

## **The philosophy of experimental chemistry: in two volumes (Volume 1).**

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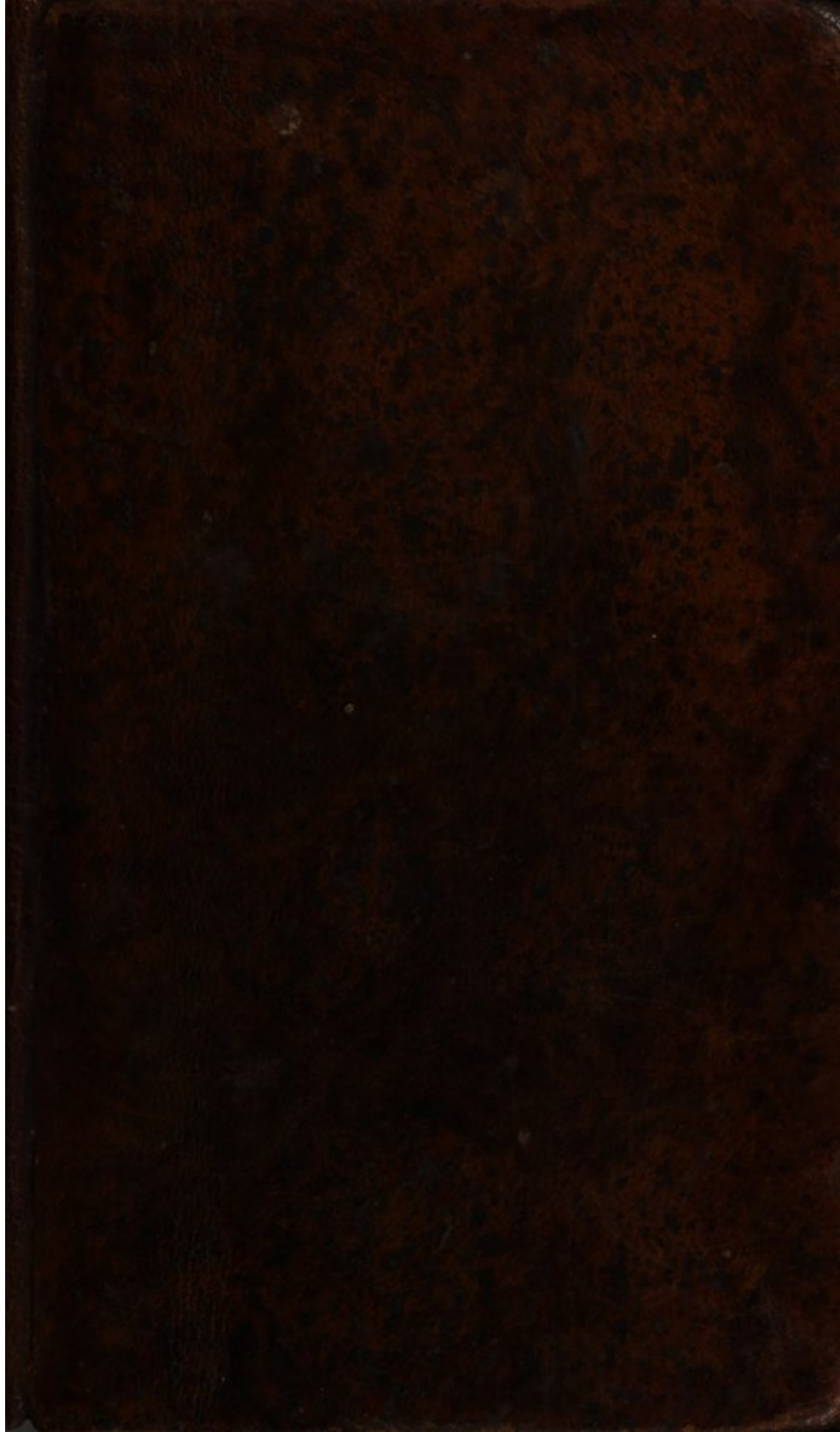
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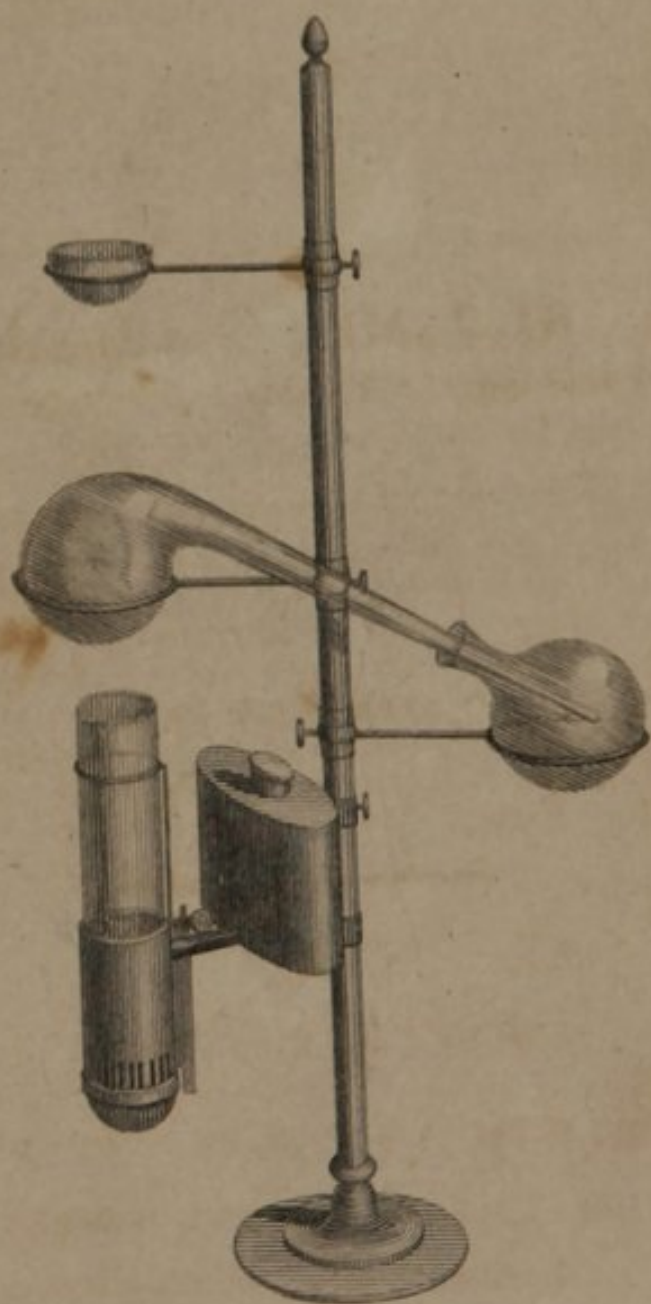
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THE PHILOSOPHY  
OF  
EXPERIMENTAL CHEMISTRY.

IN TWO VOLUMES.

BY JAMES CUTBUSH,

Professor of Chemistry, Mineralogy, and Natural Philosophy in  
St. John's College, Philadelphia, President of the  
Columbian Chemical Society, &c. &c.

VOLUME I



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PHILADELPHIA:

PUBLISHED BY ISAAC PEIRCE,

NO. 3, SOUTH FOURTH STREET.

Merritt, Printer, Watkin's-alley.

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1813.

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*The Philosophy of Experimental Chemistry. In two volumes. By James Cutbush, Professor of Chemistry, Mineralogy, and Natural Philosophy in St. John's College, Philadelphia, President of the Columbian Chemical Society, &c. &c.*

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PROFESSORS AND STUDENTS  
OF THE  
UNIVERSITY OF PENNSYLVANIA,  
AND THE  
TRUSTEES OF ST. JOHN'S COLLEGE,  
THIS WORK,  
IS RESPECTFULLY DEDICATED  
BY  
THE AUTHOR.

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## INTRODUCTION.

