which have been enumerated. Of the acetic acid, I shall treat under the head of fermentation.

Composition of the Vegetable Acids.

From the observations which were made, page 253, respecting the influence of the proportions of the ultimate elements, upon the properties of vegetable substances, it may be inferred, that in the vegetable acids, oxygen must exist, generally, in a greater proportion than in water. Besides oxygen, usually in excess, these acids all contain carbon and hydrogen, with the exception of oxalic acid, which is composed of carbon and oxygen only, and in such proportion, that it may be deemed a binary compound of carbonic oxide and carbonic acid.

Döberiener has ascertained, that, when heated with concentrated sulphuric acid, oxalic acid is converted into carbonic oxide, and carbonic acid; and Mr. Dumas recommends this process for procuring pure carbonic oxide, as the carbonic acid may be removed by potash, or lime.

OF MALIC AND OXALIC ACIDS.

Subjected to the action of strong nitric acid, sugar yields either malic acid, or oxalic acid, according to the quantity of acid employed, and the duration of the exposure.

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.

Oxalic acid derives its name from the oxalis acetosella. It is crystallizable, is not very soluble, and takes lime from all its combinations.

This acid combines with potash in three proportions—the quantity of acid being as 1, 2, and 4. Hence the appellations, oxalate, binoxalate, and quadroxalate.

The salt of sorrel is a binoxalate, consisting of one atom of potash, with two atoms of oxalic acid.

Oxalic acid is a poison. Magnesia, or bi-carbonated alkalies, are the best antidotes. In default of the bi-carbonates, a solution of pearlash, or an infusion of wood-ashes, or even a solution of soap, should be ventured.

220.—EXPERIMENTAL ILLUSTRATIONS.

Solutions of lime precipitated by oxalic acid. Crystallized acid exhibited.

OF CITRIC ACID.

The name of citric acid discloses its origin. It exists in the lime and lemon, in union with mucilage and malic acid. This combination 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.

OF TARTARIC ACID.

The tartaric acid is found in many vegetables. In the tamarind it predominates, and on the berries of the sumach it forms an exudation. It is named from tartar, an appellation given to a deposition from wine, which contains the bi-tartrate of potash. This bi-tartrate, when freed from impurities, is sold in the shops under the name of cream of tartar. When, to 24 parts of this salt, 13 of carbonate of soda are added, Sal Rochelle is produced; and, in like manner, emetic tartar, 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.

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 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 precipitate by chalk.

OF GALLIC ACID, OR ACID OF THE GALL NUT.

Gallic acid may be obtained, in crystals, from an aqueous infusion of galls, after exposure to the air, during one or two months. Pounded galls yield it by sublimation.

An infusion of galls contains the tanning principle, called tannin and gallic acid. Muriate of tin precipitates the tannin—a portion of the oxide remaining united to the acid. This oxide may be

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* See Antimony, 221.

precipitated by sulphuretted hydrogen, and the gallic acid crystallized by evaporation.

Fresh precipitated alumine will also take the tannin from a solution of galls, which, being afterwards evaporated, will yield the acid in crystals.

There is some obscurity and contradiction with respect to the properties of this acid. Henry informs us that it precipitates most of the metals proper; also the aqueous solutions of lime, barytes, and strontites, and the acid solutions of glucina, yttria, and zirconia. Thenard alleges that among all the salts, only those of the peroxide of iron are decomposed by pure gallic acid, and that it must be united to tannin, in order to display the powers ascribed to it by Henry.

The colouring matter of ink is a triple compound of tannin, gallic acid, and peroxide of iron.

221.—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.

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 muriatic 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.

222.—EXPERIMENTAL ILLUSTRATIONS.

Iron precipitated by succinic, and benzoic acid.
Crystals of benzoic acid exhibited.

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 sulphuretted hydrogen, the lead precipitates as a sulphuret. From this, a clear solution, containing an acid, called meconic acid, may be separated by filtration. This acid exists in opium combined with a vegetable alkali, to which the efficacy of the drug is mainly ascribed.

With solutions of peroxidized 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.

OF A METHOD OF DETECTING THE PRESENCE OF OPIUM.

The property which the 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 persulphate of iron, and a like quantity of sulphuric acid, should be introduced among them by means of a small glass tube. The presence of the meconic acid will then be rendered evident by the redness which ensues.

When a red colour is produced, by the means here described, it must be almost certain 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.

OF THE PHOSPHORIC AND PRUSSIC ACIDS.

Phosphoric and prussic acids, being naturally classed with the compounds of phosphorus, or cyanogen, are not enumerated among vegetable acids; yet so far as they are produced by vegetation, it may be proper to treat of them under the head of vegetable chemistry.

It appears that phosphoric acid minutely pervades most vegetable substances, especially the coverings of seeds.

The prussic acid has been detected in water distilled from bitter almonds, or from laurel leaves, or peach leaves and blossoms. Between the odour of these, and that of the acid, when dilute, it would be impossible 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. A small quantity having been given by mistake to one of my children, was productive of unpleasant symptoms. The consequences might have been much more distressing, had not vomiting mitigated the evil.

Some peach leaf water, prepared by Mr. Wetherill, gave, in my presence, indications of prussic 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.

223.—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 per-sulphate of iron.

OF KINIC ACID.

Kinic acid exists in Peruvian bark in union with quinia and cinchonia, the vegetable alkalies to which the active medicinal 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 elaborated.

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, asafœtida, euphorbium, galbanum, gamboge, myrrh, scammony and guaiacum, 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.

OF THE NEWLY DISCOVERED 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.

Thenard enumerates eight vegetable alkalies, the existence of which he considers as well established:—"morphine, strychnine, brucine, cinchonine, quinine, delphine, veratrine, and emetine." He mentions nine, of which the pretensions to the alkaline character are undecided. These are, "picrotoxine, solanine, cafeine, atropine, daphnine, hyoscyamine, daturine, aconitine, cicutine." It seems now to be conceded that "cafeine" is not an alkali. To the names of the alkalies above enumerated, real, or supposed, the English chemists affix the letter *a*, in place of the last letter, *e*, or syllable, *ne*. In treating of them I shall give both names, using the English name chiefly.

These 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 the meconic acid—cinchonia and quinia with the kinic acid—delphia, with the malic acid—veratria with the 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. Sulphuretted hydrogen is afterwards used to remove any excess of the metal. Generally, these 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 the 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.

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 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 solution resulting 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—Two grains are said to be sufficient to destroy a large dog.

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 muriatic acid, very much diluted, a considerable quantity of green fatty matter was separated. This separation is imperfectly accomplished, if the acid be strong.

The muriatic solution was of a golden yellow. 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 quinquina, (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.

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, 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 sulphuretted hydrogen, 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 SUBSTANCES ALLEGED, BUT NOT PROVED TO BE ALKALIES.

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 dissolves 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 ACONITINE.

From the aconitum napellus, or wolfsbane, the active principle has been extracted. It is supposed to be an alkali.

OF SOLANIA, OR SOLANINE.

This name has been given to a substance alleged to be an alkali, lately discovered 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 hot dissolves only a small proportion. 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 first, afterwards sleep.

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 liquid resulting 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.

Atropia, hyoscyama, and aconita, are so poisonous, that their discoverer, M. Brandes, found it impracticable to prosecute his inquiries respecting them, as far as desirable, from their injurious influence on his health.

OF DATURIA OR DATURINE.

This is the appellation given by M. Brandes, to an alkaline principle, which, he alleges, he has extracted from the seeds of the datura stramonium. His process is not described in any of the new publications which I have seen.

OF HYOSCYAMA, OR HYOSCYMINE.

To an alkali 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.

General Chemical Character 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 either nearly or 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.

Means of discriminating between the 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, proto-muriate 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 the 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 emetine 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.

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.

OF ACTIVE VEGETABLE PRINCIPLES, WHICH ARE NEITHER OILY, RESINOUS, ACID, NOR ALKALINE.

OF NARCOTIN.

In order to obtain narcotin, 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 narcotin will appear in slender prismatic crystals. To remove all the narcotin, opium must be subjected to successive portions of ether.

OF CAFFEIN.

Little is stated respecting this principle, although an object of great interest, from the universal consumption of the article from which it is obtained.

Caffein was discovered in coffee by Robiquet in the year 1821, and was soon after obtained, from the same source, by Pelletier and Caventou, without a knowledge of the discovery of Robiquet.

Pelletier, contrary to the opinion of Robiquet, considered caffein as an alkali at first, but has since admitted that it does not act like one, upon vegetable blues, nor in combining with acids.

It is a white volatile matter, soluble in boiling water, and in alcohol, from which it is deposited, on cooling, in silky filaments, like amianthus.

OF GENTIANIN.

This name has been given to a bitter principle, which is obtained from gentian by pulverization, digestion in ether, filtration, evaporation, re-solution in alcohol, re-evaporation, solution in weak alcohol, to separate oily matter, evaporation of the weak alcoholic tincture, dissolving the residue in water, neutralizing an acid by magnesia, and afterwards digesting, in ether, the precipitate which ensues, to separate the gentianin. To effect this last object thoroughly, the magnesia must be acidulated by oxalic acid.

Gentianin is described as "yellow and inodorous, with all the aromatic bitterness of gentian." It is very soluble in ether and alcohol, and sparingly soluble in water. It does not sensibly change the colour of litmus, or restore it when reddened by an acid. It is not poisonous. A solution of it, in alcohol, is represented as an advantageous substitute for the tincture of gentian.

OF LUPULIN.

The hop has long been known to possess important properties. By its bitterness, the mawkish sweetness of malt liquors is agreeably modified; while at the same time they derive from it an aromatic flavour, and an antiseptic quality, without which, they would soon become sour.

Employed in an infusion, in a tincture, or in a pillow, this vegetable has been supposed to act as a gentle anodyne.

A few years ago, Dr. Ives, of New York, drew the public attention to a yellow powder existing in hops. To this powder, which, according to his observations, is pre-eminently endowed with all their important properties, he gave the name of lupulin. It has since been found to contain a bitter principle, soluble in water, alcohol, and ether, to which, severally, it communicates bitterness. It is this principle which is now called lupulin.

OF CATHARTIN.

This name has been given to the purgative principle of senna, by the discoverers, Messrs. Lassaigne and Fenuelle.

A strained decoction of the leaves of this plant was precipitated, by acetate of lead. The precipitate was washed, diffused through water, and afterwards decomposed by sulphuretted hydrogen. The liquid resulting was then filtered, and evaporated; the residue subjected to alcohol, and the solution, thus obtained, evaporated. As the mass, remaining, contained potash, it was treated with alcohol and sulphuric acid. The potash, uniting with the acid, was thus rendered insoluble in the alcohol. To remove any excess of sulphuric acid, acetate of lead was added; sulphuretted hydrogen being employed to ensure the precipitation of any portion of the lead which might remain in solution. The liquid being then filtered and evaporated, cathartin remained.

OF PIPERIN.

This name has been given to a crystalline principle, discovered a few years ago in black pepper. An interesting memoir respecting it, has been published in Silliman's Journal, (Vol. 13, No. 2,) by Mr. G. W. Carpenter, of this city.

I subjoin the substance of Mr. Carpenter's description of piperin, and of his account of the process by which he obtained it.

Digest one pound of coarsely powdered black pepper, in one gallon of alcohol, for ten days. Distil off one-half of the alcohol by a water bath; add gradually enough muriatic acid to hold the piperin in solution, with water sufficient to precipitate the resin, and separate the oil; concentrate the solution by evaporation, and add pure potash to neutralize the acid. The piperin will be deposited in yellowish transparent crystals. The crystals may be obtained perfectly colourless, by separating the oil and resin. He observes that "The piperin, in a colourless state, is insipid and inodorous; but united with as much resin as enters into its crystallization, its taste is extremely powerful, possessing, in an intense degree, all the heat and acrimony of the pepper, with much of its odour." He considers the yellow crystals a more active preparation than the white.

I regret that he did not ascertain how much of the active medicinal qualities of the yellow piperin, as prepared by him, was due to piperin, and how much to the matter which gave it such a "powerful taste," and the "heat and acrimony of black pepper," rendering the preparation more active.

RHUBARBIN.

This name is given to a principle said to have been detected in rhubarb, and to be that in which its purgative quality resides. It has been regarded as an alkali, but without satisfactory evidence.

OF COLOCYNTIN.

The active purgative properties of the colocynth, are said to exist in a bitter principle called colocyntin.

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° F., 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 envelops 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.

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 infusion 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, in which the specific gravity of alcohol, is, to that of water, nearly, as 800 to 1000, at 60° F.

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 aëriform state, is much less than that of water. It has never been frozen. It is a powerful solvent, and a most useful agent in pharmacy, and in the delicate analysis of vegetable and animal matter.

I have ascertained, that the addition of one-seventh of oil of turpentine, will render its flame 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.

OF ETHERS, AND ETHERIFICATION.

It has been stated, that carburetted hydrogen (olefiant gas) when united to an equal volume of aqueous vapour, constitutes alcohol. It is likewise an ingredient in various etherial compounds, which differ very much from alcohol in their properties.

Thenard conceives that ethers may be distinguished into three classes; those which are produced simply by abstracting from alcohol a portion of the aqueous vapour, those which arise from substituting a volume of an acid vapour for that of the water, in alcohol, and those which result from a combination of alcohol with an acid.

Of the first mentioned genus, there are four species. Sulphuric, phosphoric, arsenic, and fluo-boric ethers. In the second genus, there are two species, the muriatic and hydriodic ethers. In the third genus, there are seven species, comprising nitric, acetic, benzoic, oxalic, citric, tartaric, and gallic ethers.

The six last mentioned ethers, of the third genus, are produced by distilling the acids, after which they are named, with alcohol and sulphuric acid. The rest are elaborated simply by the reaction between alcohol, and their acids, respectively.

ETHERS OF THE FIRST GENUS.

These ethers being constituted of the same elements, in the same proportion, may be considered as identical, though indebted for their existence to the different acids, after which they are named.

OF SULPHURIC 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, a peculiar oil, and alcohol, containing this oil, together with water and acetic 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, in which a small quantity of red lead, or manganese, has been introduced to remove the sulphurous acid. A little liquid ammonia, diluted with water, purges the fluid of 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.

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, 49, 53. It boils at 98° F. 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° F. It has peculiar and useful powers as a solvent.

It is considered as a compound of one volume of carburetted hydrogen, and half a volume of aqueous vapour, so that there is only half as much water in it, as in alcohol.

OF SWEET OIL OF WINE, AND HOFFMAN'S ANODYNE LIQUOR.

The oleaginous liquid, called oil, or 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 which has been called the sulphovinic acid, is generated, and remains in the retort. This compound is represented by these skilful chemists, as containing the same quantity of sulphuric acid as the oil of wine, with only half as much carbon and hydrogen.

Thenard, who has not noticed this statement, represents the sulphovinic acid as a compound of hypo-sulphuric acid, with a peculiar vegetable matter; and that the oil of wine differs from ether only in containing less of the elements of water.

Whatever may be the composition of this oil, it appears medicinally to be a very important product, 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 the sweet oil of wine, in alcohol, 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 this oil, produces a milky appearance with water, in consequence of the precipitation of the oil, 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 defect having been pointed out, has been corrected by some 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 oil of wine, the anodyne liquor ceased to be a concomitant product of sulphuric ether. Hence a mixture of ether and alcohol was used as a substitute for it.

224.—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 the sweet oil of wine.

Milky appearance arising from the mixture of Hoffman's anodyne, with water, exhibited.

225.—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 ETHERS OF THE SECOND GENUS.

OF MURIATIC ETHER.

Muriatic ether may be obtained by distilling alcohol with concentrated muriatic 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 a 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, acid, or water, which may rise with the ether, which, in consequence of its greater volatility, reaches the phial, and is condensed in it.

Muriatic ether may also be obtained by the process described for liquid muriatic acid, 139, 140, if there be alcohol in the first bottle, water in the second, and the third be refrigerated.

Muriatic 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 muriatic acid, gas.

OF HYDRIODIC ETHER.

This ether was generated by Gay Lussac, by distilling hydriodic 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.

OF ETHERS OF THE THIRD GENUS.

Of the seven species which have been enumerated as belonging to this genus, only two, nitric and acetic ether, are more volatile than alcohol. The others do not boil below 212°.

Of this genus, I consider it as necessary to notice, particularly, only one species; nitric ether.

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 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.

The formula for sweet spirit of nitre, in Brande's Manual of Pharmacy, allows but three ounces of nitric acid to a quart of alcohol. 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 produced, according to the formula alluded to, is not more than two ounces, or one-sixteenth of the alcohol.

It is worthy of inquiry, whether a mixture of pure nitric ether, and water, in the same proportion, would not be preferable in many cases.

APPARATUS FOR THE GENERATION OF NITRIC ETHER.

Let a tube, A, at least three feet long, and tapering from $\frac{3}{4}$ of an inch to $\frac{1}{2}$ 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 smaller tube only.

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 CHLORIC ETHER.

This name has been given to a liquid of an oleaginous consistency, which arises from the union of chlorine with carburetted hydrogen, and which caused the latter to be designated as olefiant gas.

This liquid is limpid and colourless. Its smell and taste are rather agreeable. It is heavier than water, and requires a temperature of 152° for its ebullition. It burns with a green flame, giving out muriatic acid, and much soot.

It consists of two atoms, or one volume of carburetted hydrogen, and one atom, or one volume of chlorine.

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 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, and bread, often become sour, when there has been no intervening indication of the vinous fermentation.

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, in urine, and in milk. During imperfect digestion, it is generated in the stomach. It is invariably a product of the destructive distillation of vegetable substances.

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 which ever 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 relieved, by adding a small quantity of black oxide of manganese, previously to the second distillation.

Properties of Acetic Acid.

The purest acetic acid which has been obtained, crystallizes at the temperature of about 55° F. It is colourless, inflammable, very volatile, and has a very pungent odour and taste. Its specific gravity is 1.063, at 60° F., 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.

OF PYROLIGNOUS ACID.

In the form of pyrolignous acid, in which state it is obtained by the destructive distillation of wood, as its name implies, acetic acid is a powerful antiseptic.

The keeping quality imparted to salt meat, by wood smoke, is ascribed to pyrolignous acid.

It produces an equally beneficial effect upon salt meat, when applied in the liquid form. Indeed, I consider this as the best method of application. The ordinary process is less susceptible of precision, and requiring the employment of fire, is liable to produce a rise of temperature injurious to the meat.

Pyrolignous acid consists of acetic acid, and an empyreumatic oil. From the latter, the acid cannot be separated without combining it with an alkali or earth. Lime is usually employed for the purpose. The resulting acetate is decomposed by sulphuric acid, as in the processes for obtaining citric, and tartaric, acid.

226.—EXPERIMENTAL ILLUSTRATIONS.

Distilled vinegar, and crystallizable acetic acid, exhibited: also pyrolignous 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 muriate of ammonia 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.

ON 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 corresponding varieties 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 elementary composition is nearly the same.

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, (when burnt in a candle,) be competent to produce the sensation of 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 sub-phosphate 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 sulphuretted hydrogen, 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.

Composition of Fibrin.

Fibrin may be considered as a compound of carbon 18 atoms, hydrogen 14 atoms, oxygen 15 atoms, and nitrogen 3 atoms.

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.

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 said to be sufficiently alkaline to affect tests. Its obvious properties are universally known, as seen in the whites 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 alkali causes it to re-dissolve, 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. Phosphoric and acetic acids do not have this effect. It is precipitated from blood, by acids, and the precipitate re-dissolves on adding ammonia.

By uniting with the oxides, chlorides, or iodides, of the metals, (of the four last sections of Thenard) 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 bi-chloride is, by reaction with the albumen, converted into proto-chloride, or calomel.

Albumen is coagulated by alcohol, and precipitated by tannin. It contains a minute portion of sulphur. Hence silver spoons are tarnished by eggs. It is of great use in clarifying sirups. 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.

Composition of Albumen.

Albumen probably consists of carbon, 15 atoms, hydrogen, 13 atoms, oxygen, 6 atoms, nitrogen, 3 atoms.

227.—EXPERIMENTAL ILLUSTRATIONS.

In different vessels, corrosive sublimate and albumen are diffused. The contents of the vessels being mingled, a precipitate appears.

OF GELATIN.

Gelatin, agreeably to Thenard, never makes a part of the animal humours; yet solid gelatin is to be found in muscles, skins, cartilages, tendons, and aponeuroses. The membranes contain a great quantity, the bones about half their weight.

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 tannin. Alcohol precipitates it, by taking away water; tannin, by forming a substance analogous to leather, which is insoluble.

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 action of water, with heat and pressure. Or the phosphate of lime, being removed by muriatic 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.

Confectioners' jellies are gelatin, seasoned with wine and sugar.

Composition of Gelatin.

Agreeably to the analysis of Gay Lussac, and Thenard, gelatin differs from albumen in containing between four and five per cent. more carbon, and between three and four per cent. less oxygen.

228.—EXPERIMENTAL ILLUSTRATION.

A solution of tannin being poured into a solution of glue, or ichthyocolla, a precipitation ensues.

OF CASEOUS MATTER.

This appellation has been given to the curd, obtained from milk by the rennet, which appears distinct in its properties from any other animal substance. It is white, insipid, inodorous, heavier than water, and neither acid nor alkaline.

Agreeably to the observations of Proust, caseous matter undergoes 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, are also produced by the fermentation of gluten.

It is worthy of notice, that caseous matter, by incineration, yields six and a half per cent. of phosphate of lime. This is considered as qualifying it peculiarly for the food of young animals.

OF MUCUS.

The term mucus, in an enlarged sense, is applied to a fluid which lubricates the mouth, œsophagus, stomach, the intestines, and other passages of the body. It differs from albumen, in not being liable to coagulation: nor does it gelatinize by concentration. Neither tannin, nor corrosive sublimate, affect it. Sub-acetate 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 sirup, 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 is afterwards re-dissolved, 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 matter, that urine owes the power of yielding carbonate of ammonia, by distillation.

OF THE COLOURING MATTER OF THE BLOOD.

The colour of the blood was, at one time, ascribed to sub-phosphate of iron, dissolved in the serum by means of an alkali. This explanation was afterwards proved to be erroneous by Berzelius; and Mr. Brande adduced some striking facts in favour of the opinion that the matter in question, like vegetable dyes, owes its colour to unknown causes.

Lately it has been demonstrated, by Englehart, a young German chemist, that iron does not exist either in the fibrin or serum of the blood, but does reside in the red globules. This he demonstrated not only by their incineration, but by passing chlorine through a solution of the red globules; by which means, the solution was so modified, that peroxide of iron was detected in it, by the usual tests. Englehart has also ascertained, that from a solution, containing albumen, and other soluble animal substances, oxide of iron cannot be precipitated by the alkalies, hydro-sulphuret of ammonia, or an infusion of galls.

Upon the whole, the opinion, attributing the colour of the blood, to iron, seems to have received new strength, from the observations of Englehart.

It is suggested, by Dr. Turner, that the colour may be due to sulpho-cyanic acid, as this has lately been detected in saliva, and produces, with peroxide of iron, a colour like that of venous blood.

OF ANIMAL SUGAR.

Sugar is an animal, as well as a vegetable, product. Milk whey, evaporated, redissolved, clarified by albumen, and evaporated again, 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 to make a species of wine from it; 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 muriatic acid, to thirty-two parts of ox bile, a resinous matter is dissolved—and by subsequent filtration and evaporation, 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 of 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 principally consists of a substance analogous to the resin of bile.

OF ANIMAL OILS, OR FAT.

Fat differs from oil only in consistency. The fat of the whale becomes whale oil, in regions more temperate than those inhabited by that animal. 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.

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 mutton, or of goats.

Butyrin fuses at 70° F.

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 alleged 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 aëriform 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.

Thenard enumerates twenty-six acids, which are found, either native in animals, or which may be formed by the reaction of different agents, with the products of animal life. Yet, notwithstanding this formidable list, there are very few acids 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 ready formed in animals, are the sulphuric, phosphoric, muriatic, and acetic. 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. Caseic acid is rendered interesting only by its presence in an important article of food, agreeably to the statement already made under the head of caseous matter. Butyric acid has similar pretensions to notice, as it is said to exist in a small proportion in butter.

It has been mentioned, that the margaric and oleic acids are produced during saponification. They exist also in the fat of dead bodies.

Sulpho-cyanic acid, though not mentioned among animal acids by Thenard, is said to exist in saliva.

The *amniotic* acid is alleged to have been 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 185 and 247.

I subjoin a list of the acids produced by the acidification of animal matter, the substances from which they are produced, and the agents in their production.

Name of the acid.	Substance producing it.	Agent in the production.
Pyro-uric acid,	Uric acid,	Heat.
Purpuric acid,	Uric acid,	Nitric acid.
Margaric and stearic acids	Stearin,	Potash.
Oleic acid,	Elain,	Potash.
Phocinic acid,	An oil of the dolphin,	Potash.
Butyric, caproic and capric acids	Butter,	Potash.
Saccholactic, saclactic or mucic acids,	Sugar of milk,	Nitric acid.
Hircic acid,	Fat of mutton or goat,	Potash.
Sebacic acid,	Suet or lard,	Heat.
Cholesteric acid,	Cholesterin,	Nitric acid.
Oxalic acid,	Glycerin,	Nitric acid.

OF URIC ACID.

The uric or lithic acid, was discovered, by Scheele, in the human urinary calculus. Supposing all calculi to be composed of this acid, he called it lithic acid—a name which has been supplanted by that of uric acid, since the concretions of the bladder have been found to consist, occasionally, of other substances.

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 the excrement of the silk worm, united to ammonia—and in cantharides. United to soda, it forms arthritic concretions.

It is procured by treating the sediment of urine, or the yellow urinary calculi, with a solution of potash in excess, and adding muriatic acid. This acid neutralizing the alkali, the uric acid, being almost insoluble in water, 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.

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° F., ten thousand times its weight for its 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, a residuum of a purple, carmine, or rose red colour.

OF PYRO-URIC ACID.

When the uric acid is distilled, per se, another acid is generated, called by the name above mentioned. It rises, in the form of a yellow sublimate, in union with ammonia. This sublimate, being dissolved in water, and acetate of lead added to the solution, a white precipitate ensues, which, after due ablution, is decomposed by sulphuretted hydrogen gas—and, by solution and evaporation, affords crystals of the acid, in the form of white needles.

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. It has since been alleged by Vauquelin, that this colour is not due to the acid in question, but depends upon a peculiar colouring matter generated at the same time.

OF ROSACIC ACID.

The lateritious sediment, obtained from the urine of diseased persons, contains, according to the best authority, an acid, called rosasic, from its rosy colour. It differs from the uric acid—in being very soluble in hot water—in having little tendency to crystallize—and, in precipitating muriate of gold, of a violet colour.

Sulphuric acid reddens it, and converts it into uric acid. Nitric acid has a similar effect.

OF LACTIC ACID.

Lactic acid is that produced in milk, when it sours. It acts with so much energy, on iron and zinc, as to cause the evolution of hydrogen gas.

It is now considered as acetic acid in disguise.

OF FORMIC ACID.

The formic acid is obtained by crushing ants. It appears to exist in them naturally. It was alleged, by Fourcroy and Vauquelin, to be acetic acid, disguised by impurities;—but, it appears, from the experiments of Berzelius, to approximate, in its composition, to the oxalic, more nearly, than to the acetic.

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.

OF THE BLOOD.

From the proximate elements of animal matter, we proceed to the more complex substances of which they are composed. Among these, blood is, of all others, the most important.

It consists of water, albumen, fibrin, colouring matter—of a small quantity of fatty matter—of minute portions of the muriates of potash and soda, sub-phosphate of soda, sub-carbonate of lime and magnesia, oxide of iron, and, according to Berzelius, of some lactate of soda, united to some animal matter. Its obvious properties 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.

Left to itself, blood soon separates into serum, and the crassamentum, or clot; the proportion of the latter being greater, as the animal is better fed, or more healthful. Heat was supposed to be extricated, during the coagulation; but it has been shown, of late, to be scarcely appreciable by the thermometer. The serum, like other albumen, may be coagulated by heat, and then yields a liquor, called the serosity, which, according to Berzelius, consists of water, holding, in solution, soda, albumen, the muriates of soda and potash, 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.

It has been stated, that the blood in the arteries is of a much brighter red than that in the veins. This difference is evidently consequent to its exposure to atmospheric air, during its circulation through the lungs.

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 atmospherical 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 analysed. 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.

Frugivorous animals have been found to increase the proportion of nitrogen, more than carnivorous animals; yet the change apparently made, in the proportion of nitrogen present, is so small, as to induce some very accurate chemists to consider it, as really unaltered.

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 contained in the air breathed by them. 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 a 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, founding his estimate of the heat produced by the combustion of oxygen gas, with carbon and hydrogen, on a new series of experiments, repeated the investigations of Mr. Dulong.

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 that of the whole heat generated by animal life. If these results are to be relied upon, the balance 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.

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 would be my duty to explain their chemical properties and composition. But unfortunately, the analyses which have been made of them by different eminent chemists, are contradictory, and the opinions individually 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 specially called to the subjects of them. I shall therefore conclude this part of animal chemistry, with a particular account of the gastric juice, milk, urine, and sweat.

These are mentioned, by Thenard, under the general head of acid liquids, in contra-distinction to the rest of the liquids, above mentioned, which are all alkaline.

OF THE GASTRIC JUICE.

The gastric juice is a transparent liquid, having a somewhat bitter taste. It appears to contain albumen, gelatin, and mucus. As obtained from the stomach of an animal killed while fasting, it is neither acid nor alkaline; but it has been alleged, that during digestion, muriatic and acetic acids are secreted, and that it owes its solvent powers to their presence. This opinion is supported by the alleged detection of muriatic and acetic acids, in the stomach of animals killed during digestion; but it does not appear to have been shown, that any mixture of those acids will convert animal and vegetable substances into chyme, or that the gastric juice, when devoid of acidity, is destitute of its peculiar solvent powers.

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 butter, curd, and whey. This separation is hastened by the rennet, of the effect of which, no satisfactory explanation can be afforded. As the presence of an alkali does not prevent it, acidity cannot be the cause.

Milk is composed of cheesy and buttery matter, of sugar of milk, of different salts, especially phosphates, and a little acid. The cheesy and buttery matter are only suspended in the milk, whence its opacity. When evaporated, they form a pellicle 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 likewise by alcohol. In these cases, it is probable that coagulation results from the insolubility of the caseous matter in the liquids formed by the union of the acid, or the spirit, with the water of the milk. Coagulation ensues, also, from the admixture, with milk, of other neutral substances attractive of water. Alkalies have the opposite effect, as they dissolve the caseous matter.

Whey, as I have stated, contains sugar of milk; and besides this, some other animal matter, with phosphates and muriates.

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
Muriate of soda - - - - -	4.45
Muriate of ammonia - - -	1.50
Earthy matters, with a trace of fluate of lime -	1.00
Siliceous earth - - - - -	0.03
	1000.00

OF SWEAT.

According to Thenard, sweat contains much water, a little acetic acid, muriate of soda, perhaps also muriate of potash, 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, muriates of soda and potash, lactic acid, lactate of soda, and a little animal matter.

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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:

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 ammoniaco-magnesian phosphate. It is readily soluble in dilute muriatic acid, from which the lime may be precipitated by the addition of oxalic acid; and by adding ammonia, a precipitation ensues, of ammoniaco-magnesian phosphate.

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, and to develop quicklime in this calculus, which may of course be detected by the alkaline tests.

Cystic oxide is recognised, *chemically*, by its great solubility in acids and alkalies.

OF THE 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 skin consists, as is well known, of the epidermis, and true skin. The former resembles coagulated albumen in its chemical properties, the latter, by boiling in hot water, may be converted into gelatin. Hence its utility in the manufacture of glue, and its susceptibility of the tanning process, already noticed.

OF BONES.

Besides oil, of which the marrow is mainly constituted, bones consist of cartilage and gelatin, indurated by phosphate and carbonate of lime. The two last mentioned constituents may be removed by diluted nitric, or muriatic acid.

The cartilage approximates to coagulated albumen, in its chemical properties. It 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 by Berzelius.

Animal matter	33.30
Phosphate of lime	51 04
Carbonate of lime	11.30
Fluate of lime	2.00
Phosphate of magnesia	1.16
Soda, chlorine of sodium, and water	1.20
	100.00

In addition to these, 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 fœtor 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 neutralizing 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 of 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 to decomposition, while containing both hydrogen, oxygen, and nitrogen, may arise partly from their insolubility in water, and partly from the predominancy 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 the process, but on the contrary is generated.

Besides water, ammonia, with carbonic and acetic acid, and carburetted and sulphuretted hydrogen, and in some cases phosphuretted hydrogen, may be enumerated 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 causes, from sources so limited, consequences so extensively diversified, and so susceptible of further diversification.

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 vegetable and animal chemistry, during a course of instruction limited to four months. It is, however, consolatory to reflect, that it is that branch of the 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.

AN

ALPHABETICAL TABLE

OF

CHEMICAL EQUIVALENTS, OR ATOMIC WEIGHTS,

IN TWO COLUMNS;

In one of which Oxygen, in the other Hydrogen, is considered equal to one.

(See Compendium, page 14.)

	Oxygen = 1	Hy. = 1
Acid, acetic, anhydrous[*]	6.25	50
crystallized 1 water	7.375	59
antimonic	7.5	60
arsenic	7.75	62
arsenious	6.75	54
benzoic	15.	120
boracic, 2 ox.	3.	24
carbonic, 1 c. + 2 ox.	2.75	22
chloric, 1 chl. + 5 ox.	9.5	76
chromic, 1+ chr. + 3 ox.	6.5	52
citric, anhydrous	7.25	58
crystallized, 2 water	9.5	76
ferro-cyanic	13.5	108
fluoric[†]	1.25	10
fluo-boric	4.25	34
fluo-silicic	3.25	26
gallic	7.75	62
hydrochloric, or muriatic	4.625	37
hydrocyanic 1 cy. + hyd.	3.375	27
hydrofluoric[†]	2.375	19
hyponitrous 1 nit. + 3 ox.	4.75	38
malic	7.5	60
muriatic, or hydrochloric	4.625	37
nitric real, 1 n. + 5 ox.	6.75	54
(sp. gr. 1.5, 2 water)	9.	72
nitrous, 1 n. + 4 ox.	5.75	46
oxalic, anhydrous	4.5	36
cryst. 4 water, Thom.	9.	72
3 do. Berzelius	7.875	63
phosphoric, 1 p. + 2 ox.	3.5	28
selenic — 1 s. + 2 ox.	7.	56
succinic	6.25	50
sulphuric, anhydrous, 1 s. + 3 ox.	5.	40
(sp. gr 1.85, 1 water)	6.125	49
sulphurous, 1 s. + 2 ox.	4.	32
sulphocyanic	7.375	59
tartaric, anhydrous	8.25	66
(cryst. 1 water)	9.375	75
Acid, uric	9.	72
(cryst.)	11.25	90
Alcohol, 2 ol. gas + 1 aq. vap.	2.875	23
Alum, anhydrous	32.75	262
cryst. 25 water	60.875	487
Alumina	2.25	18
(according to Philips)	3.375	27
sulphate	7.25	58
bihydrate	4.5	36
Aluminum	1.25	10
(according to Philips)	2.375	19
Ammonia	2.125	17
bicarbonate, 1 am. + 2 c.	7.625	61
cryst. 2 water	9.875	79
carbonate, 1 am. + 1 c. a.	4.875	39
citrate, anhydrous	9.375	75
fluoborate do.	6.375	51
muriate, 1 am. + 1 m. a.	6.75	54
nitrate, anhydrous	8.875	71
(cryst. 1 water)	10.	80
oxalate, anhydrous	6.625	53
(cryst. 2 water)	8.875	71
phosphate, anhydrous	5.625	45
(cryst. 2 water)	7.875	63
succinate, anhydrous	8.375	67
sulphate do	7.125	57
cryst. 2 water	9.375	75
tartrate, anhydrous	10.375	83
Antimony	5.5	44
chloride	10.	80
deutoxide, 1 a. + 1½ ox.	7.	56
dichloride	15.5	124
hydrosulphuret	8.625	69
peroxide, or antimonic acid, 1 a. + 2 ox.	7.5	60
protoxide, 1 a. + 1 ox.	6.5	52
sulphuret, 1 a. + 1 s.	7.5	60
tartarized (Thomson, 2 water)	44.25	354

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[*] Devoid of combined water.

[†] The same substance is called either fluoric, or hydrofluoric acid, accordingly as it may be deemed a compound of oxygen with an unknown radical, or of fluorine with hydrogen. See Compendium, page 192.

	Oxygen =1	Hy. =1
Antimony, tart. Phill. 3 wat.	45.375	363
Arseniate of potash, anhyd.	13.75	110
soda do.	11.75	94
Arsenic	4.75	38
chloride	9.25	74
seleniuret	9.75	78
sulphuret (orpiment)	6.75	54
sesqui-sulph. (realgar)	7.75	62
Azote	1.75	14
protoxide (nitrous oxide)	2.75	22
deutoxide (nitric oxide)	3.75	30
Barium	8.75	70
chloride 1 b. + 1 chl.	13.25	106
peroxide, 1 b. + 2 ox.	10.75	86
protoxide (barytes) 1 b. + 1 ox	9.75	78
sulphuret	10.75	86
Barytes, or protoxide of barium, anhydrous, 1 barium + 1 ox.	9.75	78
hydrate (cryst. 20 water)	32.25	258
acetate, anhydrous	16.	128
cryst. 3 water	19.375	155
biphosphate, anhydrous	16.75	134
carbonate do.	12.5	100
chlorate do.	19.25	154
chromate do.	16.25	130
nitrate, cryst. anhydrous	16.5	132
oxalate do.	14.25	114
ferro-cyanate	23.25	186
muriate, cryst. 1 water	15.5	124
phosphate, anhydrous	13.25	106
sulphate, do.	14.75	118
tartrate, do.	18.	144
Bismuth	9.	72
chloride, 1 b. + 1 chl.	13.5	108
persulphuret	13.	104
nitrate, anhydrous	16.75	134
(cryst. 3 water)	20.125	161
oxalate, anhydrous	14.5	116
oxide	10.	80
subsulphate	35.	280
sulphate, anhydrous	15.	120
sulphuret	11.	88
Borax	10.	80
cryst. 8 water	19.	152
octahedral crystals, 4wat.	14.5	116
Boron	1.	8
Brucia	51.5	412
Cadmium	7.	56
nitrate, anhydrous	14.75	118
phosphate do.	11.5	92
sulphate do.	13.	104
Calcium	2.5	20
Calomel (protochloride of mercury)	29.5	236
Carbon	.75	6
oxide (gas) 1 c. + 1 ox.	1.75	14
Carburetted hyd. (light) or bi-hydroguret of carbon, 1 car. + 2 hyd.	1.	8
olefiant, or hydroguret of carbon, 1 car. + 1 hyd.	.875	7
Cerium	6.25	50
Chlorine	4.5	36
decahydrate	15.75	126
peroxide 1 c. + 4 ox.	8.5	68
protoxide 1 c. + 1 ox.	5.5	44
Chromium	3.5	28
sulphuret	5.5	44
Cobalt	3.25	26
Columbium	18.	144
Copper	8.	64
(according to Thomson)	4.	32
acetate, 1 ac. + 1 perox.	16.25	130
cryst. 6 water	23.	184
binacetate, 2 ac. + 1 per. ox.	22.5	180
cryst. 3 water	25.875	207
biphosphate, 2 water	19.25	154
bisulphate (blue vitriol)	20.	160
(cryst. 10 water)	31.25	250
bisulphuret, 1 c. + 2 s.	12.	96
binitrate, 1 perox. + 2 ac.	23.5	188
iodide	23.5	188
perchloride, 1 c. + 2 chl.	17.	136
protochloride, 1 c. + 1 chl.	12.5	100
protosulphuret	10.	80
protoxide, 1 c. + 1 ox.	9.	72
peroxide, 1 c. + 2 ox.	10.	80
subnitrate, anhydrous, 4 perox. + 1 nit. a.	46.75	374
subacetate, 2 perox. + 1 ac.	26.25	210
subsulphate	25.	200
Corrosive sublimate	34.	272
Cyanogen, 1 nit. + 2 carb.	3.25	26
Ether, sulphuric, 4 ol. gas + 1 aq. vap.	4.625	37
muriatic, 4 ol. gas. + 1 mur. ac.	8.125	65
chloric, 2 ol. gas. + 1 chlo.	6.25	50
Fluorine ?	2.25	18
Glucina	3.25	26
Glucinum	2.25	18
Gold	25.	200
Gum	11.25	90
(according to Ure)	8.5	68
Hydrogen	.125	1
Iodine	15.5	124
Iridium	3.75	30
Iron	3.5	28
protochloride, 1 ir. + 1 chl.	8.	64
perchloride, 1 ir. + 1½ chl.	10.25	82
protoxide, 1 ir. + 1 ox.	4.5	36
peroxide, 1 ir. + 1½ ox.	5.	40
persulphate, 1 perox. + 1½ ac.	12.5	100
protosulphuret, 1 ir. + 1 s.	5.5	44
persulphuret, 1 ir. + 2 s.	7.5	60
sesquisulphuret, 1 ir. + 1½ s.	6.5	52

	Oxygen = 1	Hy. = 1
Iron, subsulphate, 4 perox. + 1 ac.	25.	200
sulphate, anhydrous, 1 prot. + 1 ac.	9.5	76
cryst. 7 water	17.375	139
Kermes mineral	8.625	69
Lead	13.	104
acetate, anhydrous	20.25	162
(cryst. 3 water)	23.625	189
arseniate, anhydrous	21.75	174
carbonate do.	16.75	134
chloride do.	17.5	140
chromate do. 1 prot. + 1 ac.	20.5	164
bichromate do. 1 prot. + 2 ac.	27.	216
bisulphuret	17.	136
subchromate, 2 prot. + 1 ac.	34.5	276
disulphuret	28.	224
deutoxide, 1 lead, + 1½ ox.	14.5	116
gallate	21.75	174
iodide	28.5	228
malate, anhydrous	21.5	172
molybdate, do.	23.	184
nitrate, cryst. anhydrous	20.75	166
nitrite	19.75	158
oxalate, anhydrous	18.5	148
peroxide, 1 l. + 2 ox.	15.	120
phosphate, anhydrous	17.5	140
phosphite	16.5	132
protoxide, 1 l. + 1 ox.	14.	112
subnitrate	34.75	278
sub-trit-acetate, 3 prot. + 1 ac.	48.25	386
sulphate, anhydrous	19.	152
sulphite do.	18.	144
sulphuret do.	15.	120
tartrate, anhydrous	22.25	178
Lime, 1 calcium + 1 ox.	3.5	28
acetate, anhydrous	9.75	78
arseniate	11.25	90
biphosphate, anhydrous	10.5	84
carbonate do.	6.25	50
chlorate do.	13.	104
chloride, 1 b. + 1 chl.	8.	64
citrate, anhydrous	10.75	86
chromate do.	10.	80
hydrate, 1 + 1	4.625	37
muriate	8.125	65
(cryst. 5 water)	13.75	110
oxalate, anhydrous	8.	64
phosphate do.	7.	56
sub-chloride	11.5	92
(6 water)	18.25	146
sulphate, anhydrous	8.5	68
(cryst. 2 water)	10.75	86
tartrate	11.75	94
(4 water)	16.25	130
Lithia, or protoxide of lithium	2.25	18
carbonate	5.	40
nitrate, anhydrous	9.	72
Lithia, phosphate	5.75	46
sulphate, anhydrous	7.25	58
Lithium	1.25	10
Magnesia, or oxide of magnesium — 1 mag. + 1 ox.	2.5	20
ammoniacal phosphate	11.625	93
(cryst. 5 water)	17.25	138
carbonate, anhydrous	5.25	42
(cryst. 3 water)	8.625	69
common, 3 carb. mag. + 1 quadro-hydr. mag.	22.75	182
chloride, anhydrous	7.	56
hydrate, 1 mag. + 1 water	3.625	29
muriate	7.125	57
nitrate, anhydrous	9.25	74
phosphate do.	6.	48
sulphate do.	7.5	60
(cryst. 7 water)	15.375	123
tartrate	10.75	86
Magnesium	1.5	12
Manganese	3.5	28
Mercury	25.	200
bichloride, cor. sub.	34.	272
bicyanide	31.5	252
bipernitrate, 1 perox. + 1 ac.	40.5	324
bipersulphate, anhydrous	37.	296
bisulphuret (cinnabar)	29.	232
protiodide	40.5	324
periodide	56.	448
perchloride (cor. sub.)	34.	272
peroxide, 1 m. + 2 ox.	27.	216
persulphuret, cinnabar	29.	232
persulphate, turpeth mineral	32.	256
protochloride, calomel	29.5	236
protonitrate, 1 prot. + 1 ac.	32.75	262
protosulphate, 1 prot. + 1 ac.	31.	248
protoxide, 1 m. + 1 ox.	26.	208
sulphuret	27.	216
Molybdenum	6.	48
Morphia	40.25	322
Naphtha from coal	5.25	42
Napthaline, 1½ carb. + 1 hyd.	1.25	10
Nickel	5.	40
arseniate, anhydrous	13.75	110
nitrate do.	12.75	102
Nitric oxide, 1 n. + 2 ox.	3.75	30
Nitrogen	1.75	14
Nitrous oxide, 1 n. + 1 ox.	2.75	22
Oil olive ?	9.875	79
turpentine	4.25	34
Olefiant gas	.875	7
Osmium		
Oxygen	1.	8
Palladium	7.	56
Phosphorus	1.5	12
Platinum	12.	96
ammoniacal muriate	27.75	222