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**ALTHOUGH** there are many excellent works on chemistry calculated for the student as well as for the professional chemist, yet, considering that they are either too extensive or elementary, the idea of a work embracing the most important matter of each, together with all the modern discoveries and improvements of the science, suggested itself to the author; while, therefore, in the formation of a book of this kind, the leading doctrines were kept in view, he considered, that as chemistry is a science founded wholly on facts, the subject would be the better treated in experiment, rationale, and remark.

He would not presume to point out defects in any chemical work; as EVERY treatise possesses merit either in the plan, arrangement, number of facts, or subject matter. Nor would he say, that, to the student, this work was better calculated than any other. It may be remarked, however, that every department is treated with that extent which a book of this size admits, in order to embrace the subjects of chemistry, as well the practice as the rationale, in experiments, theory, and observations. By this means particular experiments, either in relation to some chemical fact, preparation, characteristic property, or remarkable phenomena, become familiar; and when they tend to any useful application, particularly to the arts, their importance is pointed out. The design of the work, there-

fore, will appear on inspection. WE have in the English language several valuable and extensive works on chemistry, besides a number of elementary treatises. The works of THOMSON and MURRAY do honour to these philosophers, and to the country which gave them birth. In the French, many valuable systems and journals of chemistry have appeared. In the German also, several treatises have been written, which possess an equal share of merit.

IN the United States, since the introduction of science, it is by no means surprising that chemistry should have been so zealously cultivated; as it opens an extensive field for contemplation and study, and as its application to the arts and manufactures is important, it promises to be of the most essential advantage to all classes of the community.

THE well informed people of America, who happily constitute the majority, have appreciated the value of knowledge; and we hope that the time will soon arrive, when chemistry will become a general study throughout the union. Several original works have, accordingly, appeared, and some editions of European treatises have been published with revisions, corrections, and additions by our countrymen. The Chemical and Economical Essays of Pennington, the edition of Chaptal enlarged by the late JAMES WOODHOUSE, M. D. professor of chemistry in the University of Pennsylvania, that of Henry's Chemistry by professor SILLIMAN, of Yale College, with some others, evince, not only the learning and talents of our countrymen, but a growing taste for the encouragement of learning, and the acquisition of chemical knowledge. Besides these, in the Transactions of our societies, and in the Journals, or periodical works, several valuable papers have appeared. The genius of the medical students of the University of Pennsylvania, in particular, has been shown in a number of excellent Inaugural Dissertations; some of which have added to the improvement of chemical science.

THE first teacher of chemistry, was Dr. BENJAMIN RUSH, now professor of the Institutes and Practice of Physic, and of Clinical Practice in the University of Pennsylvania. He may be justly styled the father of chemistry in America. He commenced a course of lectures on this science in the then college of Philadelphia; and although chemistry at that day may be said to have been in its infancy, yet the Doctor did honour to the chair, the school, and his country. We now speak of him only as a chemist. We do not mean to recount his worth, nor his talents; they are sufficiently known. But we mean to say, that he then published a syllabus of his course, which embraced all the discoveries of the time; that he made a number of chemical investigations, with an accurate analysis of the mineral waters of Bath (to the truth of which the author can attest by his own experiments) as well as of other waters; and that he made a careful analysis of Dr. Martin's celebrated cancer powder, an account of which may be seen in his works. He was followed in that chair, which he resigned, by Dr. CASPAR WISTAR, now professor of Anatomy, who filled it with perfect satisfaction. Dr. CARSON then succeeded, but he died, I believe, soon after he was appointed. He was followed by Dr. HUTCHINSON, who also gave satisfaction: to him succeeded Dr. WOODHOUSE, who, as an experimenter, was unequalled, and after him, the present professor, Dr. JOHN REDMAN COXE, whose talents are well known.

THE advancement of chemistry in our city, as well as of medicine and philosophy generally, is also indebted to other institutions. The American Philosophical Society, which was formed out of two literary societies that had previously existed, in the year 1769, who have already published several volumes of Transactions; the College of Physicians, which was instituted in 1787, who have also published; the Medical Society formed in 1771; the Chemical Society, under the patronage of Doctors Seybert and Woodhouse, which has since been dissolved; the Linnean Society, instituted under the presidency of the learned Dr. BENJAMIN

SMITH BARTON; the Columbian Chemical Society, formed principally in 1811, by Dr. THOMAS D. MITCHELL, and GEORGE F. LEHMAN; the Medical Lyceum; the Academy of Natural Science, instituted by Dr. JARED TROOST; all show the zeal for useful knowledge, and philosophical inquiry.

OTHER institutions, for promoting literary subjects generally, have also been established.

Dr. JOSEPH PARRISH was the first who delivered a private course of chemistry in Philadelphia. He was succeeded in the same establishment by Dr. EDWARD CUTBUSH, and the author, in the winter of 1810, and afterwards by the Doctor alone. For the introduction of popular chemistry, the citizens of Philadelphia are also indebted to Doctors ROGERS and JONES, and to Mr. BENJAMIN TUCKER, who have taught chemistry with much zeal and talents.

THE school establishment, formed out of the Lutheran congregation of the church of St. John, have, agreeably to their plan, instituted several professorships, prior to the enlargement of that seminary, one of which, that of chemistry, mineralogy, and natural philosophy, they have conferred on the author. He is therefore engaged in delivering a course on these sciences. Nor can we in justice pass over other institutions of chemical science. Thomas Cooper, Esq. professor of chemistry in the college at Carlisle, Pennsylvania, is one of those to whom we are indebted for the promotion and cultivation of this science. Since the establishment of medical schools, besides the University of Pennsylvania, which reflects so much honour on our country, the institution of professorships of chemistry has formed a necessary appendage. In the University of Maryland, Dr. DE BUTTS, with honour to himself, and credit to the school, fills the professorship. In Columbia College, New-York, Dr. Stringham; in the College of Physicians and Surgeons Dr. Mac Nevan, and in the Medical Institution of the same city, Mr. John Griscom; who are distinguished for their talents in the cultivation of chemical science.

WITH respect to the cultivation of science, and the formation of the juvenile mind, a considerable defect has existed in the education of youth. That, while the intellect is in the act of formation, as ideas are acquired through the medium of the senses, such studies or branches of knowledge should be preferred, whose effects are the most extensive, and whose application is the most useful. The honourable Dr. SAMUEL L. MITCHILL, professor of Natural History in the University of New York, in a letter which the author had the honour of receiving from him, gives a preference to the improvement of morals, and the cultivation of the physical and natural sciences, to the classical course of dead languages, and the fabulous zoology, terrestrial and celestial, with which those tongues abound. Among these studies, as one of the physical sciences, the Doctor recommends chemistry.

THE improvement of education, by the introduction of the physical sciences, has within a few years been attended to; and since the introduction of the Pestalozzian system,\* the attention of the public mind has been drawn to this laudable endeavour. It would be an injustice to my feelings, while on this subject, were I to omit to mention the zeal, talents, and industry of several of our countrymen in this undertaking. The establishment of a society in this city for the promotion of a Rational System of Education, under the presidency of JOHN GOODMAN, Esq. is one of those attempts to bring about a reformation in school education; and among the number who have largely contributed to this subject, I would mention with pleasure the names of JOHN GREINER and DANIEL BRAEUTIGAM, whose talents and knowledge have added considerably towards the improvement.

\* The system taught by MR. NEEF appears to be a modification of Pestalozzian, if we may judge from some European publications.

## DESCRIPTION OF THE FRONTISPIECE.

IN order to conduct a number of experiments on a small scale, a LAMP FURNACE is indispensably necessary. It consists of a brass rod, fastened to a piece of metal, furnished with rings of different diameters, and thumb screws, to raise or lower the lamp and rings when in use. By this furnace evaporation, digestion, solutions sublimation, distillation, and other processes, which require a low temperature, may be performed.

THE PHILOSOPHY  
OF  
EXPERIMENTAL CHEMISTRY.

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PART I.  
OF CHEMICAL AFFINITY.

*Experiment 1.* If equal parts, by weight, of *sulphur* and *mercury* be introduced into a crucible, and in this situation exposed to a sufficient heat; a compound will be formed, called **SULPHURET OF MERCURY**.

*Experiment 2.* Mix together *sulphur* and *potash*, and throw them into water; the sulphur will separate. If the same articles be put into a crucible and melted, and then thrown into water, the **SULPHUR**, as well as the **POTASH**, will be dissolved.

*Rationale.* In the first experiment we have an instance of chemical action, as well as of single affinity, for the sulphur and mercury would remain separate if heat was not applied. In consequence of this agent, they unite into an uniform whole, totally inseparable by mechanical means, and possessing characters distinct from either of its constituent parts.

In the second experiment, the union of sulphur with potash is effected by heat; for if a sulphuret was not formed, no solution of the sulphur would take place. Hence it is, that chemical action is the consequence of a power, without which it could never ensue, and with which it always acts in unison; this power is affinity.

*Remark.* Chemistry is a science, which has for its object to discover the constituent principles of bodies, the result of the various combinations, and the laws by which those combinations are affected. Its operations, being either analytical or synthetical, consist of composition, or decomposition. The laws which govern chemical changes have been resolved into those of attraction or affinity. *Affinity of composition* or *chemical affinity* differs from that of *aggregation*, or *cohesion* or *corpuscular attraction*, by acting upon matter of a different kind; or by taking place between the ultimate constituent parts of bodies, producing by its action, substances possessing properties frequently very different, and sometimes contrary to those of the constituent parts.

There are several circumstances to be considered in these inquiries, as

1. In what manner chemical affinity takes place;
2. In what proportion bodies are susceptible of combining;
3. Under what conditions;
4. With what degree of force they unite.

These inquiries, however, will be more fully discussed in future.

While the attraction of aggregation exerts its influence upon large masses, chemical affinity acts precisely on the reverse. That power which tends to preserve the annual and diurnal motion of the earth, and the planets, in order, Newton demonstrated was attraction. This acts at sensible distances, while chemical affinity acts at insensible distances.

Chemical affinity has the following character:

1. It acts only at insensible distances, and of course affects only the particles of bodies.

2. Its force is always the same in the same particles, but it is different in different particles.

3. This difference is modified considerably by the mass. Consequently, *in every instance in comparing the affinities of two bodies for a third, a more feeble affinity, in one of the two compared, will be found to be compensated by increasing its quantity.*

If A have a greater affinity for C than B has, if the mass of B, be greatly increased while that of A remains unchanged, B becomes capable of taking part of C from A. Barytes, for instance, has a stronger affinity than potash for muriatic acid; but, if a combination of barytes and muriatic acid, be boiled in contact with a large quantity of potash, the potash will detach a part of the muriatic acid from the barytes, in direct proportion to its quantity. According to Berthollet,\* the *absolute weight of any body, multiplied by its affinity, constitutes its mass*; and bodies act not by their affinities, *abstractly considered*, but by their mass; a larger mass compensating a weaker affinity. Therefore, in the opinion of Berthollet, affinity is not *elective*, according to the old doctrine of professor Bergman, and *never* occasions decomposition, but only combination. The decompositions which take place, are attributed by him to other causes, such as insolubility, elasticity, &c. In the old doctrine, affinity is *elective*, that is, if A has a stronger affinity for O than B has; and if O be combined with B, forming a compound which we represent by O B, A, upon being mixed with this compound, has the property of separating B completely from O, and taking its place, so as to form a compound, O A, while B is entirely disengaged. Though the observations of Berthollet, no doubt, are founded in truth, for which he has the concurring testimony of experiment, yet we are inclined to believe, that some parts of his doctrine require additional proof to render them perfectly admissible.

\* Researches into the Laws of Affinity.

In the experiments already given, the sulphur and mercury unite, and form a compound differing from either the sulphur or the mercury. This takes place by virtue of single affinity.

In the second experiment, the action of heat also promotes chemical affinity. The sulphur then, is united with the potash, by single affinity, forming sulphuret of potash, a compound which is soluble in water. Other experiments will be given hereafter.

What is termed the LAWS of chemical affinity are formed out of a great number of facts, which are the result of certain invariable phenomena, namely,

1. Chemical affinity can ensue between a number of bodies, simple or compound, and unite them chemically into one whole.

2. The efficacy of chemical affinity is in an inverse ratio to that of corpuscular attraction.

3. The agency of chemical affinity, is influenced by temperature; its action is either accelerated, retarded, prevented, or rendered efficacious.

4. Chemical affinity is accompanied by a change of temperature at the instant of its action.

5. The agency of chemical affinity existing between two or more bodies, may be dormant, until it is called into action by the interposition of another body, which frequently exerts no energy upon any of them in a separate state.

6. The ratio of the energy of chemical affinity acting between various bodies, is different in different substances.

7. The agency of chemical affinity, is either limited or unlimited, in certain bodies: in other words, chemical affinity is capable of uniting bodies in definite, or indefinite proportions.

8. The energy of chemical affinity of different bodies, is modified in proportion to the ponderable quantities of the bodies placed within the sphere of action.

It may not be improper to add, that Mr. Davy has ascertained that all bodies, which have a chemical affi-

nity for each other, are even in *opposite* states of electricity, and that the natural affinities may be destroyed or modified, by inducing a change in the electrical states of bodies by artificial means.

*Experiment 3.* Eight parts of *bismuth*, five of *lead*, and three of *tin*, melted in a crucible, affords an ALLOY which melts at  $212^{\circ}$ . A tea spoon formed of this metal will melt in boiling water.

*Experiment 4.* Two parts of *lead*, three of *tin*, and one of *mercury*, form a COMPOUND, which melts at a heat even less than boiling water.

*Experiment 5.* Equal parts of *lead*, *zinc*, and *bismuth*; combined in the same manner, may be kept in fusion over a lamp.

*Rationale.* In these experiments the metals have their capacity for caloric altered, and produce compounds, whose characteristic properties are different from those of their constituent parts. They are intended to prove the truth of law 1. Other proofs might also be adduced.

*Experiment 6.* Mix together *supertartrate of potash* with *carbonate of potash*, in a mortar, no action will ensue; add warm water, and an EFFERVESCENCE will immediately take place.

*Rationale.* This experiment is in proof of law 2, in which chemical action takes place only on the addition of water, which brings the particles into contact. The *tartaric acid*, of the *supertartrate*, unites with the *potash* added, whilst the *carbonic acid*, of the *carbonate*, takes the gaseous form. The compound formed, is the neutral tartrate of potash. Tin and nitrate of copper will also exhibit this law.

*Experiment 7.* Equal parts of *muriate of ammonia* and *carbonate of magnesia*, mixed together with six parts of water, and exposed to the ordinary temperature of the atmosphere, will mutually decompose each other.

*Experiment 8.* But if equal quantities of *muriate of magnesia* and *carbonate of ammonia* be exposed to a temperature of  $200^{\circ}$  in about four parts of water, the pro-

ducts will be MURIATE OF AMMONIA and CARBONATE OF MAGNESIA.

*Rationale.* These experiments are in proof of law 3. At the ordinary temperature of the atmosphere, muriate of ammonia and carbonate of magnesia decompose each other: the muriatic acid of the muriate of ammonia, will pass to the magnesia, forming muriate of magnesia, and the carbonic acid of the carbonate of magnesia will unite with the ammonia, and form carbonate of ammonia. In the second experiment, in which muriate of magnesia and carbonate of ammonia are concerned, the *increment* of temperature produces a decomposition. The muriatic acid of the muriate, unites with the ammonia of the carbonate of ammonia, and forms muriate of ammonia, whilst the carbonic acid of the carbonate, unites with the magnesia of the muriate of magnesia, and produces carbonate of magnesia. Consequently, by an increase of temperature, the affinity of composition is changed, and the products are muriate of ammonia and carbonate of magnesia. Other experiments, proving the same fact, will be noticed hereafter.