	Oxygen = 1	Hy. = 1
Potash, or protoxide of potassium, anhydrous	6.	48
arseniate do.	13.75	110
arsenite do.	12.75	102
bicarbonate, 1 p. + 2 ac.	11.5	92
(cryst. 1 water)	12.625	101
binarseniate, anhydrous	21.5	172
bichromate do.	19.	152
binoxalate, do. 1 p. + 2 ac.	15.	120
biphosphate, do.	13.	104
bisulphate, do.	16.	128
(cryst. 2 water)	18.25	146
bitartrate, anhydrous	22.5	180
(cryst. 1 water)	23.625	189
carbonate, 1 p. + 1 ac.	8.75	70
chlorate	15.5	124
chromate, 1 p. + 1 ac.	12.5	100
citrate, do.	13.25	106
hydrate, solid, 1 water	7.125	57
hydriodate, anhydrous	21.625	173
muriate	10.625	85
nitrate, anhydrous	12.75	102
oxalate, do. 1 p. + 1 ac.	10.5	84
phosphate, do.	9.5	76
quadroxalate, do.	24.	192
subcarbonate, see carbonate		
succinate	12.25	98
sulphate	11.	88
sulphite	10.	80
tartrate	14.25	114
tungstate	24.75	198
Potassium	5.	40
bisulphuret	9.	72
chloride	9.5	76
peroxide	8.	64
phosphuret, 1 p. + 1 p.	6.5	52
protoxide, anhydrous	6.	48
protosulphuret	7.	56
subphosphuret	11.5	92
Rhodium	5.5	44
Selenium	5.	40
Silica, or oxide of silicon	2.	16
Silicium, or silicon	1.	8
Silver	13.75	110
chlorate, anhydrous	24.25	194
chloride do.	18.25	146
nitrate do.	21.5	172
oxalate do.	19.25	154
protoxide, 1 s. + 1 ox.	14.75	118
suboxide, 3 s. + 2 ox.	43.25	346
phosphate, anhydrous	18.25	146
sulphate do.	19.75	158
sulphuret	15.75	126
Soda, or protoxide of sodium	4.	32
acetate, anhydrous	10.25	82
(cryst. 6 water)	17.	136
arseniate, anhydrous	11.75	94
arsenite do.	10.75	86
bicarbonate do.	9.5	76
(cryst. 2 water)	11.75	94
carbonate, anhydrous	6.75	54
(cryst. 10 water)	18.	144
Soda sesquicarbonate	10.375	83
chlorate, anhydrous	13.5	108
chromate	10.5	84
hydrate	5.125	41
hydriodate, anhydrous	19.625	157
iodate do.	24.5	196
nitrate do.	10.75	86
oxalate do.	8.5	68
sulphate do.	9.	72
(cryst. 10 water)	20.25	162
tartarized	26.5	212
Sodium	3.	24
chloride	7.5	60
peroxide	4.5	36
protoxide, or soda	4.	32
sulphuret	5.	40
Starch	17.75	142
Strontites or strontia, protoxide of strontium	6.5	52
carbonate, anhydrous	9.25	74
hydrate, 1 water	7.625	61
muriate	11.125	89
(cryst. 8 water	20.125	161
nitrate, anhydrous	13.25	106
oxalate do.	11.	88
phosphate do.	10.	80
sulphate do.	11.5	92
Strontium	5.5	44
chloride	10.	80
oxide (strontites)	6.5	52
Strychnia	47.5	380
Sugar	10.125	81
(according to Prout)	9.375	75
Sulphur	2.	16
Sulphuretted hydrogen	2.125	17
Tannin	8.875	71
Tellurium	4.	32
Tin	7.25	58
bisulphuret	11.25	90
peroxide, 1 tin + 2 ox.	9.25	74
protoxide, 1 tin + 1 ox.	8.25	66
protochloride	11.75	94
bichloride	16.25	130
sulphuret	9.25	74
Titanium	4.	32
Tungsten	15.75	126
Uranium	26.	208
Water	1.125	9
Yttria, or oxide of yttrium	5.25	42
Yttrium	4.25	34
Zinc	4.25	34
carbonate	8.	64
chloride	8.75	70
nitrate	12.	96
oxalate	9.75	78
oxide	5.25	42
phosphate, anhydrous	8.75	70
phosphuret	5.75	46
sulphate, anhydrous	10.25	82
(cryst. 7 water)	18.125	145
sulphuret	6.25	50
Zirconia, or oxide of zirconium	6.	48
Zirconium or Zirconion	5.	40

APPENDIX.

ESSAY,

ON THE QUESTION, WHETHER HEAT CAN BE ASCRIBED TO MOTION.*

In two memoirs, published in Professor Silliman's Journal of Science and the Arts, I have endeavoured to show, that caloric and electricity are connate and co-ordinate products of galvanic action—the ratio of the former to the latter in quantity, being as the extent of the metallic surface exposed to the liquid, to the number of pairs into which it may be divided.

In those memoirs it is assumed, that the causes of heat and electricity, are material. Although this assumption is sanctioned by a great majority of chemists, it has been questioned as respects the origin of calorific repulsion, both by Rumford and Davy. With the utmost deference for these distinguished philosophers, and especially for Sir Humphry Davy, I offer the following remarks, made in answer to his suggestion, that motion may be the cause of heat. In order to prepare the reader for the arguments which I am about to offer, I shall here quote the hypothesis in question.

"It seems possible," says the illustrious author, "to account for all the phenomena of heat, if it be supposed, that in solids the particles are in a constant state of vibratory motion, the particles of the hottest bodies moving with the greatest velocity, and through the greatest space; that in fluids, and elastic fluids, besides the vibratory motion, which must be conceived greatest in the last, the particles have a motion round their own axes, with different velocities, the particles of elastic fluids moving with the greatest quickness; and that, in ethereal substances, the particles move round their own axes, and separate from each other, penetrating in right lines through space. Temperature may be conceived to depend upon the velocities of the vibrations; increase of capacity on the motion being performed in greater space; and the diminution of temperature, during the conversion of solids into fluids or gases, may be explained on the idea of the loss of vibratory motion, in consequence of the revolution of particles round their axes, at the moment when the body becomes liquid or aëriform, or from the loss of rapidity of vibration, in consequence of the motion of the particles through greater space.

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* First published in Silliman's Journal in 1822.

"If a specific fluid of heat be admitted, it must be supposed liable to most of the affections which the particles of common matter are assumed to possess, to account for the phenomena: such as losing its motion when combining with bodies; producing motion when transmitted from one body to another, and gaining projectile motion, when passing into free space; so that many hypotheses must be adopted to account for its mode of agency, which renders this view of the subject less simple than the other. Very delicate experiments have been made, which show that bodies, when heated, do not increase in weight. This, as far as it goes, is an evidence against a specific subtile elastic fluid producing the calorific expansion; but it cannot be considered as decisive, on account of the imperfection of our instruments. A cubical inch of inflammable air, requires a good balance to ascertain that it has any sensible weight, and a substance bearing the same relation to this, that this bears to platinum, could not perhaps be weighed by any method in our possession."

These suggestions of Sir H. Davy, appear to me unsatisfactory.

It is fully established in Mechanics, that when a moving body is blended with, and thus made to communicate motion to another body, previously at rest, or moving slower, the velocity of the compound mass, after the union, will be found, by multiplying the weight of each body, by its velocity, and dividing the sum of the products, by the aggregate weight of both bodies. Of course it will be more than a mean, or less than a mean, accordingly as the quicker body may be lighter or heavier than the other.

Now, according to Sir Humphry Davy, the particles of substances which are unequally heated, are moving with unequal degrees of velocity. Of course, when they are reduced, by contact, to a common temperature, the heat, or what is the same, (in his view) the velocity of the movements of their particles, ought to be found, by multiplying the heat of each by its weight, and dividing the sum of the products by the aggregate weight. Hence if equal weights of matter be mixed, the temperature ought to be a mean—and if equal bulks, it ought to be as much nearer the previous temperature of the heavier substance, as the weight of the latter is greater; but the opposite is, in most instances, true. When equiponderant quantities of mercury and water are mixed, at different temperatures, the result is such as might be expected, were the water twenty-eight times heavier; so much nearer to the previous temperature of the water, is that of the mixture.

It may be said, that this motion is not measurable upon mechanical principles. How, then, I ask, does it produce mechanical effects? These must be produced by the force of the vibrations, which are, by the hypothesis, mechanical: for whatever laws hold good, in relation to moving matter in mass, must operate in regard to each particle of that matter: since the effect of the former, can only be a multiple of that of the latter. Indeed, one of Sir Humphry Davy's reasons for attributing heat to corpuscular vibration, is, that mechanical attrition generates it. Surely, then, a motion, produced by mechanical means, and which produces mechanical effects, may be estimated on mechanical principles.

In the case cited above, the power of reciprocal communication of heat in two fluids, is shown to be inconsistent with the views of the great chemist. If we compare the same power in solids, the result will be equally objectionable.—Thus, the heating power of glass being 448, that of an equal bulk of lead will be 487, though so many times heavier; and if equal weights be compared, the effect of the glass, will be more than three times greater than that of the lead. (See Compendium, page 53.)

Consistently with this doctrine, the particles of an aëriform fluid, when they oppose a mechanical resistance, do it by aid of a certain movement, which causes them effectively to occupy a greater space than when at rest. It is true, a body, by moving backwards and forwards, may keep off other bodies from the space in which it moves. Thus, let a weight be partially counterbalanced, by means of a scale beam, so that, if left to itself, it would descend gently. Place exactly under it, another equally solid mass, on which the weight would fall, if unobstructed. If, between the two bodies, thus situated, a third be made to undergo an alternate motion, it may keep the upper weight from descending, provided the force with which it may descend, be no greater than that of the movement in the interposed mass, and that the latter act with such celerity, that, between each stroke, the time be too small for the weight to move any sensible distance. Here, then, we have a case analogous to that supposed—in which, the alternate movements or vibrations of matter, enable it to preserve to itself a greater space, in opposition to a force impressed; and it must be evident, that lengthening or shortening the extent of the vibrations of the interposed body, provided they are made in the same time, will increase or diminish the space apparently occupied by it, as the volume of substances is affected by an increase or reduction of heat. It ought, however, to be recollected, that, in the case we have imagined, there is a constant expenditure of momentum, to compensate for that generated in the weight by gravity, during each vibration. In the case of the supposed calorific vibrations, there is no generating power to make up for this loss. Gaseous particles preserve their elasticity when included in a vessel situated within an exhausted receiver; yet, under such circumstances, they can receive no accession of momentum to compensate its incessant expenditure, by their reciprocal pulsations. If, for instance, we pour mercury into a glass tube shaped like a shepherd's crook, the hook being downwards, and the lower orifice closed, the included air will prevent the mercury from occupying a portion of the tube. In this case, according to the hypothesis in question, the entrance of the mercury into the space which the air occupies, is resisted by a series of impalpable gyratory movements; so that the collision of the aërial particles against each other, causes each to occupy a larger share of space, in the manner above illustrated, by the descending weight and interposed body. The analogy will be greater, if we suppose a row of interposed bodies, alternately striking against each other, and the descending weight; or we may imagine a vibration in all the particles of the interposed mass, equal, in aggregate extent and force, to that of the whole, when performing a common movement. If the aggregate force of the vibrations made by the particles, be equivalent to that which, when performed in mass, would be necessary to preserve a certain space—it may be supposed productive of a substance like the air, by which the mercury is resisted. But how in such rare media, can there exist momentum competent to resist the pressure of a liquid so heavy as mercury, which may be considered as performing a part analogous to that of the upper weight in the case above cited for illustration?—And admitting the possibility of the existence of adequate momentum in the first instance, how is it to be sustained notwithstanding its incessant expenditure in resisting the mercury? *If* it be said, that the mercury and glass being at the same temperature as the air, the particles of these substances vibrate in a manner to maintain the aërial pulsations, I ask, when the experiment is tried in an exhausted receiver, how is momentum to be supplied to the mercury and glass? Under the most favourable circumstances, there is no small difficulty in imagining that a species of motion existing, according to the hypothesis, as the cause of expansion, in a heated solid, should create a motion productive of fusion, or vaporization; as when, by means of a hot iron, we convert ice into water, or water in vapour. Is it conceivable that the copper or iron in the boiler of a steam engine, should impart to the particles of water, a motion so different from any, which can exist in the particles of a metallic solid; and at the same time capable of such wonderful effects as are produced by the agency of steam? Since the force of moving matter can be no more than the product of its weight by its velocity, is it credible that in a few ounces of water, momentum can by any means be accumulated, sufficient to move the masses which steam is known to propel?

There appears to me another insurmountable obstacle to this explanation of the nature of heat. How are we to account for its radiation in vacuo, which the distinguished advocate of the hypothesis has himself shown to ensue? To explain this fact, recourse is had to a suggestion of Newton, that the calorific vibrations of matter may cause radiant particles to be sent off, which lose their own momentum in communicating vibrations to bodies remote from those whence they emanate. Thus, according to Sir H. Davy, there is a radiant matter producing heat, and a radiant matter producing light. The unlimited evolution of heat by friction from a finite portion of matter, is the only objection made by him to a material cause, which it is difficult to answer; yet this objection will apply equally against the existence of material calorific emanations. That the cannon heated by friction, in the noted experiment of Rumford, would have sent forth radiant heat either in pleno, or in vacuo, as well as if heated in any other way, there can, I think, be no doubt. Neither can it be doubted that the evolution of heat, when thus emitted, would be as unlimited as when yielded by the conducting process. Why then is it not as easy to conceive of an inexhaustible supply of heat, as a material substance, as to imagine an inexhaustible supply of radiant particles exciting vibrations in other bodies.

We see the same matter, at different times, rendered self-attractive, or self-repellent; now cohering in the solid form with great tenacity—and now flying apart with explosive violence in the state of vapour. Hence the existence in nature of different properties, producing opposite kinds of reaction between particles, is evident. The existence of properties implies the existence of matter to which they may belong, since nothing can have no property; consequently, the properties abovementioned as productive of opposite kinds of reaction, must appertain to matter. It may still be made a question whether they can both belong to particles of the same kind, or must be severally inherent in matter of different kinds; yet the latter alternative seems to me inevitable, since it were absurd to suppose the same particles to be at the same time self-repellent and self-attractive? Suppose them to be so —if either of the two properties were to predominate, we should not perceive the existence of the other, it would be useless, and the particles would in effect possess the predominant property alone, whether attraction or repulsion. If the properties were equal in power they would annihilate each other, and the matter would be as if void of either property.

Influenced by these considerations, I conclude that there must be particles endowed with a power of reciprocal repulsion distinct from those in which the opposite propensity of reciprocal attraction is universally recognised. There must also be as many kinds of self-repellent matter, as there are kinds of repulsion—of which the affinities, means of production, or laws of communication are different. Hence I do firmly believe in the existence of material fluids, severally producing the phenomena of light, heat, and electricity.—Substances endowed with attraction, make themselves known to us by that species of this power, which we call gravitation, by which they are drawn towards the earth, and are therefore heavy or ponderable; by their resistance to our bodies, producing the sensation of feeling or touch—and by the vibrations, or movements, which they excite in other matter, affecting the ear with sounds, and the eye by a modified reflection or transmission of light. When we perceive none of these usual concomitants of matter, we are prone to infer its absence. Hence, ignorant people have no idea of air except in the state of wind. But it must be obvious that the proof of their existence thus afforded by particles which are self-attractive, cannot be expected in the case of particles endowed with the opposite property of reciprocal repulsion. Repelling each other, they cannot resist penetration; possessing no sensible weight, the greatest velocity can endow them with no perceptible momentum:

and it is only by the changes which they induce by combining with ponderable matter, or their peculiar influence upon our senses, that it were reasonable to expect any indication of their existence.

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CONTROVERSY WITH PROFESSOR OLMSTED.

On the preceding essay some strictures were published in the American Journal of Science, Vol. II. page 358, by Dennison Olmsted, formerly Professor of Chemistry in North Carolina College, and now Professor of Natural Philosophy and Mathematics in Yale College.

After partially quoting the hypothesis of Sir H. Davy, as stated page 1, of this Appendix, Professor Olmsted proceeds as follows:—

> "He (Dr. Hare) has attempted to show, that the supposition that temperature results from the velocity of the particles of heated bodies, subjected to a vibratory motion, is inconsistent with the laws of mechanics. 'It is fully established in mechanics, (says Dr. Hare,) that when a body in motion is blended with, and thus made to communicate motion to another body, previously at rest, or moving slower, the velocity of the compound mass, after the impact, will be found by multiplying the weight of each body by its respective velocity, and dividing the sum of the products by the aggregate weight of both bodies.' He then proceeds to show that the phenomena of temperature do not coincide with this law. Thus, when water and mercury of different temperatures are added together, the resulting temperature is not a mean, as it would be, were temperature merely the operation of a law of motion; but the water is affected too little, and the mercury too much, to admit of our referring the change to such a law. Little as I am disposed to adopt the views of Sir Humphry Davy, I cannot but think that Dr. Hare has here suggested an answer which is not altogether unobjectionable. The application of his rule or test, makes it necessary to suppose, that the particles subjected to impact, are all moving in the same direction—that they all actually come into collision, each upon each, and that they are non-elastic; none of which conditions are capable of being proved actually to exist, although it is only when they are all present, that the law of motion which he adduces holds true. However, if Dr. Hare be allowed to have fully and clearly refuted the hypothesis of Sir Humphry, his argument is still imperfect, for it by no means establishes the doctrine of the materiality of heat, to prove that Davy has failed of showing that it is a product of motion. Both parties, in my view, evince how idle it is to reason respecting chemical phenomena upon mechanical principles."

To this I reply, that although it may be "*idle*" to advance mechanical principles as the means of explaining the phenomena of Chemistry, yet *when mechanical principles have been brought forward as the means of explanation*, it is not *idle* to show that the explanation thus founded is inconsistent with its own premises.

Though I might have hesitated to apply to the reasonings of so great a man as Sir H. Davy, the epithet employed by Professor Olmsted, I challenge him to point out in my essay any word which tends to show, that I do not think it idle to employ mechanical principles in reasonings on Chemistry.

We concur in disapproving of the hypothesis of Sir Humphry Davy, but because I have met it with arguments upon its own basis, instead of briefly denouncing it, Professor Olmsted accuses me, no less than the illustrious author, of introducing mechanical reasonings into chemical science.

If these reasonings be idle, let the great English chemist, who introduced them, bear the weight of Professor Olmsted's animadversion. Besides erroneously holding me up as the friend of a method of reasoning, of which I am really the antagonist, the criticisms of Professor Olmsted would convey to any person, who had not read my essay, an impression that I had considered a confutation of the hypothesis of Sir H. Davy as establishing that which I have myself espoused; and that I had advanced no direct arguments in favour of the materiality of heat, although to such arguments, the latter part of the essay is devoted. I beg leave to recommend them to an attentive perusal, as I am still of opinion that when well understood, they will be considered as unanswerable.

I cited the radiation of heat in vacuo, agreeably to an experiment of Sir H. Davy himself, in which a thermometer in the focus of one mirror, was influenced by a hot body in the focus of another mirror, the whole being within an exhausted receiver. I will thank Professor Olmsted to explain how heat can be transmitted under such circumstances, even with more ease than in pleno, if the cause of it be not material.

I did not dwell on this fact, because I supposed its importance generally known and admitted, and conceived that it would produce the most forcible impression, when viewed in its greatest simplicity.

In opposition to Davy's hypothesis, I had advanced several arguments, of which Professor Olmsted notices but one. With respect to that, it does not appear to me that he has adduced any fact, or any reasoning, which can invalidate the application, which I have made of a rule admitted by him to be true to a limited extent. It is enough for me, if the case in point fall within the limits of that rule. What is the case in point? The particles of two masses, mercury and water, while undergoing a vibratory or rotatory motion, with unequal velocities, have their movements equalized by contact. Will Professor Olmsted deny that the resulting motion ought to be nearest to that, to which the heavier particles were previously subjected?

The reasoning in my essay which Professor Olmsted has overlooked, is as follows:—As, in order for one body, or set of bodies, to convey any given degree of motion to another body, or set of bodies, the velocity must be as much greater as the weight may be less, it is inconceivable that the particles of steam should, by any force arising from their motion, impart to the piston of a steam engine the wonted power: or that the particles of air should prevent a column of mercury, almost infinitely heavier, from entering any space, in which they may be included, by beating it out of the theatre of their vibratory and rotatory movements.

Again, admitting it to be conceivable that the momentum of particles so light may be competent to such effects, it is utterly impossible that these could be permanently sustained; since in all cases where motion is communicated, what is gained by one body is lost by another: so that the motion of the body communicating the motion, is lessened at every impact, and finally ceases.—Further, since it is self-evident that a body, acting directly upon another, cannot produce a motion greater than its own, it is incredible that heated solids should, by any possible movements of their particles, produce the prodigious velocities, which, according to the disputed doctrine, must be attributed to aëriform matter, when its levity and its power of resistance, as above exemplified, are taken into view.