*Remark.* The proofs of law 4. will be found in the experiments on heat.

*Experiment 9.* Mix iron filings and water together, no action will ensue, but add sulphuric acid, and the filings will be DISSOLVED.

*Rationale.* In this case the sulphuric acid promotes the chemical action. If iron filings were introduced into concentrated sulphuric acid, no action would take place; but on the addition of water, a violent effervescence would result. In the latter case, the water is the *condition* necessary to accelerate the chemical action. As soon as the sulphuric acid comes in contact with the iron filings and water, or as soon as the water is added to the sulphuric acid and iron filings, decomposition commences. The oxygen of the water, oxydizes the metal, which is then taken up by the acid, whilst the hydrogen of the water is set at liberty.

*Experiment 10.* Make a solution of *silver* in *nitric acid*, it will form a NITRATE OF SILVER; to which add *mercury*, and the silver will be precipitated.

*Experiment 11.* To the fluid of the last experiment, which is now a NITRATE OF MERCURY, introduce a piece of sheet *lead*; the lead will be dissolved, and the mercury become precipitated.

*Experiment 12.* To the fluid of the last experiment which is now a NITRATE OF LEAD, introduce pieces of *copper*. The lead will be precipitated, and the copper take its place.

*Experiment 13.* To the result of the last experiment, which is now a NITRATE OF COPPER, immerse pieces of sheet *iron*, and the copper will be precipitated.

*Experiment 14.* To the fluid which now remains, add *zinc* in pieces, and the iron will become precipitated. The fluid is now a NITRATE OF ZINC.

*Experiment 15.* If to the nitrate of zinc of the last experiment, carbonate of potash be added, the zinc will be separated, and the potash take its place, forming NITRATE OF POTASH.

*Rationale.* In all these experiments, which are intended to illustrate law 6th, we are presented with the changes which bodies undergo from one state to another, when under the operation of chemical action. Although, agreeably to the old doctrine of affinity, elective attraction is the cause of these changes, yet according to the theory of Berthollet there is not a total transfer of the base, but that a division is made between the two opposite attracting substances, in a compound ratio of the relative force of affinity and quantity of each.

It is plain, however, that if the doctrine of professor Bergman, as it stands, be adopted, the mercury has a greater affinity for the nitric acid than the silver, lead than the mercury, copper than the lead, iron than the copper, zinc than the iron, and potash a still stronger affinity. We ought to remark, however, that these affinities, with an exception to the last, are affected also by corresponding affinities for oxygen; for all metals,

previously to solution, must be oxydized, either before or in the act of solution: and, of course, when the metal is precipitated, its oxygen, which was necessary to its solution, must be transferred to the other metal, which is to take its place. But in the last experiment a mutual decomposition ensues; the nitric acid unites with the potash, whilst the carbonic acid combines with the oxyd of zinc, which is precipitated.

*Experiment 16.* *Alcohol*, when mixed with *water*, will COMBINE with it in any proportion.

*Remark.* This experiment is in illustration of law 7.

*Experiment 17.* Take one ounce of *muriatic acid*, dilute it with *water*, and add by degrees some *chalk*, or *magnesia*, either a SUPER MURIATE or a MURIATE OF LIME, or MAGNESIA, (if it be used) will be formed, according to the quantity added.

*Remark.* When the acid will dissolve no more, it is said to be *saturated*.

*Rationale.* This is a combination of lime, or magnesia, with muriatic acid: if a smaller portion than is necessary to saturate the acid be added, it forms a *supersalt*; if the combination is at its *maximum*, the result is a *neutral salt*. If more chalk, or magnesia, is used than is necessary to complete the saturation, instead of being taken up, it will fall to the bottom. It is on this account, that water can dissolve only a certain quantity of salt, spirit of wine a certain quantity of resin, &c.

*Remark.* Chemical affinity is of three kinds, viz. *simple affinity*, *compound affinity*, and *disposing affinity*. That power, which tends to preserve the component parts of a body in union, is called by Mr. Kirwan the *quiescent affinity*, and, on the contrary, the attraction which tends to destroy the original compound, is called the *divellent affinity*.

*Experiment 18.* Put *acetate of potash* into a retort, pour *muriatic acid* upon it, and apply heat; ACETIC ACID will be expelled.

*Experiment 19.* If *nitric acid* be added to the residue of the last experiment, and heat applied, the MURIATIC

ACID will be disengaged, and the nitric acid take its place.

*Experiment 20.* If *sulphuric acid* be now added, and heat again applied, the NITRIC ACID will be expelled, and the sulphuric acid remain in possession of the alkali.

*Rationale.* These changes take place in consequence of simple affinity, as follows: The acetic acid is united with the potash by virtue of chemical affinity. When it is exposed to heat in contact with muriatic acid, the former combination is destroyed, and a new one, composed of muriatic acid and potash, is formed. The potash has, therefore, a greater affinity for muriatic acid, than it has for the acetic. When nitric acid is added to the muriate of potash, thus formed, the muriatic acid in like manner is expelled, and a nitrate of potash remains. When this is treated with sulphuric acid, the nitric acid is disengaged, and a compound consisting of sulphuric acid and potash is the result. Thus the acetate of potash, is finally converted into the sulphate of potash.

*Experiment 21.* Dissolve the compound last formed in water, and add thereto a solution of *acetate of lead*, a decomposition will take place; on filtering the liquor and evaporating it, ACETATE OF POTASH (provided all the sulphate was decomposed) will be reproduced.

*Rationale.* This effect ensues in consequence of double or compound affinity, which will be presently noticed; suffice it to add, that the acetic acid is transferred from the lead to the potash.

*Experiment 22.* If into a solution of *sulphate of ammonia*, there be poured *nitric acid*, no decomposition is produced; but if a solution of *nitrate of potash* be poured in, we obtain by evaporation two new bodies, SULPHATE OF POTASH and NITRATE OF AMMONIA.

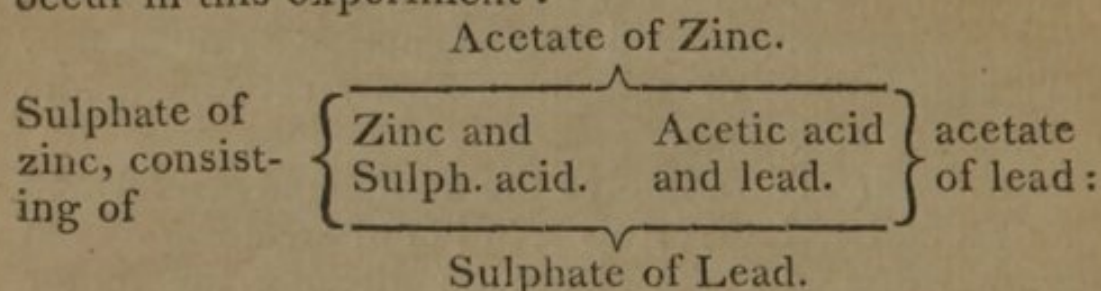
*Rationale.* In this experiment, the addition of nitrate of potash decomposes the sulphate of ammonia, by compound affinity. The sulphuric acid possesses a stronger affinity for the potash, than it has for the ammonia, consequently, sulphate of potash is first formed. The nitric acid in its turn unites with the ammonia, and

forms nitrate of ammonia. The sulphuric acid then attracts the potash, and the nitric acid attracts the ammonia. As both salts are soluble, they produce no visible phenomena; but on evaporation, the *laws of crystallization* separates them in separate states.

*Experiment 23.* If into a solution of *sulphate of zinc*, a piece of *lead* be immersed, no effect will follow; but if to a solution of sulphate of zinc, acetate of lead in solution be added, an immediate decomposition will result, and one of the products be precipitated.

*Rationale.* In this case the sulphuric acid of the sulphate of zinc passes to the lead, for which it has an affinity, while the acetic acid of the acetate of lead unites with the zinc, and constitutes the acetate of zinc, which remains in solution.

The following scheme will exhibit the changes that occur in this experiment :



The original compounds are included in the vertical brackets; and the horizontal brackets points out the new ones, viz. acetate of zinc and sulphate of lead. The point of the bracket turning upwards denotes that the acetate of zinc remains in solution; and, by that of the lower one being directed downwards, it is meant to express, that the sulphate of lead falls down, or is precipitated.

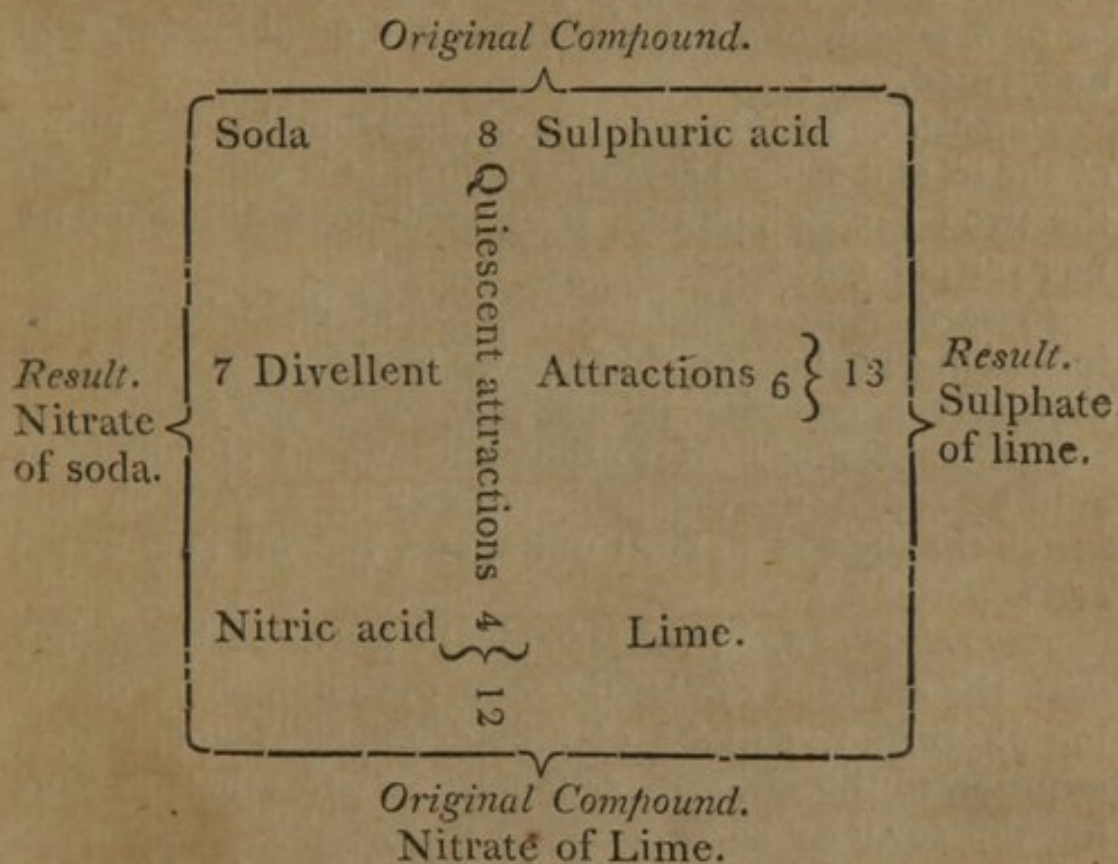
As it respects the opinions of Berthollet on the subject of double affinity, it appears that it is equally influenced by the circumstance of *quantity*, with those of single affinity.

*Experiment 24.* Add the solutions of *sulphate of soda* and *nitrate of lime* together, a mutual decomposition will ensue.

*Rationale.* In this case, as in the former, a double exchange of principle takes place: the sulphuric acid

passes to the lime, forming sulphate of lime, and the nitric acid passes to the soda, and produces nitrate of soda.

*Remark.* In order to shew in what manner the terms *quiescent* and *divellent* affinities are applied, and, consequently, the force of attraction, (provided the theory be true, which however has been modified) let us introduce the following diagram.



If, to separate the acid from the soda, we add some lime, in order to make it combine with the acid, we shall fail in our attempt, because the soda and the sulphuric acid attract each other by a force, which is (by way of supposition) represented by the number 8; while the lime tends to unite with this acid by an affinity equal only to the number 6. It is plain, therefore, that the sulphate of soda will not be decomposed, since a force equal to 8 can not be overcome by a force equal only to 6. Again, if we attempt to decompose the salt by nitric acid, which tends to combine with soda, we shall be also unsuccessful, as nitric acid unites with the alkali by a force equal only to 7. But, if nitrate

of lime be added, the constituents of which are united by a power equal to 4, a decomposition will ensue; because the numbers 8 and 4 shew, that the sum is less than 8 and 6, which represent the degrees of affinity of the two new compounds, that will in consequence be formed.

*Experiment 25.* Pour a little *water* into a vial containing about an ounce of *olive oil*, and shake them together, no union will take place; but if *caustic potash* be now added, and the vial shaken, a combination will be formed.

*Rationale.* In this case the *alkali* promotes the union of the *oil* and *water*, serving as a bond as it were between the two; the compound, thus formed, is the SOAP OF POTASH, or soft soap.

*Remark.* This effect is produced by *disposing affinity*, in which two bodies, having no tendency to unite of themselves, combine in consequence of the addition of a third substance. If to the compound, so formed, an acid be added, the disposing affinity is destroyed, because the acid and alkali unite, and the oil and water are separated.

*Experiment 26.* Proceed as in the last experiment, but with the addition of caustic soda, the compound resulting therefrom will be of a firmer consistence, and, if exposed to the air, will gradually become hard, forming the SOAP OF SODA, or hard soap.

*Rationale.* The same affinity takes place in this as in the other experiment.

*Experiment 27.* Pour *oil* on *water*, no union will ensue; but add *liquid ammonia*, and the oil will become united with the water, as in the former experiments, forming the SOAP OF AMMONIA, or volatile liniment.

*Rationale.* The same as the preceding.

It may not be improper in this place to offer some remarks on affinity as it respects gases, liquids, and solids.

The mutual mixture, which some of the gases exhibit when brought into contact with each other, is similar to what happens when liquids are mixed together. Mr.

Dalton observes, that this effect is owing entirely to the difference between the size of the particles of different gases. Several gases again, when mingled together lose their former state of existence, and new products possessing peculiar properties are generated. The following are examples of this kind.

*Products.*

Oxygen with nitrous gas	{ nitrous acid. nitric acid.
Ammonia with { vapour	liquid ammonia.
{ muriatic acid	muriate of ammonia.
{ fluoric acid	fluat of ammonia.
{ carbonic acid	carbonate of ammonia.
{ sulphuretted hydrogen	hydrosulphuret of ammonia.

Other gases are united only under particular circumstances, as by combustion, passing them through a red heat, or by the electric shock. Among these are,

*Products.*

Oxygen with { hydrogen	water.
{ carbonic oxyd	carbonic acid.
{ azote	nitric acid.
{ muriatic acid	oxymuriatic acid.
{ oxymuriatic acid	hyperoxymuriatic acid.
{ sulphurous acid	sulphuric acid.
{ nitrous oxyd	nitric acid.

When gaseous bodies unite, they unite either in equal bulks of each, or two or three parts by bulk of one, unite with one part by bulk of the other, as appears from the following table.

*Compounds.*

*Constituents by bulk.*

Muriate of ammonia	100 ammoniacal	100 mur. acid gas
Carbonate of ammonia	100 do.	100 carb. acid gas
Subcarbonate of ammo.	100 do.	50 do.
Water	100 hydrogen gas	50 oxygen
Nitrous oxyd	100 azotic gas	50 do.
Nitric oxyd	100 do.	50. do.