I must leave it to the reader to judge how far these arguments merit the oblivion, to which Professor Olmsted would consign them.

The essay which called forth the criticisms of Professor Olmsted was entitled "Essay, *on the question whether heat can be ascribed to motion?*"[*] and it was particularly designated in the commencement as "*remarks made in opposition to his* (that is to Davy's) *hypothetical views.*"[†] Yet the learned Professor alleges—

> "If Dr. Hare be allowed to have fully and clearly refuted the hypothesis of Sir Humphry, his argument is still imperfect, for it by no means establishes the doctrine of the materiality of heat, to prove that Davy has failed of showing that it is a product of motion."

It seems to me that it were just as reasonable to object to the 1st proposition in Euclid, because it does not establish the 45th, as to represent my arguments as "imperfect" in showing that heat cannot be motion, because I have not, in the opinion of the author, proved its materiality at the same time.

In Vol. XIII. page 8, of the American Journal of Science, Professor Olmsted (alluding to my essay on the question whether heat can be motion) alleges, that I have committed an oversight in making Davy's hypothesis "wear a much more mechanical aspect" than it did originally, and in "applying to it principles which have no bearing on it whatever."

According to Johnson's Dictionary, "*Mechanics is the geometry of motion, a science which shows the effect of powers, or moving forces, so as they are applied to engines, and demonstrates the laws of motion.*"

The phenomena of heat, being by Sir H. Davy ascribed to motion, how can my arguments, showing that they are not consistent with the laws of motion, make that hypothesis unduly "*wear a mechanical aspect,*" or subject it to *an application of principles* "*which have no bearing on it whatever.*"

In his first critique, the professor alleged Davy's reasonings to be "idle," because they were "mechanical." In the critique now under consideration, I am condemned for treating them as "mechanical."

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[*] This is the title which I gave the essay when republished: that which was attached to it in Silliman's Journal was added by the editor.

[†] These are the words of the essay as first published. In this Appendix they have been slightly varied.

A sufficient answer to this objection is afforded in my essay. See last paragraph, page 2.

> "In the hypothesis (says Professor Olmsted,) the motions supposed, are those which occur between particles of matter, and at insensible distances. In the refutation, the principles applied are such as belong to those motions which occur between masses of matter and at sensible distances."

The laws which regulate the production, or transfer, of motion, being established as respects any given mass, or quantity, can the division of it into any possible number of parts, or particles, render those laws inapplicable? The same argument may be opposed to his distinction between sensible and insensible distances, as if a law could cease to operate in consequence of the spaces being too small for our vision!

Since a whole can be no more than a multiple of its parts, a law cannot be true of motion, in any given distance, which does not hold good with respect to any part of that distance.

The minuteness of the distances, within which, movements can take place in solids, is cited by me, as a potent objection to ascribing to intestine motion the expansive power imparted by them, when heated, to vaporizable substances, as in the case of water converted into steam by hot iron. But if such phenomena do result from intestine motion, and if the transfer of expansive power be a transfer of such motion, however insensibly small may be the spaces in which it occurs, however minute the atoms concerned, still, evidently, the same laws must prevail, as in the case of larger spaces and larger masses.

Professor Olmsted proceeds:

> "The motions contemplated by the hypothesis, are either rotatory or vibratory; those supposed in the refutation, are rectilinear, and in one continued direction; for to no other does the law of percussion adduced apply."

As this allegation is unsupported by any proof, it can have but little weight. I will however throw my opinion into the opposite scale. I assert that the law which I have laid down is universally applicable where motion is communicated from one moving body, or set of bodies, to another body, or set of bodies, whether the movements be vibratory, rotatory, or rectilinear.

If while two planets are revolving, or two pendulums vibrating, one overtake the other, will not the heavier be least altered from its previous motion? If two wheels, two globes, or two cylinders, while rapidly rotating, were to come into contact, would not the same law prevail?

> "The refutation (says Professor Olmsted) supposes the particles to come into collision, each upon each; whereas the hypothesis does not warrant the supposition that any two particles ever strike against each other at all. For it is plain that the revolutions of particles round their own axes, do not bring them into collision with each other, nor do the vibrations of the particles make it necessary to suppose that they ever hit each other; for if there be space enough between the particles to permit them to vibrate at all, it is clear that they may vibrate without coming into collision."
>
> "Finally, if they did impinge against one another, it must be remembered, that the motion is backwards and forwards, and therefore this is not a case to which the law of percussion, as adduced by Dr. Hare, applies.

> "I cannot but think, therefore, that Dr. Hare has refuted a consequence, not of Sir Humphry Davy's, but of his own creating."

It were obviously as absurd to allege, that particles cannot move without coming into collision, as to assert that the bow of a violin cannot move unless it rub against the strings. Yet as in the one case, friction is necessary to produce music, so in the other, collision is indispensable to keep the particles asunder. Would the diurnal movements of the planets prevent them from falling into the sun? Their annual motion has this effect, by generating a centrifugal force; but it cannot be imagined that in every mass expanded by heat, the particles, by revolving about a common centre of gravity, generate a centrifugal force, which counteracts cohesive attraction; and thus enables them to exist at a greater distance from each other, than their inherent reciprocal attraction would otherwise permit.

When by the affusion of hot water upon mercury, the temperature of the latter is raised, how can the velocity of the vibrations in which temperature consists, according to the hypothesis, be increased in the last mentioned liquid without some contact between the mercurial and aqueous atoms?

If motion be not productive of a collision among the particles, in what way can it enable them to sustain that remoteness in their respective situations, which expansion requires? It cannot be supposed that they will become either reciprocally repulsive, or less susceptible of cohesive attraction, merely in consequence of their undergoing a vibratory movement.

Professor Olmsted had evidently a very imperfect recollection of the design, or execution of my essay, when he wrote his critique; or he could not have denounced it as idly employing in chemistry, those mechanical reasonings which it was intended to explode. In the article now under consideration, he repeats this error in the following words:

> "In the year 1822, Dr Hare published an essay aiming to prove that caloric, or the cause of heat, is a material fluid."

I never wrote an essay, to which this description is applicable. It did not appear to me expedient to recapitulate all the various well known arguments in favour of a material cause of calorific repulsion. To explain the phenomena of heat, but two hypotheses had been suggested, one ascribing them to caloric, the other to motion. The object of my essay was mainly to show, that motion could not be the cause of heat, and I only incidentally introduced some direct arguments in favour of a material cause.

I shall proceed to give other instances of the precipitancy of Professor Olmsted.

The existence of repulsion and attraction as properties of matter, being referred to, as self-evident, and their co-existence as properties of the same particles, shown to be inconceivable, I assumed that there must be a "matter in which repulsion resides, as well as a matter in which attraction resides."

This induces Professor Olmsted to make the following inquiry:

> "Does Dr. Hare maintain that the attraction which bodies exert, resides in a kind of matter extrinsic to the bodies themselves?"

It would be impossible, I think, to give a better answer to this query, than is afforded by the following words of my essay, contained in the very next paragraph below that, which has given rise to Professor Olmsted's embarrassment.

"Substances endowed with attraction make themselves known to us by that species of this power which we call gravitation, by which they are drawn towards the earth, and are therefore heavy or ponderable; by their resistance to our bodies, producing the sensation of feeling, or touch; and by the vibrations, or movements, which they excite in other matter, affecting the ear with sounds, and the eye by a modified reflection or transmission of light."

Had not the Professor neglected this sentence, he could not have required any further information respecting the kind of matter in which attraction resides, pursuant to my view of the subject; and independently of this unaccountable oversight, I do not know how he could take up the idea, that I considered the matter in which attraction resides, as any other than that usually recognised as matter, by people of common sense. Does my allegation that there must be as many kinds of matter as there are incompatible properties, convey the idea, that there must be more kinds of matter than there are of such properties? Founding injudicious inferences with respect to my opinions, upon errors arising from his own inattention, the Professor proceeds—

> "I have met with no late writer who has taken it for granted that there is matter in which attraction resides, distinct from the bodies themselves, which exert this influence on each other. But if Dr. Hare is not thus to be understood—if he do not mean to assert such a doctrine, then why does he conceive it necessary to suppose a fluid upon which the phenomena of repulsion depend—in which the self-repellent power resides, distinct from the bodies themselves, which exhibit such repulsion?"

I have said that the particles of ponderable matter obviously possess the power of mutual attraction; they cannot then be endowed at the same time with reciprocal repulsion. But if they cannot be endowed with repulsion, why should they be endowed with attraction, says my antagonist.

If I were to allege the whiteness of a thing, as a reason why it could not be black, would any person in his senses say, but if it cannot be black, how can it be white? Does the presence of attraction prove the absence of attraction, because it proves the absence of repulsion?

Since there is no permanent quality observed in the particles of ponderable matter, inconsistent with their exercising attraction, and as it would be unphilosophical to suppose more causes than are necessary to explain the phenomena, so it would be unreasonable to ascribe their attractive power to an extraneous principle. I allude here to attraction of cohesion or gravitation. That chemical affinity is much under the influence of the electric fluid, is now generally admitted. But to return to the critique—

"Will Dr. Hare explain the fact, that caloric sometimes increases the attraction of bodies for each other? What would he say of the fact, that the attraction of two gases is sometimes increased by heat?"

I will not undertake to explain that which does not occur. When a mixture of hydrogen and oxygen gas is heated, it expands. So long as expansion continues, it is obvious that caloric does not increase attraction. At the temperature of ignition, the heterogeneous particles combine, and an explosion ensues.

Thus at the same moment that the simple atoms unite, the compound atoms formed by their union, separate explosively. The elevation of temperature is productive of expansion throughout the whole process; first, of the gaseous mixture, and afterwards of the aqueous vapour. The union which is meanwhile effected of the heterogeneous atoms, is evidently dependent on some principle or property of which we are ignorant

In a mixture of hydrogen and oxygen gas, the caloric with which they are severally combined may attach itself in the first instance to both poles of each simple particle, after their union, to only one pole of each simple particle; and of course to two poles of the compound particle forming water. Elevation of temperature may favour this change by its mysterious influence on the electric polarities of the particles; as in the case of the tourmaline; or because the enlargement of the calorific atmospheres renders the preservation of their independency more difficult.

That caloric is alternately an exciting cause of combination, and decomposition, we all know. Mercury is oxidised at one temperature, and revived at another. At a low temperature potassium absorbs oxygen more greedily than carbon or iron, while the reverse is true when these are heated to incandescence. I have long suspected that heat promotes and modifies chemical action, by influencing electrical polarities. The elements of water are severed by the voltaic poles. If in this case their polarity is influenced in one way, elevation of temperature, when it causes their reunion, must have an opposite effect, and of course must influence polarity.

I suppose in this case a change in the attractive power of the poles, of combining atoms, analogous to that which may be induced in iron bars, which attract or repel each other accordingly as the magnetism communicated to their poles, is alike, or unlike.

Platina sponge, a cold metallic mass, is found to cause the union of the hydrogen and oxygen in a gaseous mixture: yet it is utterly inconceivable that the presence of particles so inert as to combine with neither of the elements of water, can cause an increase of attraction between them.

That the phenomena just alluded to, belong to a department of chemistry, with which we are but imperfectly acquainted, I admit; but on that very account inferences, founded on them, ought not to be allowed to invalidate the demonstration, of which the existence of a material cause of heat is, upon other grounds, susceptible.

Professor Olmsted cannot discover that there is

> "Any more difficulty in conceiving why a heated body should communicate its influence to another body without the aid of air, than why the sun should communicate his attractive influence to Saturn or Uranus, without the aid of such a medium!"

It would seem then that Professor Olmsted is of opinion that the planets owe their power of attracting each other, and all the bodies on or near their surfaces, to the sun, as they owe their light; and that his removal from the system would destroy the attraction between them and their satellites. This is a glaring error. The reaction between the sun, planets, and satellites, is reciprocal, arising from a quality inseparable from either, and which admits of no transfer.

If the sun did "communicate his attractive influence" to the other bodies in the solar system, I should be unable to say why he might not communicate any other property. The transmission of heat, in vacuo, is analogous to the radiation of light, not to the reciprocal influence of gravitation. If the illumination of Saturn or Uranus, could be explained without supposing the existence of a material fluid, I grant that the passage of heat in vacuo ought to admit of a similar explanation.

But as it is to me inconceivable, and contradictory to the obvious meaning of the word, to suppose the existence of a property without matter to which it may belong, so it appears impossible that there can be a transfer of a property effected through a space otherwise void, without a transfer of matter.

The following paragraph was written in opposition to the hypothesis of motion. It is noticed by Professor Olmsted, as if intended directly to support the materiality of heat, as the reader will perceive by his remarks, which I shall also quote. My language is as follows:

"It is inconceivable that the particles of steam, should by any force, arising from their motion, impart to the piston of a steam engine the wonted power; or that the particles of air should prevent a column of mercury, almost infinitely heavier, from entering any space in which they may be included, by beating it out of the theatre of their vibratory and rotatory movements."

To this Professor Olmsted replies:

> "Has not Dr. Hare plainly fallen into a mistake here? It evidently is not heat which moves the piston of a steam engine, but it is the elastic force of steam. But, it may be asked, is not that elasticity caused by heat? True; but the effect is not the same thing with the cause."

Was ever an inquiry more irrelevant? Where have I said that heat does move the piston of a steam engine? In the paragraph above quoted, which gives rise to the inquiry, I have only alleged that the particles of steam could not move it in consequence of a force arising from their motion. In order to show that I have committed a mistake "here," it must be proved that it is conceivable that the particles of steam should, by a force arising from their motion, impart to the piston of the steam engine the wonted power, or that the particles of air should, in like manner, "support a column of mercury almost infinitely heavier."

It evidently would be absurd to suppose that the piston of a steam engine could be propelled by the direct influence of caloric, without the intermediate effect of the elasticity of vapour.

The author combats strange opinions, created in his own imagination, as if I were answerable for them.

"It is difficult," says Professor Olmsted, "to see why heat should impart such a wonderful power to steam; nor does our supposing it to be a material fluid diminish this difficulty." He might with equal propriety add, it is difficult to understand how light can impart to the objects around us the wonderful power of conveying their images to the sensorium; nor does the idea of a material fluid, passing from them to the retina of the eye, diminish the difficulty.

It is difficult to understand why lead should be heavy; nor does the idea, that the earth attracts it, diminish the difficulty.

My mind is much less embarrassed by supposing a cause, where I observe an effect. That the earth should, by solar attraction, be kept in its orbit, is in the highest degree wonderful, yet it much less embarrasses me than if there were no solar attraction. Wonderful as it is that all the phenomena of vision should be due to the transmission, reflection, refraction, or polarization of a subtile matter emanating from every luminous point in the creation, the phenomena in question appear far less perplexing, than when I endeavour to dispense with the agency of a material cause. The opposite properties of the tenacity of ice, and the explosiveness of steam, however surprising, are less so when considered as belonging, the one to calorific, the other to aqueous particles, than when I suppose the same particles to assume them alternately, so as to cohere at one time, and at another fly apart with violence, without any cause for the change.

It seems to me, that without the special interference of the Creator, the properties of any species of matter, must always remain the same. Should any property appear to cease, or to be varied, there must be an accession or an avolation of matter differently endowed from that in which the change is observed.

"Has not Dr. Hare committed a mistake in understanding Sir Humphry Davy to assert that heat is motion; whereas, his doctrine is, that motion is the cause of heat."

The author forgets that the word heat is used to signify a cause as well as an effect; when I have spoken of motion as substituted for heat, I meant that it was substituted for the cause of sensible heat. The phenomenon which we call sensible heat, is the effect of motion according to one hypothesis of caloric; or latent heat, according to the other. It appears, therefore that, when correctly examined, the definition which I have given of Davy's hypothesis, is the same as that which the author sanctions.

To conclude, I regret that instead of having only to encounter difficulties inherent in the subject, I should be obliged to occupy so many pages in refuting criticisms respecting which, I can sincerely say in the author's own language, that they are "idle," and have "no bearing whatever" upon the subject which has called them forth.

ESSAY,

ON THE GALES EXPERIENCED IN THE ATLANTIC STATES OF NORTH AMERICA.

Of the gales experienced in the Atlantic States of North America, those from the north-east, and north-west, are by far the most influential: the one, remarkable for its dryness—the other, for its humidity. During a north-western gale, the sky, unless at its commencement, is always peculiarly clear, and not only water, but ice, evaporates rapidly. A north-east wind, when it approaches to the nature of a durable gale, is always accompanied by clouds, and usually by rain or snow. The object of the following essay, is to account for this striking diversity of character.

When by a rise of temperature in any surface with which the lower particles of any non-elastic fluid may be in contact, they are rendered warmer, and of course lighter than the particles which are above them, an exchange of position must ensue. The particles which being at the top, were coldest at first, after their descent, and consequent contiguity with the heated surface, becoming the warmest, resume their previous elevation, from which, they are again displaced by particles subsequently rendered still warmer. Thus the temperatures of the particles, reversing their situations, and the change of their situations causing a reversal of temperature, a circulation is kept up, tending to restore the equilibrium.*

Precisely similar would be the case with our atmosphere, were *it* a *non-elastic fluid*, and its density regulated by heat, independently of pressure. In temperature its variations would be much less extensive, and far more gradual than at present. An interchange of position would incessantly take place, between the colder air of the upper regions, and the warmer, and of course lighter, air, near the earth's surface, where there is the most copious evolution of solar heat. Currents would incessantly set from the poles to the equator below, and from the equator to the poles above. Such currents would constitute our only winds, unless where mountains might produce some deviations. Violent gales, squalls, or tornadoes, would never ensue. Gentler movements would anticipate them. But the actual character of the air, with

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* See Compendium, page 58, article 58.

respect to elasticity, is the opposite of that which we have supposed. Being perfectly elastic, its density is dependent on pressure, as well as on heat; and it does not follow, that air which may be heated, in consequence of its proximity to the earth, will give place to colder air from above. The pressure of the atmosphere varying with the elevation, one stratum of air may be as much rarer by the diminution of pressure, consequent to its altitude, as denser by the cold, consequent to its remoteness from the earth—and another may be as much denser by the increased pressure arising from its proximity to the earth, as rarer by being warmer. Hence when unequally heated, different strata of the atmosphere do not always disturb each other. Yet after a time, the rarefaction in the lower stratum, by greater heat, may so far exceed that in an upper stratum, arising from an inferior degree of pressure, that this stratum may preponderate, and begin to descend. Whenever such a movement commences, it must proceed with increasing velocity; for the pressure on the upper stratum, and of course its density and weight, increases as it falls; while the density and weight of the lower stratum, must lessen as it rises. Hence the change is, at times, so much accelerated, as to assume the characteristics of a tornado, squall, or hurricane. In like manner may we suppose, the predominant gales of our climate to originate. Dr. Franklin, long ago, noticed, that north-eastern gales are felt in the south-westernmost portions of the continent first—the time of their commencement being found later, as the place of observation is more to the windward.

The Gulf of Mexico is an immense body of water, warm, in the first place, by its latitude, in the second place, by its being a receptacle of the current produced by the trade winds, which blow in such a direction, as to propel the warm water of the torrid zone into it, causing it to overflow and produce the celebrated Gulf Stream, by the ejection, to the north-east, of the excess received from the south-east. This stream runs away to the northward and eastward of the United States, producing an unnatural warmth in the ocean, as well as an impetus, which, according to Humboldt, is not expended, until the current reaches the shores of Africa, and even mixes with the parent flood under the equator. The heat of the Gulf Stream, enables mariners to ascertain, by the thermometer, when they have entered it: and in winter, this heat, by increasing the solvent power of the adjoining air, loads it with moisture—which, on a subsequent reduction of temperature, is precipitated in those well known fogs, with which the north-eastern portion of our continent, and the neighbouring seas and islands, especially Newfoundland and its banks, are so much infested. An accumulation of warm water in the Gulf of Mexico, adequate thus to influence the ocean at the distance of two thousand miles, may be expected, in its vicinity, to have effects proportionally powerful. The air immediately over the Gulf must be heated, and surcharged with aqueous particles. Thus it will become comparatively light; first, because it is comparatively warm—and in the next place, because aqueous vapour, being much lighter than the atmospheric air, renders it more buoyant by its admixture.

Yet the density, arising from inferiority of situation in the stratum of air immediately over the Gulf, compared with that of the volumes of this fluid lying upon the mountainous country beyond it, may, to a certain extent, more than compensate for the influence of the heat and moisture derived from the Gulf: but violent winds must arise, as soon as these causes predominate over atmospheric pressure, sufficiently to render the cold air of the mountains heavier.

When, instead of the air covering a small portion of the mountainous or table land in Spanish America, that of the whole north-eastern portion of the North American continent, is excited into motion, the effects cannot be less powerful, and must be much more permanent. The air of the adjoining country first precipitates itself upon the surface of the Gulf, and afterwards, that from regions more distant. Thus a current from the north-east is produced below. In the interim, the air displaced by this current rises, and being confined by the table land of Spanish America, and in part, possibly, by the trade winds, from passing off in any southerly course, is, of necessity, forced to proceed over our part of the continent, forming a south-western current above us. At the same time, its capacity for heat being enlarged, by the rarefaction arising from its increased altitude, much of its moisture will be precipitated; and the lower stratum of the south-western current, mixing with the upper stratum of the colder north-eastern current below, there must be a prodigious condensation of aqueous vapour.

The reason is obvious, why this change is productive only of north-eastern gales; and that we have not northern gales, accompanied by the same phenomena. The course of our mountains, is from the north-east to the south-west. Thus no channel is afforded for the air proceeding to the Gulf, in any other course, than that north-eastern route which it actually pursues.

That the table lands of Mexico are competent to prevent the escape, over them, of the moist warm air, displaced from the surface of the Gulf, must be evident, from the peculiar dryness of their climate, and the testimony of Humboldt. According to this celebrated traveller, the clouds formed over the Gulf, never rise to a greater height than four thousand nine hundred feet; while the table land, for many hundred leagues, lies between the elevation of seven and nine thousand feet. Consistently with the chemical laws, which have been experimentally ascertained to operate throughout nature, air, which has been in contact with water, can neither be cooled nor rarefied, without being rendered cloudy by the precipitation of aqueous particles. It follows, that the air displaced suddenly from the surface of the Gulf of Mexico, by the influx of cold air from the north-east, never rises higher than the elevation mentioned by Humboldt, as infested by clouds. Of course, it never crosses the table land, which, at the lowest, is 2000 feet higher.