*Compounds.**Constituents by bulk.*

Nitric acid	100 azotic gas	200 oxygen
Nitric acid	200 nitrous gas	100 do.
Ammonia	100 azotic gas	300 hydrogen
Sulphuric acid	100 sulphurous acid	50 oxygen
Oxymuriatic acid gas	300 muriatic do.	100 do.
Carbonic acid	100 carbonic oxyd	50 do.

Some gases have the property of mutually decomposing each other, as

Oxygen with phosphuretted hydrogen.

Oxymuriatic acid with { ammonia.  
phosphuretted hydrogen.  
hydrogen.  
carburetted hydrogen.  
carbonic oxyd.  
olefiant gas.  
sulphuretted hydrogen.  
sulphurous acid.  
nitrous gas

Sulphuretted hydrogen with { nitrous gas.  
sulphurous acid.

On the contrary, in some, decomposition is effected by combustion; of this description we may reckon

Oxygen with { sulphuretted hydrogen.  
carburetted hydrogen.  
olefiant gas.  
vapour of ether.  
alcohol.

Nitrous oxyd with { hydrogen.  
phosphuretted hydrogen.  
sulphuretted hydrogen.  
carbonic oxyd.  
carburetted hydrogen.  
olefiant gas.  
vapour of ether.  
alcohol.

Nitric oxyd with { hydrogen.  
sulphurous acid.

Hydrogen with { sulphurous acid.  
carbonic acid.

Vapour of water with  $\left\{ \begin{array}{l} \text{carburetted hydrogen.} \\ \text{olefiant gas.} \\ \text{muriatic acid} \end{array} \right.$

As it respects the combination of gases with water, it appears that Mr. Dalton has made a happy generalization of his experiments, in which he conceives that the degree of absorption of the following gases is in this order, namely, of

Carbonic acid	}	water absorbs its own bulk $= \frac{1}{13}$
Sulphuretted hydrogen		
Nitrous oxyd		
Olefiant gas		1-8th its bulk $= \frac{1}{23}$
Nitrous gas	}	water absorbs 1-27th $= \frac{1}{33}$
Oxygen gas		
Phosphuretted hydrogen		
Carburetted hydrogen		
Azotic gas	}	water absorbs 1-65th $= \frac{1}{43}$
Hydrogen		
Carbonic oxyd		

Combination of a gas with water, according to the experiments of Dr. Henry, may be facilitated by *pressure*, and in this way water may be made to absorb any quantity of a gas whatever. The following table will shew the bulk of each gas absorbed by one ounce measure of water. It must be observed, however, that as the temperature increases, the absorbability of the gases by water diminishes.

Oxymuriatic acid	1.5 +
Sulphurous acid	3.3
Fluoric acid	175 +
Muriatic acid	516
Ammoniacal gas	780

As an increase of bulk ensues, when a cubic inch of water is saturated with these gases, the following table will exhibit the magnitude of water when thus saturated, supposing the original bulk to have been 1.

Saturated with	{	oxymuriatic acid	1.002 +
		sulphurous acid	1.040
		muriatic acid	1.500
		ammoniacal	1.666

It appears, therefore, that the water undergoes an expansion, so that the density of the gases absorbed is not so considerable as what would be supposed.

The *real densities* of these gases in water, in the order above named, are as follow:

$$\begin{aligned} 1.5 \\ 31.7 &= 33 \text{ nearly} \\ 344.0 &= 73 \\ 468.0 &= 83 \end{aligned}$$

A number of other circumstances, on the affinity of gases with water, with each other, &c. will be considered hereafter.

As to the combination of liquids with each other; some liquids will mix, and of course combine in any proportions, as

Water with  $\left\{ \begin{array}{l} \text{alcohol.} \\ \text{nitric acid.} \\ \text{sulphuric acid.} \end{array} \right.$

Alcohol with ether.

Sulphuric acid with nitric acid.

Fixed oils with  $\left\{ \begin{array}{l} \text{petroleum.} \\ \text{volatile oils.} \\ \text{fixed oils.} \end{array} \right.$

Volatile oils with  $\left\{ \begin{array}{l} \text{petroleum.} \\ \text{volatile oils.} \end{array} \right.$

When these liquids are mixed they form a homogeneous compound. An evolution of heat, consequently a certain degree of condensation takes place on mixture.

Other liquids, again, unite only in certain proportions, as

Water with  $\left\{ \begin{array}{l} \text{ether.} \\ \text{volatile oils.} \\ \text{oxymuriate of tin.} \end{array} \right.$

Alcohol with  $\left\{ \begin{array}{l} \text{volatile oils.} \\ \text{petroleum.} \\ \text{phosphuret of sulphur.} \end{array} \right.$

Ether with  $\left\{ \begin{array}{l} \text{volatile oils.} \\ \text{petroleum, \&c.} \end{array} \right.$

Of the liquids, which do not *combine* in any sensible degree, are

Water and	{	petroleum.
		fixed oils.
		supersulphuretted-hydrogen.
Fixed oils and	{	alcohol.
		ether, &c.

As it respects the combination of solids, the following table will exhibit some substances which will unite with each other in any proportion whatever, by the agency of heat:

Sulphur with phosphorus.

Carbon with iron.

Metals with most metals.

Protoxyd of antimony with sulphuret of antimony.

Earths with earths.

Earths with some metallic oxyds.

Some earths with fixed alkalies.

Fixed alkalies with solid oils.

Solid oils with each other and with bitumen.

Other bodies, however, combine only in determinate proportions, as

Sulphur with	{	metals.
		some metallic oxyds.
		earths.
		fixed alkalies.

Phosphorus with	{	carbon.
		metals.
		some earths.

Acids with	{	alkalies.
		earths.
		metallic oxyds.

On the combination of acids with alkalies, earths and metallic oxyds, a vast number of experiments have been made, in order to ascertain the proportion in which their constituents combine.

In the following table, which exhibits the general results of these experiments, the numbers represent the weight of the different acids and bases, which neutralize each other respectively:

*Acids.*

Sulphurous	50	Barytes	63
Oxalic	39.5	Strontian	37
Nitric	34	Potash	38
Sulphuric	31	Soda	23.3
Phosphoric	22	Lime	21.8
Muriatic	18	Magnesia	17.6
Carbonic	16.5	Ammonia	9.00
Phosphorous	16		

Suppose, for instance, that a *combination* of sulphuric acid and soda is to be formed; it is evident, from the table, that 23.3 parts of soda added to 31 of sulphuric acid will saturate each other.

I have before observed, that the doctrine of elective attractions, on which the whole system of Bergman is founded, has been considerably modified by the experiments and observations of Berthollet, and accordingly a new system framed. All those cases of chemical affinity, which either really or apparently contradict the general laws, which are called *anomalies*, may be reduced to two classes; viz. those depending on the variable force of affinity itself, and those occasioned by the action of *opposite* attractions. We have already illustrated this position by experiment.

As the tables of chemical decompositions, commonly called tables of affinity, may prove useful, we shall here insert them with some corrections.

# TABLES OF SIMPLE AFFINITY, OR CHEMICAL DECOMPOSITIONS.

<i>Oxygen.</i>	<i>Oxygen.*</i>	<i>Carbon.</i>	<i>Nitrogen.</i>
Carbon,	Titanium,	Oxygen,	Oxygen,
Charcoal,	Manganese	Iron,	Sulphur,
Manganese,	Zinc,	Hydrogen.	Phosphorus,
Zinc,	Iron,		Hydrogen.
Iron,	Tin,		
Tin,	Uranium,		
Antimony,	Molybdenum,		
Hydrogen,	Tungsten,		
Phosphorus,	Cobalt,		
Sulphur,	Antimony,		
Arsenic,	Nickel,		
Nitrogen,	Arsenic,		
Nickel,	Chromium,		
Cobalt,	Bismuth,		
Copper,	Lead,		
Bismuth,	Copper,		
Caloric,	Tellurium,		
Mercury,	Platinum,		
Silver,	Mercury,		
Oxyd of arsenic,	Silver,		
Nitric oxyd,	Gold.		
Gold,			
Platinum,			
Carbonic oxyd,			
Muriatic acid,			
White oxyd of Manganese,			
White oxyd of Lead.			