Our north-western winds are produced, no doubt, by the accumulation of warm moist air upon the surface of the ocean, as those from the north-east are, by its accumulation on the Gulf of Mexico. But in the case of the Atlantic, there are no mountains to roll back, upon our hemisphere, the air displaced by the gales which proceed from it, and to impede the impulse, thus received, from reaching the Eastern Continent. Our own mountains may procrastinate the flood, and consequently render it more lasting and violent, when it can no longer be restrained. The direction of the wind is naturally at right angles to the boundary of the maritime region producing it, and to the mountainous barrier which delays the crisis.

The course of the North American coast is, like that of its mountains, from north-east to south-west—and the gales, in question, are always nearly north-west, or at right angles, to the mountains, and the coast. The dryness of our north-west wind may be ascribed not only to its coming from the frozen zone, where cold deprives the air of moisture, but likewise to the circumstance above suggested, that the air of the ocean is not, like that of the Gulf, forced back over our heads, to deluge us with rain.

Other important applications may be made of our chemical knowledge. Thus, in the immense capacity of water for heat, especially when vaporized, we see a great magazine of nature, provided for mitigating the severity of the winter.—To cool this fluid, a much greater quantity of earth must sustain a proportionable increase of its sensible heat.—Aqueous vapour is incessantly a vehicle for conveying the caloric of warmer climates, to colder ones. Mistaking the effect for the cause, snow storms are considered by the ignorant as the cause of cold weather. But it is well known that the aqueous vapour, which by condensation and congelation is converted into snow, during this conversion abandons as much caloric as would raise ten times its weight of liquid water 100 degrees. The quantum of caloric which can raise ten parts of water one hundred degrees, would raise one part one thousand degrees, nearly (or to a red heat visible in the day).

Further—the quantum of heat which would raise water to 1000, would elevate an equal bulk of glass to 2000. Hence we may infer, that from every snow, there is received twice as much caloric, as would be yielded by an equal weight of red hot powdered glass.

It is thus that the turbulent wave, which at one moment rocks the mariner's sea-boat, on the border of the torrid zone, transformed into a cloud, and borne away towards the arctic, soon after supports the sledge, or the snow-shoe, of an Esquimaux or Greenlander; successively cooling or warming the surrounding media, by absorbing or giving out the material cause of heat.

STRICTURES

ON A PUBLICATION ENTITLED CLARK'S GAS BLOWPIPE.*

(*See Compendium, page* 77.)

Dr. Clark has published a book on the Gas Blowpipe, in which he professes a "sincere desire to render every one his due." That it would be difficult for the conduct of an author to be more discordant with these professions, I pledge myself to prove in the following pages, to any reader whose love of justice may gain for them an attentive perusal.

In the year 1802, in a memoir republished in the 14th Vol. of Tilloch's Philosophical Magazine, London, and in the 45th Vol. of the Annales de Chimie, I had given the rationale of the heat produced by the combustion of the aëriform elements of water, and had devised a mode of igniting them free from the danger of explosion. I had also stated in the same memoir that the light and heat of the flame thus produced were so intense, that "the eyes could scarcely sustain the one, nor the most refractory substances resist the other," and had likewise mentioned the fusion of the pure earths and volatilization of the perfect metals as among the results of the invention.

Subsequently, in the first part of the 6th Vol. of American Philosophical Transactions, an account of the fusion of strontites, and the volatilization of platinum, was published by me.

About the same time my experiments were repeated before Dr. Priestley, who gave them the credit of being quite original.

Some years afterwards, Mr. Cloud, of the United States' Mint, who had distinguished himself by the discovery of a native alloy of gold with palladium, having obtained some platina which he considered as perfectly pure, requested me to subject a portion of it to the flame of the compound blowpipe. In the presence of Mr. Cloud I was enabled completely to dissipate a portion of the platina which he had thus prepared.

He was so much pleased with my experiments that he made an apparatus for himself, simplifying that part which was employed for holding the aëriform agents, by the omission of some appendages which were not necessary to his purpose.† Thus modified, my apparatus was introduced into use by Mr. Rubens Peale; and was for about ten years employed by him to amuse visiters at the celebrated museum established by his father in Philadelphia.

It appears by the testimony of Professor Silliman and others, that Dr. Hope had, during his lectures at different times within a period of eight years, employed my blowpipe, and awarded the invention of it to me. A reference to the third edition of Murray's Chemistry, published before Dr. Clark attended to the subject,

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* First published in 1819.

† It has been erroneously alleged that he simplified the blowpipe.

will demonstrate the impressions of the author of that work; as the results which I had published, are there quoted as mine exclusively.

The memoir of Professor Silliman, read before the Connecticut Academy of Sciences, in May, 1812, and republished in Tilloch's Magazine, but which Dr. Clark has not ventured to notice, affords the most unanswerable evidence that we had anticipated him in almost every important experiment.

Mr. Reuben Haines, corresponding secretary of the Academy of Natural Sciences of Philadelphia, informed me, in 1813, that in the laboratory of Dr. Parish, a mixture of the gaseous elements of water had been inflamed while issuing in a stream from a punctured bladder previously filled with them and duly compressed. Any relaxation of the pressure was of course productive of an explosion. Mr. Haines recollects that I at the same time suggested that the hydro-oxygen flame might be supported by a stream of the gases, mingled previously in a reservoir in due proportion, the danger of explosion being obviated by the interposition of a water valve. Cares more imperious, however, soon diverted my thoughts from the execution of a plan which I did not consider as preferable to that which I had before successfully pursued.

Some time afterwards, Sir Humphry Davy's discovery of the influence of narrow metallic apertures in impeding explosions, encouraged Dr. Clark and others to hazard the use of a mixed stream of hydrogen and oxygen gas, ignited while flowing from a common recipient, instead of allowing them, as I had done, to mix only during their efflux. There is another unimportant difference in the modes of operating. In mine, hydrostatic pressure is employed to expel the gases from a vessel into which they are introduced either directly from the generating apparatus, or indirectly from bell glasses and other receptacles, by means of a bellows. In the new mode, being pumped into the recipient by one aperture, they flowed out at another in consequence of their elasticity.

Dr. Clark pretends that the process he has employed is the best. Admitting this, would it afford him any excuse for taking so little notice of mine, or attributing the discovery of it to others, especially while professing to give *a fair history* of the invention?

If I may be allowed to compare small things with great, when Mr. Cruikshank and Sir H. Davy improved the galvanic apparatus by modifying and enlarging it, did they on that account forget that Volta was the inventor of the pile? was it not still (though no longer a pile) called the Voltaic series?

Dr. Clark, finding that he cannot prove himself and his associates to have originated the hydro-oxygen blowpipe, ascribes it to Lavoisier. Had this been stated in his first papers his motives would have been less questionable. But why does he not refer to his authorities? In other cases he is very particular in making such references.

We all know, that with a view to recompose water, Lavoisier caused the gaseous constituents of this fluid to burn within a glass globe, into which they entered by orifices *remote* from each other;* but if he ever caused them to burn at a common orifice in the open air for the purpose of producing heat, wherefore is Dr. Clark the first and only person to communicate the fact to the public? How does it happen that we can find neither in the elementary treatise of Lavoisier, nor in any of the cotemporary journals, any account of the invention, or of the results alleged to have been attained by it. On the contrary, in the Elements just alluded to, the celebrated author treats of the heat produced by oxygen and carbon, as the highest producible by art.

Dr. Clark alleges that Dr. Thomson, now Professor of Chemistry at Glasgow, made experiments with the mixed gases seventeen years ago, but was induced to abandon the undertaking, in consequence of accidents which happened to his apparatus. Can any thing more fully display unfairness, than that abortive experiments, made subsequently to those in which I was successful, should be adduced as subversive of my pretensions?

Dr. Clark states that the Americans claim the invention on account of experiments made by me in 1802. They were published in 1802; my apparatus and my first experiments were made in 1801.

Had Lavoisier, or any other person, availed himself of the heat produced by the union of the gaseous elements of water, how could the sagacious Dr. Thomson fail in his efforts to retrace a path so well and recently trodden: or if deriving any advantage from the experiments either of the French philosopher, or those which he so imperfectly tried, why did he conceal it when occupied during so many years in communicating to the world all his chemical knowledge in five successive editions of his system?

So far were Dr. Thomson's experiments, or his knowledge on these subjects, from reaching the facts discovered by me, that he appears to have considered the authority of one name inadequate to establish, what he vainly had endeavoured to effect. Hence until plagiarism had given them a new shape, and perhaps a false gilding, they were totally overlooked in his compilations. He neither treated of the pure earths as susceptible of fusion, nor of platina, as susceptible of volatilization, until many years after I had proved them to be so, and promulgated my observations.

Dr. Clark assumes great credit for having first pointed out the importance of employing the gases in such relative quantities as might enable them fully to saturate each other. To me it would seem, where the highest heat is desired, evidently absurd to employ them in any other way, because if either gas were present in too great a quantity to be acted upon, the excess would be worse than useless. Is it not universally an object with chemists to use ingredients in the proportions in which they saturate each other, especially, when within a given space and time the most intense reaction is to be induced?

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* See plate, fig. 10—also, Compendium, page 130, article 134.

The author of this *professedly candid* publication would wish to convey the idea of my apparatus being so inferior in power to that adopted by him, as to render it unnecessary, in a history of the invention, to quote my experiments. Accordingly he alludes to them obscurely, and in a manner tending rather to derogate, than to do justice. This procedure would be unjustifiable, were the heat which he has produced, decidedly greater than that produced by me. But the fact is otherwise. He fuses with difficulty Oolite, Iceland crystal, and pure native magnesia. The fusion of the best magnesia of the shops, and of quicklime from pure limestone was among my first efforts, and was mentioned in a preface, omitted in republishing my memoir. Lately I have fused a piece of oystershell lime, which is perhaps as pure as any to be obtained by artificial purification.

Dr. C. has employed platina in some cases to secure refractory earths while exposed to the action of his instrument, although this metal is dissipated by the heat of mine.

It will be evident, from some passages which I shall presently quote, that Dr. Clark did not anticipate Professor Silliman or myself, in his inferences respecting the decomposition of the earths: that his alleged reduction of them, to the metallic state, was imaginary, as I hinted in the first edition of this essay, is now, I believe, universally admitted.

But while the superiority of the temperature attained by mixing the gases before emission is questionable, there are great and undeniable advantages in having them propelled from different reservoirs. First, a degree of security from explosion, which cannot be attained with one common recipient.* 2d. The possibility of operating on a large scale without danger. 3d. The power of varying the relative proportions of the gases so as to oxidize, or deoxidize, as may be desirable. This power is given by the common blowpipe, though in a different way, and is well known to be very useful.

I cannot perceive the smallest foundation for the analogy which the author supposes between the phenomena of the gas blowpipe, and those of volcanoes.

In order to put the gas blowpipe into operation, it is indispensable that there should be hydrogen and oxygen gases, confined under moderate and equable compression, so as to flow out regularly from a common aperture, at which they may be ignited. How are these

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* Where the gases are kept unmixed in separate reservoirs, and meet only near the point of efflux in an orifice sufficiently large, as was the case with the original compound blowpipe, explosion is obviously impossible. If the orifice be made smaller, and the gases mix at a greater distance from the place of efflux, valves should be interposed in the pipes, or the gases should be kept under equable pressure, as it is possible that if subjected to unequal pressure, the gas which is more compressed, may pass from one reservoir to the other, on leaving the cocks open, accidentally. This, however, is an oversight not likely to take place, as it is so evidently accompanied by a waste of the gas, that an operator will hardly be so careless as not to close the cocks when the flame is not wanted. Closing them is in fact the usual mode of extinguishing the flame.

requisites to be obtained in nature? Whence the pure hydrogen or oxygen? Has Dr. Clark, or any other person, known them to be extricated in purity? Is not the former always carburetted or sulphuretted, or otherwise impure, and the latter never purer than in the atmosphere? When obtained by art, fire is requisite to liberate oxygen, but in nature, the fumes of the fire would contaminate any gas which it might evolve; and it ought not to be forgotten that the circumstances which are favourable to the evolution of oxygen, are inimical to the liberation of hydrogen. Again, supposing the gaseous materials generated, where is the presiding demon with the genius to design, and skill to regulate, that due admixture of them which the author exults in having discovered to be necessary. And granting that there could be in nature any competent substitute for human agency in a process so intricate, by what means, in operations so rude and extensive, is that retrocession of the flame to be prevented, to obviate which, in operating with his minute apparatus, a capillary tube has been found indispensable. In subterranean caverns, the gaseous elements of water might create explosions, but could never support the permanent heat requisite to fuse an ocean of lava.

The only difficulty this subject presents, is that of explaining the nature of volcanic fires, of which the incessant existence is self-evident. The access of the atmosphere is necessary to fire in all its ordinary forms. In that of volcanoes, it appears to subsist without any adequate supply of this principle. Dr. Clark, far from relieving us from this difficulty, has increased it, by alleging the necessity of another aëriform substance. A better solution, as I should suppose, was long ago afforded by a reference to the combustion of metals by sulphur, in the vapour of which some of them burn more readily than in the atmosphere. Lately, the metallic origin of earthy matter being discovered, it has been supposed possible, that at some distance from its surface the globe may consist of a great metalloidal nucleus, which acting on water, may produce intense ignition.* The prodigious quantity of ignited matter ejected during volcanic eruptions, demonstrates the existence of immense subterranean fires, whatever may be the rationale of their origin. The obvious proximity of springs, rivers, and even of the sea itself, with the well known force of steam, renders it easy to point out the proximate cause of earthquakes, or of volcanic explosions and eruptions, without calling in the gas blowpipe to our assistance.

That Dr. Clark could not without great injustice bring forward his mode of operating, otherwise than as another method of attaining results which I had previously accomplished, nor his experiments, unless as an extension of those made by Professor Silliman and myself, will be perfectly evident, if it be considered that we all employed a flame of the gaseous elements of water, in the one

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* We are indebted for this hypothesis, as well as for the facts upon which it rests, to Sir H. Davy.

case, mixed during the efflux, in the other, before; and that the most important results in both instances will, on comparison, be found nearly the same.

The mode of confining and propelling the gases through the pipe or pipes to the place of efflux, is irrelevant to the question. There are many methods by which this object may be accomplished. The principle of the apparatus used by Dr. C. will be found the same as that of the air vault employed in England to regulate the blast of large bellows at founderies and forges. Mr. Brook was the first to apply it to the regulation of a blowpipe, and published his account of it in April, 1816.

I will proceed to quote and exhibit alternately, the observations and experiments of Dr. Clark, and those of Professor Silliman and myself.

I shall refer to Tilloch's Philosophical Magazine, Vol. 14, for my memoir; to Vol. 50 for that of Silliman.*

For Dr. Clark's experiments commenced in 1816, I shall quote his book on the gas blowpipe, published in 1819.

Experiments on Lime.

Hare, page 304. "Lime and magnesia are extremely difficult to fuse, not only because they are the most refractory substances in nature, but from the difficulty of preventing them from being blown on one side by the flame: nevertheless, in some instances, by exposure on carbon to the gaseous flame, small portions of these earths were converted into black vitreous masses. Possibly the black colour of these products of fusion, may have been caused by iron contained in the coal; for in the high temperature of the gaseous flame a powerful attraction is exerted between iron and the earths."

Hare, page 306. "There is a species of coal (anthracite) found on the banks of the Lehigh in this State, which is extremely difficult to ignite; yet when exposed to a high degree of heat and a copious supply of air, it burns, yielding an intense heat, without either smoke or flame, and leaving little residue. By exposure to the gaseous flame on this coal, both magnesia and lime exhibited strong symptoms of fusion. The former assumed a glazed and somewhat globular appearance, the latter became converted into a brownish semivitreous mass."

Silliman, page 109. "A piece of lime from the Carrara marble was strongly ignited in a covered platina crucible; one angle of it was then shaped into a small cylinder, about one-fourth of an inch high, and somewhat thicker than a great pin. The cylinder remained in connexion with the piece of lime. This was held by a pair of forceps, and thus the small cylinder of lime was brought into contact with the heat without danger of being blown away, and without a possibility of contamination. There was this further advantage (as the experiment was delicate, and the determination of the result might be difficult) that as the cylinder was held in a perpendicular position, if the lime did really melt, the column must sink and become at least to a degree blended with the supporting mass of lime. When the compound flame fell upon the lime, the splendour of the light was perfectly insupportable by the naked eye, and when viewed through deep coloured glasses the lime was seen to become rounded at the angles, and gradually to sink, till in the course of a few seconds, only a small globular protuberance remained, and the mass of supporting lime was superficially fused at the base of the column for a space of half an inch in diameter. The protuberance as well as the contiguous portion of lime was converted into a perfectly white and glistening enamel. A magnifying glass discovered a few minute pores, but not the slightest earthy appearance. This experiment was repeated several times, and with uniform success; may not lime therefore be added to the list of fusible bodies?"

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* Silliman's experiments were performed in December, 1811, and published in Bruce's Journal in 1812.

Clark, page 47. "Lime in a state of perfect purity and in the pulverulent form being placed within a platinum crucible, and exposed to the flame of the blowpipe, its upper surface became covered with a limpid botryoidal glass, resembling hyalite; the inferior surface was quite black. Its fusion was accompanied by a lambent purple flame. This colour therefore may be considered as a characteristic hue of one at least of the oxides of calcium."

Clark, page 49, *No.* 6. "Compact transition limestone (limestone of Parnassus). The specimen was taken from the summit of Parnassus by the author. It was fused, but with great difficulty, exhibiting after fusion a white milky enamel with points of intumescence that were transparent."

Experiments on Magnesia.

Silliman, page 110. "The same circumstances that rendered the operating on lime difficult, existed in a still greater degree with respect to magnesia: its lightness and pulverulent form rendered it impossible to confine it for a moment upon the charcoal; and as it has very little cohesion, it could not be shaped by the knife as the lime had been. After being calcined at full ignition in a covered platinum crucible, it was kneaded with water, till it became of the consistency of dough. It was then shaped into a rude cone as acute as might be, but still very blunt. The cone was three-fourths of an inch long, and was supported upon a coiled wire. The magnesia thus prepared was exposed to the compound flame; the escape of the water caused the vertex of the cone to fly off repeatedly in flakes, and the top of the frustum that thus remained gave nearly as powerful a reflection of light as the lime had done. From the bulk of the piece (it being now one-fourth of an inch in diameter at the part where the flame was applied) no perceptible sinking could be expected. After a few seconds, the piece being examined with a magnifying glass, no roughness or earthy particles could be perceived on the spot, but a number of glassy smooth protuberances whose surface was a perfectly white enamel. This experiment was repeated with the same success. May not magnesia then be also added to the table of fusible bodies?"

Notwithstanding the previous publicity of these results obtained by my friend and myself, Dr. Clark, in the following note, endeavours to convey an impression of the incompetency of my apparatus to fuse lime and magnesia. Note 5, page 46. "Professor Hare in America could not accomplish the fusion either of lime or magnesia by means of his hydrostatic blowpipe. See Annales de Chimie, tome 45, page 126." But why overlook Silliman's experiments. It is moreover strange that an English writer should refer his readers to the French Annales in preference to a London Magazine, for a memoir published in both.[*]

Pure Oxide of Magnesium (Magnesia).

Clark, page 53. "Fusion, per se, extremely difficult. When the earth is made to adhere (by moisture with distilled water and subsequent desiccation) and placed upon charcoal, it is fusible into a whitish glass; but the parts in contact with the charcoal acquire an imposing pseudo metallic lustre with a purple coloured flame."

Hydrate of Magnesia (pure foliated Magnesia from America).

Clark, page 53. "This substance is incomparably refractory; with the utmost intensity of the heat of the gas blowpipe, it is ultimately reducible to a white opake enamel invested with a thin superficies of limpid glass. Its fusion is accompanied with a purple coloured flame."

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[*] I have mentioned above my having fused a piece of oyster shell lime. It was exposed to the flame within an envelope of platina foil, which was soon reduced to a fluid globule. The application of the heat being suspended (when both substances had become cold,) the earth was found adhering on top of the metal. This enabled me to make it receive the greatest heat of the flame on renewing the process. The lime then melted into a liquid, which subsiding round the globule of platina caused it to appear after cooling, as if set in enamel.

Experiments on Corundum.

Silliman, page 112. "Corundum of the East-Indies was *immediately* and *perfectly* fused into a grey globule." "Corundum of China the same with active ebullition."

Clark, page 56. "Common corundum (greenish gray crystallized primary corundum from the East Indies,) *fusible but with difficulty,* into a greenish coloured translucent glass nearly transparent, which at last becomes melted into a bead-like form; or otherwise exhibits upon its surface minute cavities caused by the escape of gas during its fusion. This gas is probably the same which pure silica more abundantly exhibits. A slightly coloured greenish flame accompanies the fusion of corundum."

Experiments on Sappar.

Silliman. "Sappar or kyanite perfectly and instantly fused with ebullition into a white enamel."

Clark, page 57. "This mineral, owing to its refractory nature, was used by Saussure as a supporter in experiments with the common blowpipe. It fuses very readily into a snow white frothy enamel."

Experiments on Zircon.

Silliman, page 112. "Zircon, of Ceylon, melted with ebullition, into a white enamel."

Clark, page 58. "One of the most refractory substances, exposed to the heat of the gas blowpipe, it becomes first opake and of a white colour; and afterwards its superficies undergoes a *partial fusion* and exhibits a white opake enamel resembling porcelain."*

Experiments on the Spinelle Ruby.

Silliman, page 112. "Spinelle ruby fused immediately into an elliptical red globule."

Clark, page 58. "Fuses readily and undergoes a partial combustion and volatilization with loss of colour and of weight. One of the solid angles of an octahedral crystal was entirely burned off, and volatilized in one of these experiments."

Experiments on Silex, Alumine, Barytes.

Hare, page 304. "By exposure to the gaseous flame either on supports of silver or of carbon, barytes, alumine, and silex were completely fused. The products of the fusion of alumine and silex were substances very similar to each other, and much resembling white enamel."

Silliman, page 109. "Silex, being in a fine powder it was blown away by the current of gas, but when moistened with water it becomes agglutinated by the heat, and was then perfectly fused into a colourless glass."