\* Vauquelin's Table of the affinity of the metals for oxygen, according to the difficulty with which their oxyds are decomposed by heat.

## TABLES OF SIMPLE AFFINITY CONTINUED.

<i>Hydrogen.</i>	<i>Sulphur.</i> <i>Phosphorus.</i>	<i>Potass, Soda, and</i> <i>Ammonia.</i>
Oxygen,	Potass,	<i>Acids.</i> Sulphuric.
Sulphur,	Soda,	— Nitric,
Carbon,	Iron,	— Muriatic,
Phosphorus,	Copper,	— Phosphoric,
Nitrogen.	Tin,	— Fluoric,
	Lead,	— Oxalic,
	Silver,	— Tartarous,
	Bismuth,	— Arsenic,
	Antimony,	— Succinic,
	Mercury,	— Citric,
	Arsenic,	— Lactic,
	Molybdenum.	— Benzoic,
		— Sulphurous,
		— Acetous,
		— Mucous,
		— Boracic,
		— Nitrous,
		— Carbonic,
		— Prussic,
		Oil,
		Water,
		Sulphur.

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<i>Baryta.</i>	<i>Strontia.</i>	<i>Lime.</i>
<i>Acids.</i> Sulphuric,	<i>Acids.</i> Sulphuric.	<i>Acids.</i> Oxalic,
— Oxalic,	— Phosphoric,	— Sulphuric,
— Succinic,	— Oxalic,	— Tartarous,
— Fluoric,	— Tartarous,	— Succinic,
— Phosphoric,	— Fluoric,	— Phosphoric,
— Mucous,	— Nitric,	— Mucous,
— Nitric,	— Muriatic,	— Nitric,
— Muriatic,	— Succinic,	— Muriatic,
— Suberic,	— Acetous,	— Suberic,
— Citric,	— Arsenic,	— Fluoric,
— Tartarous,	— Boracic,	— Arsenic,

## TABLES OF SIMPLE AFFINITY CONTINUED.

<i>Baryta.</i>	<i>Strontia.</i>	<i>Lime.</i>
<i>Acids.</i> Arsenic,	<i>Acids.</i> Carbonic,	<i>Acids.</i> Lactic,
— Lactic,	Water.	— Citric,
— Benzoic,		— Malic,
— Acetous,		— Benzoic,
— Boracic,		— Acetous,
— Sulphurous,		— Boracic,
— Nitrous,		— Sulphurous,
— Carbonic,		— Nitrous,
— Prussic,		— Carbonic,
Sulphur,		— Prussic,
Phosphorus,		Sulphur,
Water,		Phosphorus,
Fixed oil.		Water,
		Fixed oil.

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<i>Magnesia.</i>	<i>Alumina.</i>	<i>Silica.</i>
<i>Acids.</i> Oxalic,	<i>Acids.</i> Sulphuric,	Fluoric acid,
— Phosphoric,	— Nitric,	Potass.
— Sulphuric,	— Muriatic,	
— Fluoric,	— Oxalic,	
— Arsenic,	— Arsenic,	
— Mucous,	— Fluoric,	
— Succinic,	— Tartarous,	
— Nitric,	— Succinic,	
— Muriatic,	— Mucous,	
— Tartarous,	— Citric,	
— Citric,	— Phosphoric,	
— Malic,	— Lactic,	
— Lactic,	— Benzoic,	
— Benzoic,	— Acetous,	
— Acetous,	— Boracic,	
— Boracic,	— Sulphurous,	
— Sulphurous,	— Nitrous,	
— Nitrous,	— Carbonic,	
— Carbonic,	— Prussic.	
— Prussic,		
Sulphur.		

## TABLES OF SIMPLE AFFINITY CONTINUED.

<i>Ox. of Platinum.</i>	<i>Ox. of Silver.</i>	<i>Ox. of Mercury.</i>
<i>Gold.</i>		
Ether. Gallic acid.	Gallic acid,	Gallic acid,
Muriatic,	Muriatic,	Muriatic,
Nitric,	Oxalic,	Oxalic,
Sulphuric,	Sulphuric,	Succinic,
Arsenic,	Mucous,	Arsenic,
Fluoric,	Phosphoric,	Phosphoric,
Tartarous,	Sulphurous,	Sulphuric,
Phosphoric,	Nitric,	Mucous,
Oxalic,	Arsenic,	Tatarous,
Citric,	Fluoric,	Citric,
Acetous,	Tatarous,	Malic,
Succinic,	Citric,	Sulphurous,
Prussic,	Lactic,	Nitric,
Carbonic.	Succinic,	Fluoric,
	Acetous,	Acetous,
Ammonia,	Prussic	Benzoic,
	Carbonic,	Boracic,
	Ammonia.	Prussic,
		Carbonic,
<i>Oxyd of Lead.</i>	<i>Oxyd of Copper.</i>	<i>Oxyd of Arsenic.</i>
Gallic,	Gallic,	Gallic,
Sulphuric,	Oxalic,	Muriatic,
Mucous,	Tartarous,	Oxalic,
Oxalic,	Muriatic,	Sulphuric,
Arsenic,	Sulphuric,	Nitric,
Tartarous,	Mucous,	Tartarous,
Phosphoric,	Nitric,	Phosphoric,
Muriatic,	Arsenic,	Fluoric,
Sulphurous,	Phosphoric,	Succinic,
Suberic,	Succinic,	Citric,
Nitric,	Fluoric,	Acetous,
Fluoric,	Citric,	Prussic,
Citric,	Lactic,	

\* Omitting the oxalic, citric, succinic, and carbonic, and adding sulphuretted hydrogen after ammonia.

## TABLES OF SIMPLE AFFINITY CONTINUED.

<i>Oxyd of Lead.</i>	<i>Oxyd of Copper.</i>	<i>Ox. of Arsenic.</i>
Malic,	Acetous,	Fixed alkalies,
Succinic,	Boracic,	-----
Lactic,	Prussic,	Ammonia,
Acetous,	Carbonic,	-----
Benzoic,	-----	Fixed oils,
Boracic,	Fixed alkalies,	-----
Prussic,	-----	Water.
Carbonic,	Ammonia,	-----
-----	-----	-----
Fixed oils,	Fixed oils.	
-----		
Ammonia.		

<i>Ox. of Iron.</i>	<i>Ox. of Tin.*</i>	<i>Ox. of Zinc.</i>	<i>Ox. of Ant.</i>
Ether. Gallic,	Gallic,	Gallic,	Gallic,
Oxalic,	Muriatic,	Oxalic,	Muriatic,
Tartarous,	Sulphuric,	Sulphuric,	Benzoic,
Camphoric,	Oxalic,	Muriatic,	Oxalic,
Sulphuric,	Tartarous,	Mucous,	Sulphuric,
Mucous,	Arsenic,	Nitric,	Nitric,
Muriatic,	Phosphoric,	Tartarous,	Tartarous,
Nitric,	Nitric,	Phosphoric,	Mucous,
Phosphoric,	Succinic,	Citric,	Phosphoric,
Arsenic,	Fluoric,	Succinic,	Citric,
Fluoric,	Mucous,	Fluoric,	Succinic,
Succinic,	Citric,	Arsenic,	Fluoric,
Citric,	Lactic,	Lactic,	Arsenic,
Lactic,	Acetous,	Acetous,	Lactic,
Acetous,	Boracic,	Boracic,	Acetous,
Boracic,	Prussic,	Prussic,	Boracic,
Prussic,	-----	Carbonic,	Prussic,
Carbonic.	Ammonia.	-----	-----
		Fixed alka-	Fixed alka-
		lies,	lies,
		Ammonia.	Ammonia.