Clark, page 59. "Pure precipitated silica (peroxide of silicium) becomes instantly fused into an orange coloured transparent glass. The colour may be due either to the charcoal serving as a support, or to the carbon of the oil used for making it into a paste."

On the Reduction of the Earths to the Metallic State.

Hare, page 394. "The result of the fusion of barytes was a substance of an ash coloured cast, which after long exposure sometimes exhibited brilliant yellow specks. If it be certain that barytes is an earth, these specks must have been discoloured particles of the silver support, or of the pipes from which the flame issued."

Silliman, page 113. "During the action of the compound flame upon alkaline earths, provided they were supported by charcoal, distinct globules rolled and darted out from the ignited mass, and burnt sometimes vividly and with peculiarly coloured flame. From the nature of the experiments it will not be easy to prove that these globules were the bases of the earths, and yet there is the strongest reason to believe it. Circumstances could scarcely be devised more favourable to the simultaneous fusion and decomposition of these bodies: charcoal highly ignited for a support and an atmosphere of hydrogen also in vivid and intense ignition. That the oxygen should be under these circumstances detached is not surprising;

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* I might say here with truth, Professor Clark in England was unable to fuse zircon, in his mode of operating with the gas blowpipe.

but the high degree of heat and the presence of oxygen necessarily burn up the metalloids almost as soon as produced. If means could be devised to obviate this difficulty, the blowpipe of Mr. Hare might become an important instrument of analytical research. We can scarcely fail to attribute some of the appearances during the fusion of the leucite to the decomposition of the potash it contains. This impression was much strengthened by exposing potash and soda to the compound flame with a support of charcoal; they were evidently decomposed; numerous distinct globules rolled out from them and burnt with the peculiar vivid white light and flash which these metalloids exhibit, when produced and ignited in the galvanic circuit. It is hoped these hints may produce a further investigation of this subject. This communication has already been extended further than was contemplated: but on concluding, it may be allowable to remark that there is no body in all probability except a few of the combustible ones which is exempt from the law of fusion by heat."

Is there any apology for the manner in which, without the smallest acknowledgment for these suggestions, Dr. Clark has, in the following paragraph, brought himself and his friend before the public?

Clark's Gas Blowpipe, page 66.

"In proceeding to state the revival of two of the metals of the earths before the flame of the gas blowpipe, and of other metals under similar circumstances, it may be proper to prefix the ingenious theory of the Rev. J. Holme, of St. Peters' College, Cambridge, respecting the cause of the decomposition that takes place. 'It is entirely owing to the powerful attraction which hydrogen has to oxygen at such an exalted temperature.' The reduction or decomposition of oxides when exposed to the *gaseous flame** is therefore often instantaneous, and it is as instantly followed by the combustion of the minute particles thus revived, and ultimately by the decomposition of the regenerated oxide which is a result of that combustion. Hence the coloured flame; hence also the appearance of an oxide in a state of incomparably extreme division upon the supports used whether of metal or charcoal; an irrefragable test of the revival of the metal from whose combustion this newly formed oxide has been derived."

Experiments on Strontites.

Hare, Vol. 6, 1*st part*, American Philosophical Transactions, page 100. Republished Annales de Chimie, Vol. 5, page 81. "About the same time I discovered strontites to be a fusible substance; for having obtained a portion of this earth pure, from a specimen of the carbonate of strontites from Argyleshire in Scotland, I exposed it on charcoal to the flame of the compound blowpipe after the manner described in my memoir above alluded to. It became fused into a blackish semi-vitreous mass in shape somewhat semi-globular."

Clark, page 71. "Here a different process is necessary; the revival of the metal is rendered more difficult owing to the pulverulent state of the earth. The particles must be made to adhere before fusion can be accomplished, and this oxide being much more refractory than the preceding, is almost infusible, per se, even with the aid of the gas blowpipe."

Thus he admits that a substance is almost infusible in his hands, which has been repeatedly fused under mine.

Experiments and Observations on the Fusion, Volatilization, and Combustion of the Perfect Metals.

Hare, page 305.† "Had I sufficient confidence in my own judgment, I should declare that gold, silver, and platina, were thrown into a state of ebullition by exposure on carbon to the gaseous flame; for the pieces of charcoal on which they were exposed became washed or gilt with detached particles of metal in parts adjoining the spots where the exposure took place. Some of the particles of the metal thus detached exhibited symptoms of oxidizement."

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* The very phrase used by me in my original memoir. See quotation on the opposite page.

† Tilloch's Magazine.

Combustion of pure Gold.

Clark, page 90. "As this experiment affords decisive evidence of the *combustion of gold,* and of course its combination with oxygen, and also exhibits the oxide under a very beautiful appearance, it may be considered as one of the most pleasing experiments with the gas blowpipe."

Experiments on Platinum.

Hare, page 304.[*] "Platina was fused by exposure on carbon to the combustion of hydrogen gas with atmospheric air. But the fusion of this metal was rapidly accomplished by the gaseous flame either when exposed to it on carbon or upon metallic supports."

"A small quantity of this metal in its native granular form being strewed in a silver spoon and passed under the gaseous flame, the track of the flame became marked by the agglutination of the metal; and when the heat was for some time continued on a small space, a lump of fused platina became immediately formed. About two pennyweights of the native grains of platina, when subjected to the gaseous flame on carbon, became quickly fused into an oblate spheroid as fluid as mercury. This spheroid, after being cooled, was exposed as before; it became fluid in less than the fourth of a minute."

Hare, Vol. 6, 1*st part* of the Philosophical Transactions, page 99, republished Annales de Chimie, Vol. 60, page 81. "Being induced last winter to reinstate the apparatus by which these experiments were performed, I was enabled to confirm my judgment of the volatilization of platina by the observation of Drs. Woodhouse and Seybert; for in the presence of these skilful chemists, I completely dissipated some small globules of this metal of about the tenth of an inch in diameter. In fact I found platinum to be equally susceptible of rapid volatilization, whether exposed in its native granular form, or in that of globules obtained from the orange coloured precipitate of the nitro-muriatic solution by the muriate of ammonia."

Silliman, page 3. "Platinum was not only melted, but volatilized with strong ebullition."[†]

Clark, page 92. "The fusion of this metal, *owing to the great improvements here mentioned in the mode of using the gas blowpipe,* is now become so easy that this metal melts faster than lead in a common fire. It is no longer necessary to make use of wire in exhibiting its fusion and combustion. The cuttings which are sold by the manufacturers of platinum utensils are placed in a cupel, either mounted on a stand or held in a pair of forceps. The mouth of the jet is bent downwards so as to admit of a perpendicular direction of the gaseous flame upon the metal in the cupel. The flame is then suffered to act upon the platinum, about a quarter of an ounce of the metal being placed in the cupel at first; as soon as this begins to melt, more may be added until a cupel of the common size is nearly full of the boiling metal: and in this manner a mass of platinum weighing half an ounce at the least may be obtained in one brilliant bullet. This when rolled out, so that all air holes being removed the mass possesses a uniform density, will be found to have a specific gravity equal to 20.857. During the fusion of the metal, its combustion will be often if not always apparent. It will burn with scintillation, and particles of the black protoxide of platinum, if care be used, may be caught upon a sheet of white paper while combustion is going on."

Dr. Clark here evidently endeavours to produce the false impression that the facility with which platinum may be fused by the hydro-oxygen blowpipe, is owing to "the great improvements" made fourteen or fifteen years after I had, by similar means, attained the same results.

Silliman, last page. "The experiments which have now been related in connexion with the original ones of Mr. Hare, sufficiently show that science is not a little indebted to that gentleman for his ingenious and beautiful invention. It was

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[*] Tilloch's Magazine.

[†] *This note was added by Professor Silliman:—*

"The fusion and combustion and complete dissipation of platinum, gold, silver, nickel, cobalt, and most of the metals, and the fusion of the principal earths and of their most refractory compounds, by the use of Professor Hare's compound blowpipe, have been *the familiar and easy class experiments* of every course of chemistry in Yale College for these eight years."

certainly a happy thought, and the result of very philosophical views of combustion to suppose that a highly combustible gaseous fluid by intimate mixture with oxygen gas must when kindled produce intense heat, and it is no doubt to this capability of perfectly intimate mixture between these two bodies and to their great capacity for heat, that the effects of the compound blowpipe are in a great measure to be ascribed."

Clark, Journal of the Royal Institution, page 122. "I consider this improvement of the blowpipe one of the most valuable discoveries for the sciences of chemistry and mineralogy that have yet been made"—and thus does he modestly claim for his modification the whole merit of the discovery; for it must be observed, he does not in saying "improvement of the blowpipe," allude to the compound blowpipe contrived by me, but to the ordinary blowpipe of the mechanic or mineralogist. Other instances might be adduced, but it is presumed that more than enough has been brought forward to show that if the merit of this invention is to be awarded according to the motto "suum cuique;" adopted by Dr. Clark, there would be little left for himself and his coadjutors.

The following engraving was first published in 1820. Some of the apparatus represented in it has been, in my laboratory, superseded by modifications which I have described in the compendium. Yet as the copper plate is in my possession, I have thought it expedient to accompany this article by impressions from it, and of course with the necessary explanations. To those who have a taste for chemistry, varieties of apparatus are always interesting and instructive.

Explanation of the Plate.

Fig. 1. Original compound blowpipe, consisting of two common brass blowpipes, each soldered at its point into a perforation in a frustum of silver or platina. After receiving the blowpipes, the perforations converge till they form one, the open end of which is their common orifice.

Fig. 2. An enlarged representation of the frustum. It may be of brass, the orifice being protected by platina, as the touch-holes of guns are sometimes. The whole of the instrument being comprised in fig. 1st, an error has evidently been committed by those who have spoken of it as cumbrous, or requiring simplification.*

Fig. 3. The compound blowpipe under another form. A is a brass ball with two arms furnished with coupling screws, for attaching the instrument to the tubes through which the gases are to be supplied. B is the pipe which receives and emits them as mixed for ignition. It is screwed into a perforation in the ball at right angles to another perforation bored through the common axis of the ball and arms. This pipe is made of stout brass wire, drilled so as to admit a piece of hollow platina wire about three-fourths of an inch long, to be inserted at one end. The platina wire is rendered firm without solder, by passing the brass wire with the platina in it through a wire plate by the wire drawing process. The bore of the platina wire may be reduced to any size less than at first, by successive drawings through holes gradually smaller. Hence, by having the bore in the first instance made larger than can be wanted in any case, it is easy to produce pipes with orifices of every desired diameter.

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* It has been said that Mr. Cloud simplified it. If he simplified any thing, it was that part of the apparatus in which the gases are confined.

Fig. 4. exhibits, on a smaller scale, the form of the compound blowpipe above described, attached to the supply tubes. See Compendium, page 77.

For the supply of the compound blowpipe, almost any kind of gasometer or air holder will answer; or two boxes or kegs, into which the gaseous materials may be pumped by a condenser, as in the case of Mr. Brooks' apparatus, used by Clark, represented by fig. 9. A, reservoir, C, bladder holding gas, B, condenser, D, blowpipe, W, a contrivance to prevent explosions.

In default of a better mode, two smaller tubs or kegs, or air tight boxes inverted into larger ones, might be resorted to. Being filled with water, this fluid might be displaced by gas delivered from the vessels generating it, and the gas thus collected would be propelled by the pressure of the water through tubes connected with the compound blowpipe.

Fig. 5 represents a simple pneumatic cistern with shelves, under which are cells for holding gas, and one of which may be employed for hydrogen, the other for oxygen.

A more commodious apparatus is represented by fig. 6. At A is a cistern divided by a partition into two apartments, in which there are two gasometers, not differing materially from those used for confining carburetted hydrogen for gas lights, excepting that one of them is so contrived as to act as a self-regulating reservoir of hydrogen generated within it. A tray of copper full of holes, is supported by a sliding band and screw on the pipe in the centre, so that it may be fixed at any desired elevation. This tray being covered by a stratum of granulated zinc, diluted sulphuric acid may be poured into the containing vessel till all the atmospheric air is expelled from the gasometer through the pipe situated in its axis, and communicating with the blowpipe, seen with its table annexed to the cistern. The cock of this pipe being then closed, the action of the acid solution on the zinc causes hydrogen to be rapidly evolved, which fills the gasometer; and if the latter be prevented from rising too high, depresses the acid below the metal so as to suspend its action, until the escape of the gas through the blowpipe being permitted, by opening the cock, the acid rises again over the metal, and the evolution of gas recommences. The elevation of the sides of the gasometers above the horizontal partition or diaphragm, constitutes an external cavity, in which water may be poured so as to load them sufficiently.

A B C D, cistern—E F, partition dividing it—H, gasometer, or self-regulating reservoir of hydrogen—G, gasometer for oxygen—T T, two pipes closed at top and inserted air-tight into the gasometers—L M, two smaller pipes in the axis of those last mentioned, open at top, passing water tight through the bottom of the cistern and communicating with the blowpipe *n o*. *m m*, extension of the pipe M, by means of which oxygen may be introduced from the iron bottle *f**—P P, rods which pass through holes in a sort of gallows,

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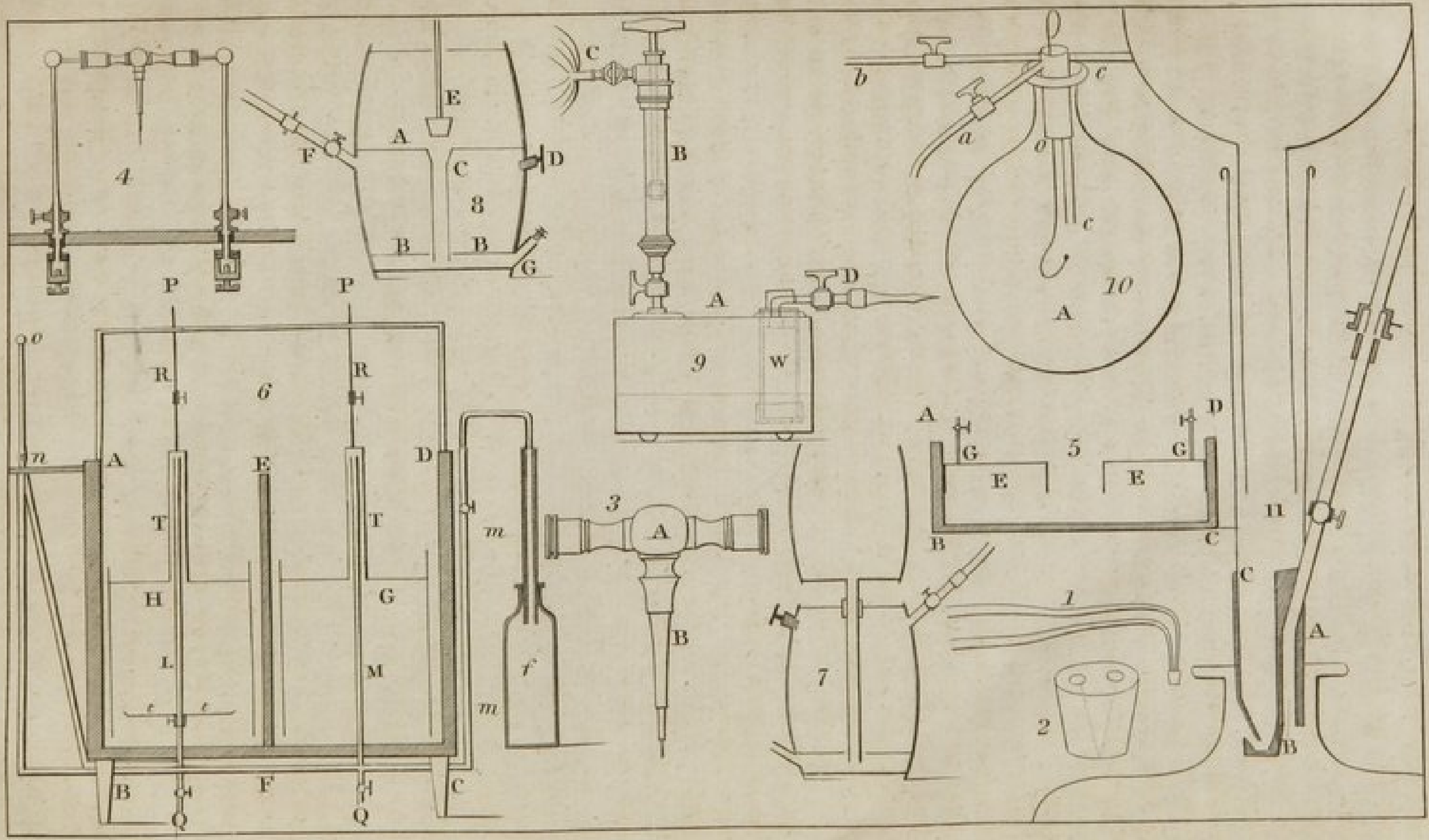
* The iron bottles used in commerce to hold quicksilver answer perfectly well. The narrow end of a gun barrel usually fits them, and when not large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so as to regulate the movements of the gasometers, and stop them by the bands and screws R R, at any height desired—Q Q, cocks for draining the pipes L and M of any moisture which may condense in them.

Other self-regulating reservoirs of hydrogen are represented by fig. 7, and fig. 8. A, fig. 8, a partition dividing the cask into two apartments, the lower the largest. B B, a false bottom, full of holes, raised about an inch from the real bottom of the cask. C, a copper or leaden pipe, inserted at its upper end into the partition, and extending downwards a little beyond the false bottom. D, a conical brass screw plug, inserted into a hole in the cask. E, a plug of wood for closing the pipe C. F, a cock for regulating the escape of gas. The plug D being removed, and zinc, in pieces, introduced by the hole so as to cover the false bottom, diluted acid is to be poured into the cask, till the lower apartment becomes full. The plug D being replaced, and the cock F being closed, the hydrogen produced by the chemical action soon expels so much of the acid from the lower apartment of the cask, as to depress it below the zinc, when the action stops till the expenditure of the gas allows the acid again to reach the metal. The plug E is of use to prevent the acid from pressing on the gas below, when pressure is not wanted.

Fig. 7 may be understood by its analogy with fig. 8, being merely another mode of putting the same principle into operation. Casks of the form of fig. 8 may be used as oxygen gas holders. The lower apartment is to be filled with water, the cock closed, and the plugs E D put into their places so as to be quite tight. The pipe G only is to be open, and through this the end of the tube is to be introduced, proceeding from a vessel in which oxygen may be generated. The gas displaces the water, which as it flows is to be caught and poured into the upper apartment of the cask. When the lower apartment becomes full, G is to be closed. It is necessary to remove the plug, E, in order to allow the water to press upon the gas, and propel it, when requisite, through a tube to the blowpipe.

Fig. 11 represents a contrivance, by which any vessel, with but one orifice, as a bottle, a demijohn, or carboy, may be made to act as an air holder; so that several may be filled with oxyen gas over a pneumatic cistern, may be laid by, and then used as wanted. The cylinder, A, is to be inserted in the place of the cork or stopple. This cylinder has two perforations nearly collateral, one not more than one quarter of the diameter of the other. The smaller one, B, communicates with a small tube, furnished with a cock and coupling screw, for attaching a longer tube, communicating with the compound blowpipe. The larger perforation at C opens into a wide cylinder of sheet metal. Into this cylinder another vessel

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enough at the muzzle, there is always some point nearer the breech, at which, if cut, it will be found of the proper size.

It may be luted into the bottle with clay or lime, and white of egg, and the breech screw being removed, into the aperture which it leaves, a long leaden flexible pipe, terminating in a brass ferrule, is easily luted.

with a long neck is inverted after being filled with water. This fluid will of course run into the bottle, until the gas within is so much condensed, as to resist the pressure of a column of it sufficiently high to reach the orifice of the inserted vessel.

When this takes place no more will descend, until by opening the cock, a portion of gas escapes: but as long as it is escaping, a proportionable quantity of water will come down, so as to keep the gas under an equable pressure, and produce, when required, an even flow towards the blowpipe.

Fig. 10 represents Lavoisier's apparatus for the recomposition of water, which Dr. Clark so uncandidly insinuates as suggesting the contrivance of the hydro-oxygen blowpipe. At *a* is a tube, by which to exhaust the vessel, A, of air. At *b* is another tube for supplying oxygen. At *cc* a third tube for supplying hydrogen, to be ignited by a spark from the knob of the bent wire below it. A better engraving of Lavoisier's apparatus may be seen in the Compendium, opposite page 134.

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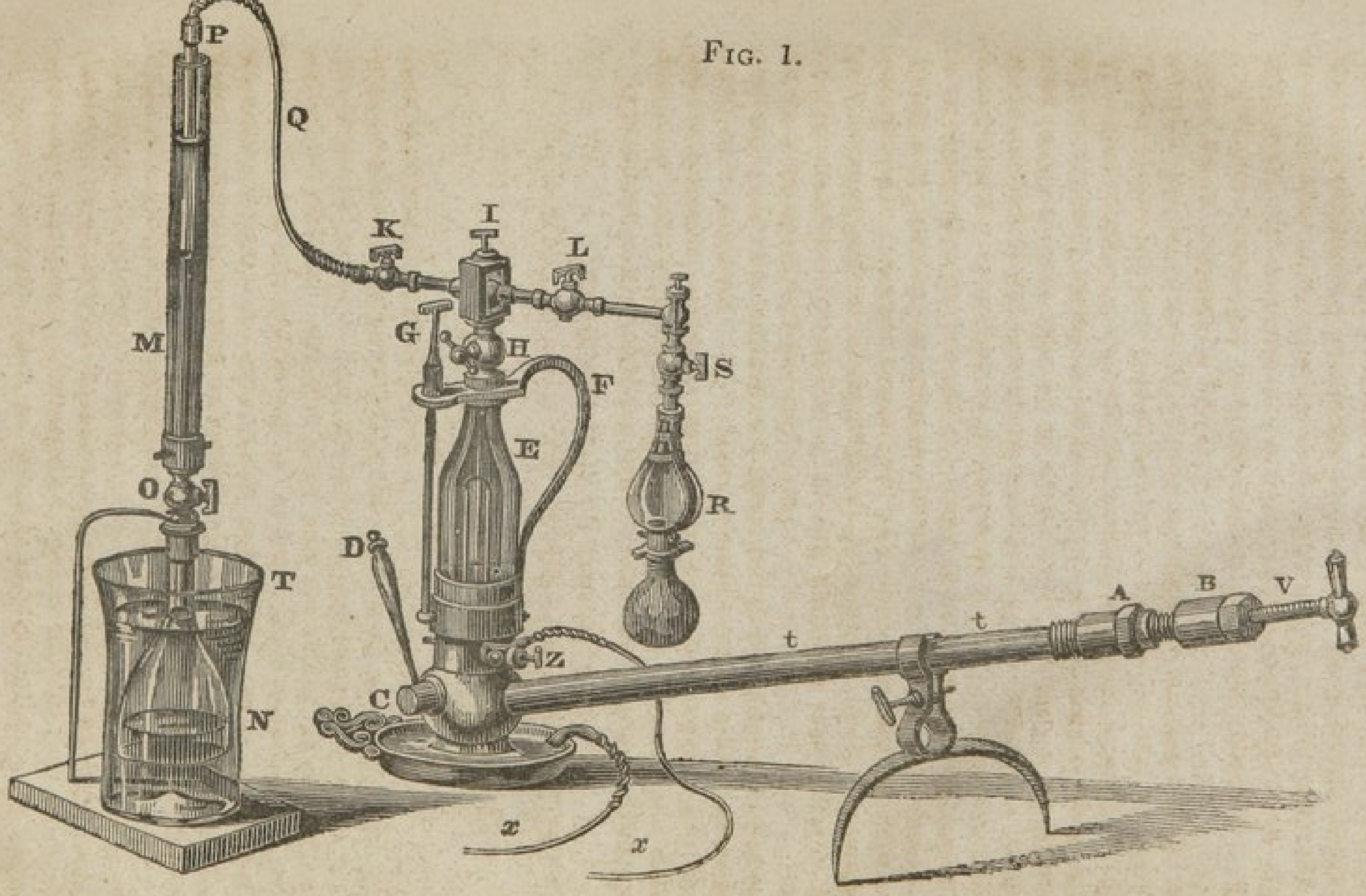
1. DESCRIPTION OF AN IMPROVED MERCURIAL SLIDING ROD EUDIOMETER.

The aqueous sliding rod hydro-oxygen eudiometer, (see Compendium, page 121) although perfectly well qualified for experiments, in which water is employed, does not answer well when used over mercury. The great weight of this liquid causes the indications to vary, during manipulation, in consequence of changes of position too slight to be avoided.

The instrument represented in the figure on the opposite page is furnished with a water gage, O M, which, being appealed to, enables us to cause the pressure of any contained gas, to be in equilibrio with that of the external air, and consequently to measure it with accuracy. Excepting the gage, the mechanism by which the measurement is effected, is the same as that of the sliding rod eudiometers for water (Compendium, page 121). However, in addition to the stuffing box at A, there is, in the mercurial eudiometers, a collar of cotton wick soaked in oil, and packed by a screw, B, which includes the cotton and compresses it about the rod. The object of this addition is to supply oil to the rod where it enters the collar of leather; otherwise, they would soon become so dry, as to allow air or mercury to pass.

Let us suppose that this eudiometer has been thoroughly filled with mercury, and that it is firmly fixed in the position in which it is represented in the drawing, so that the lower part may descend about an inch below the surface of some mercury contained in an iron cup. At C is a cock, the key of which, in addition to the perforation usual in cocks, has another at right angles to, and terminating in the ordinary perforation. When the lever, D, attached to the key, is situated as it appears in the drawing, the tube

FIG. 1.



containing the sliding rod communicates with the receiver, but not with the mercury in the cup. Supposing the lever moved through a quarter of a circle to the other side of the glass, the tube in which the rod slides, will communicate at the same time with the receiver, E, and the mercury. F is a steel spring, which has a disk of oiled leather let into it, so as to correspond with the surface of the apex of the receiver, E, which is ground as true as possible. Hence, a slight pressure from the screw, G, renders the joint made between the apex of the receiver and the spring, air-tight; while at the same time the bore of the cock, H, communicates with the cavity of the receiver by means of a perforation through the leather and spring. On the other hand, the relaxation of the screw permitting the spring to rise, opens a communication between the cavity of the receiver, and the external air. The cock, H, supported by the spring, carries a gallows with a screw, I, which serves to fasten a small brass casting, so perforated and fitted, as to produce a communication between the cock, H, and two others, K L, with which the ends of the casting are severally furnished. The cock, K, serves to open or close the communication with the gage, M, and bell glass within the jar, N. The bell glass is furnished with a cock, upon which the socket, O, of the gage, screws.

Description of the Water Gage.

The gage consists of three tubes, the interstices between which are partially supplied with water. In the first place a larger and outer glass tube, O M, open at the upper end, is at the lower end cemented into a socket attached to the cock, O, of the bell glass. Secondly, a small tube of varnished copper, the axis of which is made to coincide with that of the larger tube, is inserted into the bore of the cock. Lastly, a glass tube in size and situation intermediate between the tubes just mentioned, and open at the lower end, at the upper end enters the pipe, Q, which communicates with the bore of the cock, K, and of course when this is open, with the cavity of the receiver. When water is poured into the tube, M, if the pressure within and without be in equilibrio, it rises in the interstices between the three tubes to the same height; but whenever there is any diversity of pressure between the air of the inner, and outer glass tubes, it is indicated by a consequent difference in the height of the liquid columns included.

Description of the Contrivance for the removal of Carbonic Acid, from the Gas left after exploding Gaseous Mixtures, partly consisting of the Compounds of Carbon.

The glass receptacle, R, fastens, by means of a gallows screw, to a knob at the end of a perforated cylindrical projection from the cock, L; so as, with the aid of interposed leather, to make an air-tight juncture. Between the gallows screw and the receptacle, another cock, S, is interposed, the bore of which communicates by means of corresponding perforations with that of the cock, L.

Below the receptacle a caoutchouc bag is fastened, which, as well as the receptacle, must be filled with lime water.

Means of causing the Explosion of Gaseous Mixtures within the Receiver of the Sliding Rod Eudiometer.

A gaseous mixture, when contained in the sliding rod eudiometer, may be inflamed by galvanic ignition excited in a platina wire, in a mode analogous to that already described in the case of the barometer gage eudiometer, see article 128, page 127.

The circuit is established by means of the leaden rods, *x x*, one of which communicates with the mercury of the cistern, while the other is fastened to the insulated wire by means of the gallows, *z*. To the rod which communicates with the mercury, a piece of iron should be soldered so that the lead need not be immersed, and consequently corroded. The insulated wire, where it enters the cavity of the eudiometer, is made air-tight by means of a small stuffing box. It is protected from the mercury within the receiver, by a covering of twine, well soaked in, and coated with, shell lac varnish.

2. DETERMINATION OF THE QUANTITY OF CARBONIC OXIDE, IN A GASEOUS MIXTURE, BY THE IMPROVED MERCURIAL SLIDING ROD EUDIOMETER.

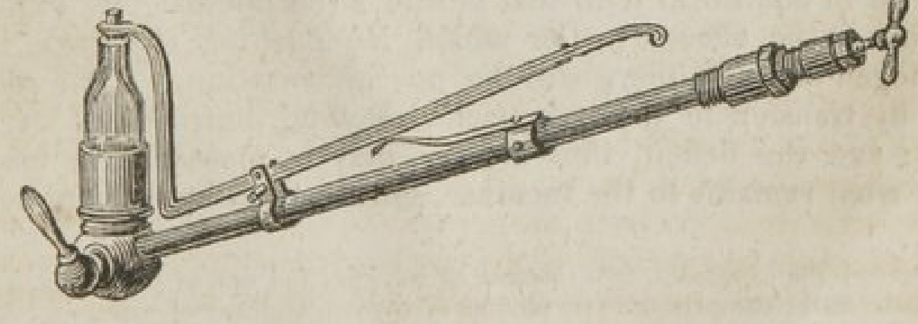
In the first place the mixture must be well washed with lime water, or a caustic alkaline solution, in order to remove carbonic acid, if present. In the next place let us imagine the bell glass, O N, after being adequately supplied over the pneumatic cistern with equal measures of the purified mixture and oxygen gas, has been transferred to the jar, I, containing a sufficiency of water to displace the gaseous mixture as required.

In order to fill the receiver with gas, through the gage tube and the pipe, Q, by which it communicates with the gaseous mixture in the bell glass, the eudiometer must be filled with mercury to the total exclusion of air, and the sliding rod wholly within its tube. Under these circumstances the spring being pressed upon the apex of the receiver by the screw, G, and the three cocks, H K O, being open; on drawing out the rod the receiver will be proportionally supplied from the bell glass with the gaseous mixture. The receiver being thus supplied, the cock, O, of the bell closed, and K, and H, being open, on pushing the rod home, the gaseous mixture driving the air before it through the interstices between the gage tubes, will in part effect its escape, in part supply in the tubes, the place of the air which it has expelled. This process may be repeated two or three times. After the atmospheric air has, in this way, been removed from the apparatus, the cocks between the bell and receiver being open, if the rod be drawn out 200 degrees, 200 measures of the mixture, consisting of 100 of each gas will enter the eudiometer. This being effected, the cock of the bell must be closed. In consequence of the hydrostatic pressure to which the gas will have been subjected in the bell, its density, within the receiver, will be unduly great. Hence, the pressure of the screw on the spring must be relaxed until the gage indicate, that the gas within the receiver has, by the escape of a portion of it, become with respect to pressure, in equilibrio with the atmosphere. The cock communicating with the gage, is then to be closed, the pressure on the spring restored, and an explosion effected. The communication with the gage is now to be opened. The indicated deficit must be compensated, and measured, by pushing in the rod, until the columns of water in the interstices of the gage are on a level. In the next place, close the cock, K, communicating with the gage, and open the cocks, H L S, which are between the receiver and the receptacle, R. Into this receptacle, by forcing the rod home, the gas is to be transferred. Being agitated with the lime water, it is drawn back into the eudiometer, brought into equilibrio with the atmosphere, by appealing again to the gage, and then measured by noticing the number of graduations which the sliding rod must enter, in order to effect its expulsion. This residual air, and the deficit produced by the explosion being deducted from 200, the remainder will be the quantity of the carbonic acid, and of course of carbonic oxide originally in the mixture; since carbonic oxide, in passing to the state of carbonic acid, absorbs half of its bulk of oxygen without any enlargement of volume.

3. ANALYSIS OF OLEFIANT GAS.

As a volume of this gas has been ascertained to be equivalent to two volumes of carbon, and two volumes of hydrogen, it must require 3 volumes of pure oxygen for its complete combustion, and must leave, after the union, two volumes of carbonic acid. In order to insure a competent supply of oxygen, four volumes of it may be mixed with one of the olefiant gas in the bell glass, and the same manipulation resorted to, as in the case of carbonic oxide, excepting that before the explosion, the rod, V, must be drawn out to the greatest extent; and that as soon as the explosion has taken place, the rod must be returned into the tube, so as nearly to compensate the condensation, before resorting to the gage.

FIG. 2.—SUBSIDIARY EUDIOMETER.



4. OF THE USE OF THE SUBSIDIARY EUDIOMETER.

It may sometimes happen that the quantity of gas to be examined may be too small to be measured into the bell glass by a volumeter, as above described. In that case, a subsidiary eudiometer is employed. Excepting that it is shorter, the rod, in this instrument, has precisely the same dimensions as in that described in the preceding article; and the graduation, in both, is exactly the same. The use of the spring and lever, also the method of manipulation, may be learned from article 124—Compendium, page 121.

5. ANALYSIS OF CYANOGEN.

Let us suppose it were an object to ascertain the products which result from the combustion of a volume of cyanogen.

A quantity of oxygen gas amply sufficient for the intended experiments must be introduced into the bell glass, N, fig. 1, and two hundred measures drawn into the receiver of the principal eudiometer, the manipulation being the same as above described in the case of the mixture. In the next place, the subsidiary eudiometer must be supplied with 100 measures of cyanogen, by introducing the apex into a bell glass containing the gas over mercury, and duly drawing out the rod, the orifice of the receiver being kept open by pressing on the lever, only while above the surface of the mercury, and inside of the bell. The gas thus taken into the subsidiary instrument is next to be transferred to the principal one, *which must in this case be placed over the mercurial reservoir*, and be filled with mercury, the rod, V, being half withdrawn from its tube. By moving the lever, D, a communication must also be opened between the receiver, E, and the reservoir, and the apex of the subsidiary eudiometer must be introduced into a funnel-shaped cavity, with which the cock, C, is furnished. The rod of the subsidiary instrument being, under these circumstances, pushed home, the gas must pass from it into the funnel-shaped cavity, and thence rise into the receiver above it. When this object has been effected, close the communication with the reservoir, and open that with the iron tube, *t t;* also open the cock, H. Then appealing to the gage, adjust the rod so that the pressure of the included gas may be in equilibrio with that of the atmosphere. An explosion is now to be effected; after which, on opening the gage, if the cyanogen be pure, there will be no condensation.* The residual gas, by transfer to the receptacle, may be deprived of carbonic acid: and the deficit, thus arising, may be measured by transferring what remains to the receiver, and ascertaining how many mea-

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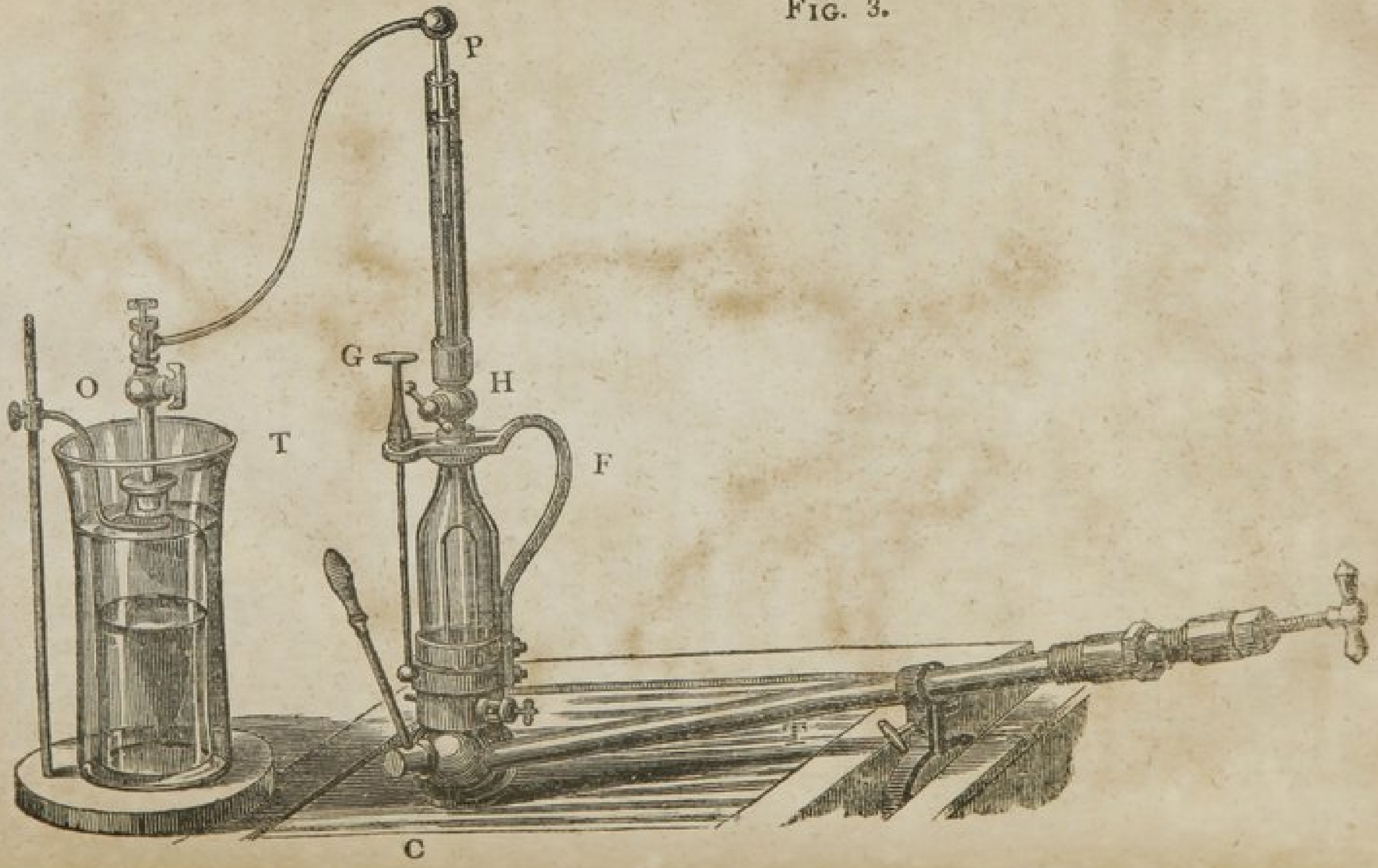
* Before the explosion, two volumes of oxygen, and one of cyanogen, are present; the latter comprising two volumes of carbon, and one of nitrogen. During the inflammation, the carbon is transferred to the oxygen, without altering it in bulk, while the nitrogen is set at liberty, uncondensed, so as to occupy as much space as the cyanogen did previously.

FIG. 3.



sures the rod must enter, in order to eject it into the air, or to return it into the receptacle.

6. MODIFICATIONS OF THE EUDIOMETER, DESCRIBED IN THE PRECEDING ARTICLE.

The opposite figure represents another form of the sliding rod eudiometer, in which the apparatus for the removal of carbonic acid is omitted. The gage in this eudiometer is attached to the cock of the receiver, instead of surmounting the bell glass. It answers equally well in either situation.

If instead of the bell and jar, a self-regulating reservoir of hydrogen (see Compendium, article 120) were attached to the flexible pipe, a convenient arrangement would be obtained for ascertaining the proportion of oxygen in the atmosphere. In that case, the mode of operating would be as follows. The pipe and tubes of the gage being filled with hydrogen, and the receiver with mercury, also the cocks, H and O, being open, draw out the sliding rod fifty degrees. A quantity of hydrogen, in bulk equivalent to the part of the rod withdrawn, will pass from the reservoir through the flexible pipe, into the cavity of the receiver. The cock, O, being shut, on appealing to the gage it will be found that the hydrogen, in consequence of the hydrostatic pressure of the reservoir, will be a little denser than if in equilibrio with the atmosphere. By relaxing the pressure of the screw, G, upon the spring, as much hydrogen will escape as may be necessary to produce an equilibrium. If while the cavity of the receiver is thus, in communication with the atmosphere, the cock, H, being shut, the sliding rod be drawn out 100 degrees further, so as to reach to 150 on the scale, 100 measures of air must enter. The pressure of the screw, G, upon the spring, F, being restored, and an explosion effected, agreeably to the directions already given, by returning the rod into its tube, more or less, and appealing to the gage, the deficit may be ascertained. If no error shall have taken place, expelling the residual gas will just return the rod to the situation, which it occupied when the experiment commenced. Of the deficit, of course, one-third is due to oxygen. It may be proper to mention that some delay is necessary, in order to permit the residual gas to part with the heat, acquired from the combustion of the hydrogen and oxygen.

As for the analysis just described, the eudiometer may, as represented in the preceding figure, be seated in a cup of mercury, instead of being placed over a mercurial reservoir; and since the apparatus, when once put into operation, enables us to multiply experiments with great facility; it will be found peculiarly well calculated for a series of observations, under circumstances in which access to a pneumatic cistern cannot be had.

7. *Eudiometrical Apparatus analogous to the preceding, excepting that it is constructed of Brass, used with Water, and that Explosions are caused in it by an Electric Spark.*

In the analysis of atmospheric air, agreeably to the process last described, no gaseous product being generated, which is absorbable by water, it is not necessary to employ mercury, and, consequently, to have the metallic part of the eudiometer of iron and steel. It is in fact preferable to have it of brass, as in that case it will not rust, and may be kept in operation for many months, without requiring much adjustment. I have an apparatus thus made, and so contrived as to be ignited by an electric spark. Excepting the substitution of brass for iron, there is no material difference between that apparatus and the one represented by the figure, excepting that the receiver, E, is exchanged for one of which there is an engraving in the Compendium—See article 124, fig. B.

In the brass eudiometer last described, the cock, C, is omitted; while, at right angles to the receiver, a small cock is inserted, which supports a glass vessel holding water. By these means, any excess or deficiency of this liquid is easily remedied, and the employment of the cup, beneath the eudiometer, rendered unnecessary.

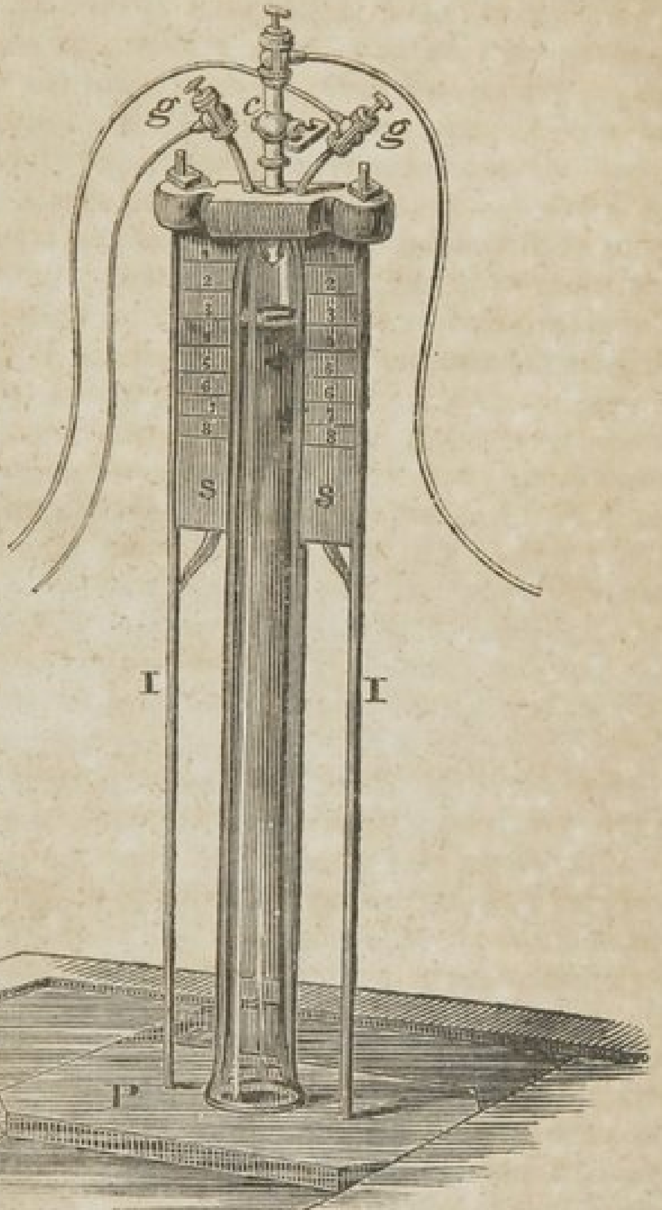
8. DESCRIPTION OF THE VOLUMESCOPE.

In the next page there is an engraving of an instrument which I have advantageously employed, in order to illustrate the experimental basis of the theory of volumes, and some other eudiometric phenomena.

As I find it very inconvenient not to have a name for every variety of apparatus, I shall call this instrument a volumescope.

It consists of a very stout glass tube, of 36 inches in height, and tapering in diameter inside from $2\frac{1}{8}$th to $1\frac{1}{8}$ inches. The least thickness of the glass is at the lower end, and is there about $\frac{5}{8}$ths 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 rivetted, 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 greased leather in a corresponding hollow, formed, 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

FIG. 5.



air-tight. To the upper end of these wires, gallows screws, *g g*, are attached. The lower ends of the wires, within the tube, are made to communicate by means of a fine platina wire fastened to them by solder.

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 four inches of the tube into eight equal parts. These parts were measured by introducing into the tube, previously filled with water, one hundred measures of air, from a sliding rod gas measure, eight times, and marking the height of the water after each addition.* As each degree thus indicated by the strips will be equal to 100 of those of the sliding rod, the whole may be considered either as comprising eight hundred measures of the latter, or as eight volumes, each divisible into 100 parts, by means of the gas measure.

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 conveniently 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 leathern 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 theory of volumes.

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* See Compendium, page 125.

9. APPLICATION OF THE VOLUMESCOPE TO THE ILLUSTRATION OF THE RATIO, IN WHICH NITRIC OXIDE, AND THE OXYGEN IN ATMOSPHERIC AIR, ARE CONDENSED BY ADMIXTURE.

FIG. 4.

The tube being filled with water by exhausting it of air, as in the preceding experiment, let five volumes of atmospheric air be introduced into it. Afterwards, by means of a volumeter, or sliding rod gas measure, add at once three volumes of nitric oxide. In the next place fill the syphon, S Y, and the caoutchouc bag attached to it with water, and pass the leg, Y, up through the bore of the eudiometer tube; then by alternate pressure and relaxation, the water may be propelled from the bag, through the syphon, into the gaseous mixture, so as to accelerate the absorption.

If in five volumes of atmospheric air there be one of oxygen gas, there will be just enough to condense two volumes of nitric oxide, by converting them into nitrous acid. Of course of the eight volumes in the tube, three will disappear and five remain. Hence the gas, after the absorption of the red fumes, will occupy the same space as the air before the introduction of the nitric oxide. The extent of the deviation, from this result, may be measured by introducing hydrogen by means of the sliding rod gas measure, until the quantity added causes the gas to extend to the next graduation. By these means, it is easy to ascertain how much the residue differs from five or six volumes. I have generally found it rather less than five volumes.

10. APPLICATION OF THE VOLUMESCOPE TO THE ANALYSIS OF CARBONIC OXIDE, OR OLEFIANT GAS, SO AS TO SHOW THAT THE RESULT CONFIRMS THE THEORY OF VOLUMES.

Carbonic oxide requiring for its saturation half its bulk of oxygen; in order to analyse it in the apparatus last described, after the preliminary preparations mentioned as necessary, in case of the gaseous elements of water, introduce two volumes of carbonic oxide, and one of oxygen gas, and ignite the platina wire. A feeble explosion will take place, and one volume will disappear. To complete the analysis, by means of a funnel screwed on to the cock inserted into the perforation in the mahogany block at the top of the eudiometer, lime water may be introduced, and thus all the carbonic acid, generated by the combustion of the carbonic oxide with the oxygen gas, may be absorbed. Of course, if the gases be pure, the absorption will be complete. It might perhaps be found preferable to introduce lime water by means of the syphon and bag, fig. 4.

11. ACCORDANCE OF THE ANALYSIS OF OLEFIANT GAS WITH THE THEORY OF VOLUMES, ILLUSTRATED BY THE VOLUMESCOPE.

As a volume of olefiant gas consists of two volumes of hydrogen, and two volumes of carbon vapour, if it be exploded with an excess of oxygen, say four volumes, all the hydrogen, and one volume of oxygen, will be converted into water. Meanwhile, two volumes of oxygen, uniting with two of carbon vapour, will constitute two volumes of carbonic acid. These may be absorbed by lime-water introduced as in the case of carbonic oxide. It follows that one volume of oxygen will remain.

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12. ANALYSIS OF A MIXTURE OF CARBONIC OXIDE, WITH ONE OR MORE OF THE GASEOUS COMPOUNDS OF CARBON WITH HYDROGEN.

(See Compendium, page 180.)

If olefiant gas be present, it may be condensed by mingling, in any tall narrow vessel protected from light, over water, 100 measures of the mixture, with 200 measures of chlorine; and at the end of about a quarter of an hour, agitating the residue with a caustic alkaline solution, to remove any excess of the last mentioned gas.* The measurement may be easily performed by means of the sliding rod eudiometer, fig. 1, page 143, Compendium; the residue being transferred into, and measured from the receiver, fig. 2, same page, agreeably to the instructions given in the case of nitric oxide, article 148.

The bihydroguret of carbon, usually called carburetted hydrogen,† consists of two volumes of hydrogen and one of carbon condensed into one volume. This gas not being condensible by chlorine, when light is excluded, a mixture of it with carbonic oxide, should be analysed by the following process.

Being mixed with three times its bulk of oxygen gas within the bell glass, O N, communicating with the receiver of the sliding rod eudiometer, (fig. 1, page 32 of this appendix) an adequate quantity may be exploded, pursuant to the directions in the case of carbonic oxide, and olefiant gas.

More than half a cubic inch of the gaseous mixture, with the necessary addition of oxygen, cannot be safely exploded at once in any ordinary eudiometer: but by successive operations a large quantity may be exploded, and inferences may be founded upon the accumulated result.

Let it be imagined that the relative weights of the gaseous mixture in question, of the oxygen gas added to it, and of the carbonic acid produced, have been calculated by multiplying their respec-

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* See Traité de Chimie par Thenard, vol. 5, page 34.

† It is sometimes called light carburetted hydrogen.

tive quantities, as ascertained by the eudiometer, by their specific gravities.*

Since a mixture of carbonic oxide and bihydroguret of carbon, by combustion with an excess of oxygen, must be wholly converted into water and carbonic acid; and since the carbonic acid is entirely absorbed by lime-water, it follows that the residual gas must be the unconsumed portion of the oxygen gas added to the mixture. Deducting this residual oxygen from the whole quantity of this gas employed, the remainder is the quantity consumed. The weight of the oxygen consumed, with the weight of the gaseous mixture, must constitute the whole weight of the products, consisting, according to the premises, of water and carbonic acid only, and deducting the latter, the remainder will be the whole weight of the water generated. Of this, agreeably to the table of equivalents, $\frac{8}{9}$ths must be oxygen, and $\frac{1}{9}$th hydrogen.

And since the ratio of the carbon to the oxygen, in carbonic acid, is as 75 to 200, $\frac{75}{275}$ths or $\frac{3}{11}$ths of the weight of the acid produced, will be carbon, and $\frac{200}{275}$ths or $\frac{8}{11}$ths oxygen. If we add, therefore, $\frac{8}{9}$ths of the weight of the water, to $\frac{8}{11}$ths of that of the acid, we shall have the weight of all the oxygen in the products. If from the weight, thus ascertained, we deduct that of all the oxygen gas consumed, the remainder will be the weight of oxygen in the mixture before the oxygen gas was added. This portion of oxygen is that which entered into the composition of the carbonic oxide, and must, agreeably to the table of equivalents, have been to the carbon in union with it, as four to three. Deducting the weight of the carbon, thus ascertained to exist in the carbonic oxide, from that in the carbonic acid, as above stated, the remainder will be the weight of carbon in the carburetted hydrogen.

The rule may be thus briefly expressed.

From the sum of the weights of the gaseous mixture, and oxygen gas consumed, deduct the carbonic acid generated. To $\frac{8}{9}$ths of the remainder, add $\frac{8}{11}$ths of the weight of the carbonic acid, and deduct the weight of oxygen consumed. The remainder will be the oxygen of the oxide. The carbon in it will be one-fourth less, and this carbon deducted from $\frac{3}{11}$ths of the weight of the carbonic acid, will give the weight of the carbon united to the hydrogen.†

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* The specific gravities of oxygen gas, of carbonic oxide, and of carbonic acid, may be known from the table, page 196, Compendium. That of the gaseous mixture may be ascertained, agreeably to the instructions in article 184.

† The problem may be stated algebraically as follows:—

Let M be the weight of the gaseous mixture.
O, of the oxygen gas consumed.
C, of the carbonic acid generated and absorbed.
Then $M + O$ will constitute the whole weight of the products.
And $M + O - C$ the whole weight of water.

Also $\frac{8}{9}(M + O - C) =$ all the oxygen in the water.

$\frac{8C}{11}$ will be all the oxygen in the carbonic acid.

When there is a copious supply of the gas to be examined, the barometer gage eudiometer may be used advantageously, as much larger quantities of gas may be exploded in it, than could be exploded in the same time, in the sliding rod eudiometer. See Compendium, article 128.

In order to render the process with the barometer gage eudiometer safe, the quantity introduced in the first instance should be as small as can be ignited. Afterwards successive portions may be introduced and exploded, until the receiver be nearly full of the residual gas. That this operation may be still more secure, I propose to employ, as a receiver, an iron bottle (such as are used to hold mercury) surmounted by a very stout glass tube, in which the platina wire may be situated, which is to cause ignition. This tube would be the only part of the apparatus which it would be desirable to have transparent. Indeed transparency may be dispensed with altogether, the explosion being perceptible from the noise, and the effect upon the gage.

13. ANALYSIS OF A GASEOUS MIXTURE, IN WHICH BIHYDROGURET OF CARBON, CARBONIC OXIDE, AND EITHER HYDROGEN OR NITROGEN, OR BOTH THE LATTER, ARE INTERMINGLED.

When, as in the case under consideration in the preceding article, there is no nitrogen present, the gas which remains after the action of the lime-water, may be considered as oxygen; but if ni-

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$\frac{3\,C}{11}$ all the carbon in that acid, and consequently the whole contained in the products.

$\frac{8}{9}\,(M + O - C) + \frac{8\,C}{11}$ will be all the oxygen in the products.

And $\frac{8}{9}\,(M + O - C) + \frac{8\,C}{11} - 0$ will be that portion of oxygen which existed previously in the gas, which call X.

We have therefore the following equation

$$X = \frac{8\,M + 8\,O - 8\,C}{9} + \frac{8C}{11} - O.$$

which may be thus reduced.

$$X = \frac{88\,M + 88\,O - 88\,C + 72\,C}{99} - O.$$

$$X = \frac{88\,M + 88\,O - 16\,C}{99} - O.$$

$$X = \frac{88\,M + 88\,O - 16\,C - 99\,O}{99}$$

$$X = \frac{88\,M - 16\,C - 11\,O}{99}$$

It follows from the atomic weights, and the premises, that

$\frac{3\,X}{4}$ = the carbon in carbonic oxide. And $X + \frac{3X}{4}$ = weight of carbonic oxide.

Also $\frac{3\,C}{11} - \frac{3\,X}{4}$ = the carbon united to hydrogen.

And $\frac{3\,C}{11} - \frac{3X}{4} + \frac{M + O - C}{9}$ = weight carburetted hydrogen.

trogen be present, the residual gas must be analysed in order to ascertain the quantity of oxygen which remains unconsumed.

This is easily accomplished by propelling the residual gas into the receptacle for carbonic acid, R, fig. 1, and substituting a self-regulating reservoir of hydrogen for the bell glass. Then having filled the gage and pipes with the pure hydrogen, by the manipulation already described in the case of oxygen, (article 2,) the residual gas may be drawn into the receiver, exploded, and the resulting deficit ascertained—to one-third of which the oxygen is equivalent.

Instead of resorting to the method just mentioned, the residual gas, after being included in the receptacle, may be transferred to the pneumatic cistern, and analysed by the aqueous sliding rod eudiometer. See Compendium, article 121.

If we subtract from the weight of the "*residual gas*," the weight of the oxygen found in it, the remainder being both incombustible and insusceptible of absorption by lime water, should be considered as the weight of the nitrogen. This would have to be deducted from that of the gaseous mixture, the calculation being otherwise unaltered.

If after having analysed a gaseous mixture, agreeably to the directions given in the last article, it be found that the quantity of hydrogen indicated exceed, in weight, one-third of the carbon allotted to it, the excess must be considered as pure hydrogen: since, agreeably to the table of equivalents, the weight of the carbon, in the bihydroguret, is to the hydrogen, as 3 to 1.[*]

14. METHOD OF ASCERTAINING THE PROPORTIONS OF BIHYDROGURET OF CARBON AND CARBONIC OXIDE, IN A MIXTURE OF THOSE GASES, PROVIDED NO OTHER INFLAMMABLE GAS BE PRESENT.

BY FRANKLIN BACHE, M. D., &c. &c. &c.

I will here subjoin an excellent method of ascertaining the proportions of bihydroguret of carbon and carbonic oxide, in a mixture of those gases, which has been ingeniously and correctly suggested by my friend Dr. Bache.

"The proportion of carbonic oxide, in a mixture of this gas and bihydroguret of carbon, may be calculated from the quantity of oxygen consumed by them when exploded, in the following manner.

"If we suppose a gas to be all bihydroguret of carbon, it will consume twice its volume of oxygen: if, on the other hand, it be all carbonic oxide, it will require half its volume for complete combustion. It must be evident, therefore, that a mixture of these gases will consume a volume of oxygen, intermediate between half the volume and twice the volume of the mixture; and that what-

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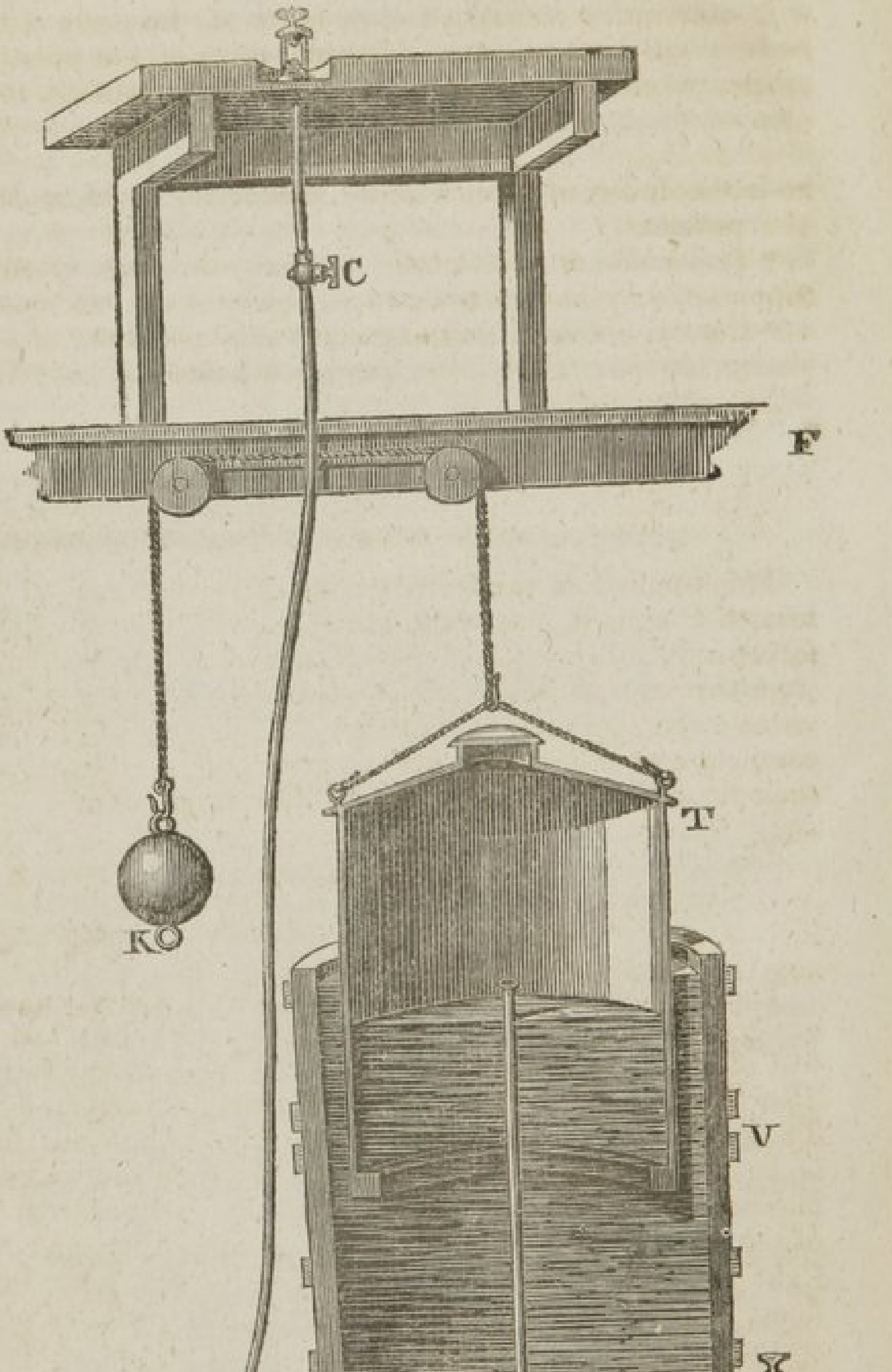
[*] That is puttting H for the pure hydrogen, we should have

$$H = \frac{M + O - C}{9} - \frac{1}{3}\left(\frac{3\,C}{11} - \frac{3\,X}{4}\right)$$

Fig. 6.



ever may be the volume of the oxygen consumed, it will bear a constant proportion to the carbonic oxide present.

"Reasoning from the analysis of the pure bihydroguret, which requires twice its volume for complete combustion, it must be apparent, that the introduction of the least portion of carbonic oxide will necessarily diminish the quantity of the oxygen consumed. Now it will be found, that this diminution of the quantity of the oxygen required, bears to the carbonic oxide present, the constant ratio of 3 to 2. Hence we have this proportion:—

"As 3 is to 2,
So is the deficit of oxygen above alluded to, to the carbonic oxide present.

"This mode of calculating the carbonic oxide in the mixture supposed, may be expressed in an algebraic formula, as follows:—

"Let M = volume of the gaseous mixture, and
O = oxygen consumed.

Then $\frac{2M - O \times 2}{3}$ = vol. of carbonic oxide present.

And as carbonic oxide contains half its volume of oxygen, then $\frac{2M - O \times 2}{6}$ = vol. of oxygen in the carbonic oxide."

This method is evidently preferable in the case of a mixture known to consist of pure bihydroguret and carbonic oxide: but unfortunately it is inapplicable if hydrogen be present in any other state than as a definite compound with carbon, requiring twice its volume of oxygen for saturation. The process of Dr. Bache is not competent to inform us what the gases are; but enables us, when their nature is known, to discover their proportions.

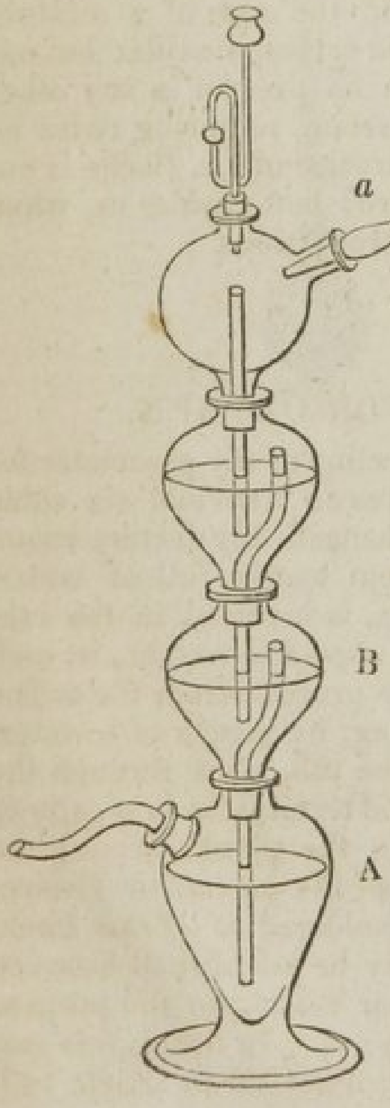
15. LARGE GASOMETER FOR OXYGEN.

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 placed in the cellar beneath my lecture room. 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, rises through the floor, F, is furnished with a cock at C, and terminates in a gallows screw. This is fixed in a cavity made in the plank forming the table of my lecture room, in the vicinity of the pneumatic cistern. Hence by means of it, 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 the gas. In filling this gasometer, the copper vessel and bell glass (described in article 143, Compendium) may be used 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. See Compendium, page 100.

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 vessel 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 parallelopipeds. 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 Compendium, article 175.)

16. ENGRAVING AND DESCRIPTION OF KNIGHT'S SUBSTITUTE, FOR WOULFE'S APPARATUS.*



We have here an outline of Knight's Vertical Apparatus, being a substitute for Woulfe's. It consists of a series of vessels, of which the first vessel, A, has an orifice ground to receive the tapering extremity of the second vessel, B. This vessel has, in like manner, an orifice fitted to receive the tapering extremity of the third vessel; and the fourth, and uppermost vessel, being similarly joined to the third, is surmounted by a tube of safety. Into the tubulure in the side of the uppermost vessel, the beak of the retort enters, or it may enter the adopter, *a*.

The three lower vessels being duly supplied with water, the gas enters the upper one, which serves to condense any accompanying vapour. The gas thus depurated, passes through the tube, into the liquid of the next vessel. The excess, beyond the quantity absorbed in this way, passes, in like manner, into the nearest vessel below; and by a similar process, reaches the lower vessel. Any portion which is not there absorbed, escapes, through the tube in the side of this vessel.

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* See Compendium, article 139.