\* Bergman places the tartarous before the muriatic.

## TABLES OF SIMPLE AFFINITY CONTINUED.

Sulphuric acid.	Sulphurous acid.	Phosphoric acid.	Phosphorous acid.
Prussic*	Succinic†	Carbonic‡	
Baryta,	Baryta,	Baryta,	Lime,
Strontia,	Lime,	Strontia,	Baryta,
Potass,	Potass,	Lime,	Strontia,
Soda,	Soda,	Potass,	Potass,
Lime,	Strontia,	Soda,	Soda,
Magnesia,	Magnesia,	Ammonia,	Ammonia,
Ammonia,	Ammonia,	Magnesia,	Glucina,
Glucina,	Glucina,	Glucina,	Alumina,
Gadolina,	Alumina,	Alumina,	Zirconia,
Alumina,	Zirconia,	Zirconia,	Metallic ox-
Zirconia,	Metallic ox-	Metallic ox-	yds.
Metallic ox-	yds.	yds,	
yds.		Silica,	

	Fluoric Acid.	Acetous Acid.	Oxalic Acid.
Nitric Acid.	Boracic —.	Lactic —.	Tartarous—.
Muriatic—.§	Arsenic —.¶	Suberic —.**	Citric —.††
	Tungstic —.		
Baryta,	Lime,	Baryta,	Lime,
Potass,	Baryta,	Potass,	Baryta,
Soda,	Strontia,	Soda,	Strontia,
Strontia,	Magnesia,	Strontia,	Magnesia,
Lime,	Potass,	Lime,	Potass,
Magnesia,	Soda,	Ammonia,	Soda,
Ammonia,	Ammonia,	Magnesia,	Ammonia,
Glucina,	Glucina,	Metallic ox-	Alumina,
Alumina,	Alumina,	yds,	Metallic ox-
Zirconia,	Zirconia,	Glucina,	yds,
Metallic ox-	Silica.	Alumina,	Water,
yds.		Zirconia.	Alcohol.

\* With the omission of all after ammonia.

† Ammonia should come before magnesia, and strontia, glucina and zirconia should be omitted.

‡ Magnesia should stand above ammonia, and alumina and silica should be omitted.

§ Ammonia should stand above magnesia.

|| Silica should be omitted, and instead of it water and alcohol be inserted.

¶ Except silica.

\*\* With the omission of strontia, metallic oxyds, glucina and zirconia.

†† Zirconia after

## TABLES OF SIMPLE AFFINITY CONTINUED.

<i>Benzoic Acid.</i>	<i>Camphoric Acid.</i>	<i>Fixed Oil.</i>	<i>Alcohol.</i>	<i>Sulphuretted Hydrogen.</i>
White ox- yd of ar- senic, Potass, Soda, Ammonia, Baryta, Lime, Magnesia, Alumina,	Lime, Potass, Soda, Baryta, Ammonia, Alumina, Magnesia,	Lime, Baryta, Potass, Soda, Magnesia, Oxyd of Mercury, Other me- tallic ox- yds, Alumina,	Water, Ether, Volatile oil, Alkal. sul- phurets.	Baryta, Potass, Soda, Lime, Ammonia, Magnesia, Zirconia,

As the tables of affinity stand, it is obvious that in the case of sulphuric acid, either zirconia, alumina, ammonia, magnesia, or lime will decompose the metallic salts, in which, according to Bergman, the elective attraction is stronger for the acid; and if to any of these new compounds, either soda, potash, strontia, or barytes is added, they will severally decompose the new salt or salts.

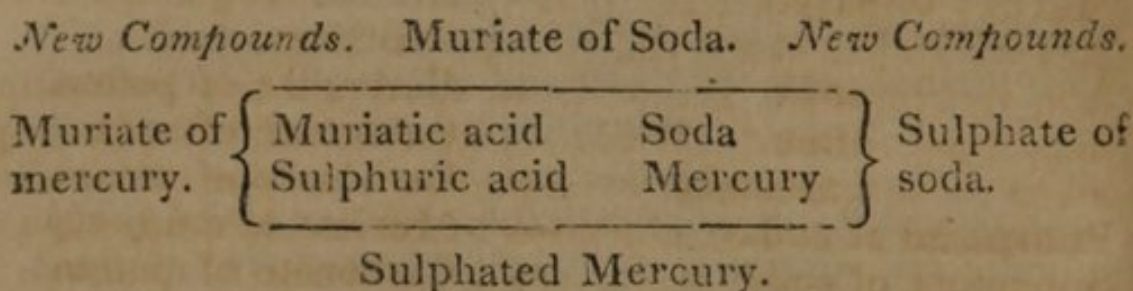
Dr. Gren observes,\* that all attractions in the *dry way*, or by heat, when one substance is separated in the elastic form, though called simple, imply a double affinity, in which caloric constitutes the fourth member, and do not belong to simple affinity.

For instances where muriatic acid is expelled from muriate of soda, in the *dry way*, by means of phosphoric acid, he remarks that it cannot be called a simple, but must be called a double affinity; because two new combinations are formed, phosphate of soda and muriatic acid gas, though in similar cases only one separation should take place. Nor is it material whether the caloric be applied from without, or whether it be already a constituent part of one of the bodies submitted to the operation.

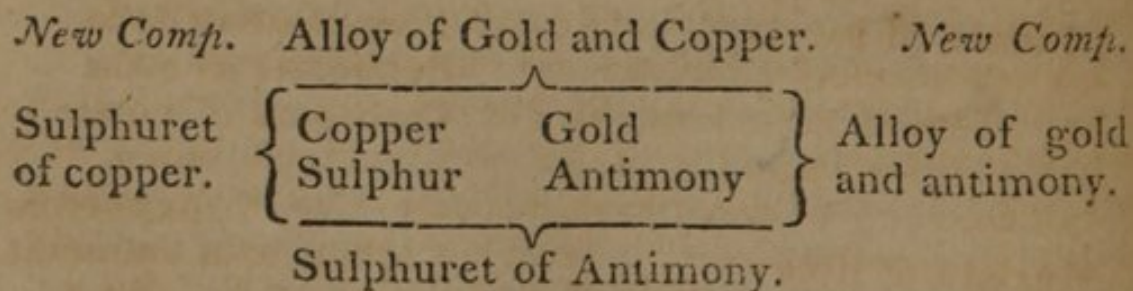
\* Gren's Chemistry.

The cases of affinity, which take place in the dry way, as it is called, in which heat is the decomposing power, appear to be subject in some degree to the objections, on the theory of elective attractions, given by Berthollet. It is unnecessary, therefore, to annex a table of affinities by heat, as our knowledge of these operations is but partial, and little utility can arise from them. One or two examples may prove useful.

In the preparation of *corrosive sublimate*, a double decomposition, *by fire*, takes place, as will appear in the following diagram.



Therefore, on exposing a mixture of sulphate of mercury and muriate of soda to heat, the sulphuric acid quits the mercury and passes to the soda, forming sulphate of soda, which remains at the bottom of the subliming vessel, whilst the muriatic acid unites with the mercury, and sublimes into a muriate of mercury. Or, if an alloy of gold and copper be exposed to heat with sulphuret of antimony (crude antimony) a sulphuret of copper, and an alloy of gold and antimony will be produced, as follows.



The following cases of mutual decomposition, which take place either by simple or compound affinity, are extracted from Duncan's Pharmacopœa.

## CASES OF MUTUAL DECOMPOSITION.

## 1. FROM SIMPLE AFFINITY.

Sulphate of potass	with Muriate of baryta.
soda	— Nitrate of potass.
ammonia	— Muriate of soda.
magnesia	— Carbonate of potass.
Supersulphate of alumina	— Muriate of lime.
Nitrate of potass	— baryta.
ammonia	— Phosphate of soda.
Muriate of baryta	— All the sulphates and nitrates.
soda	— Carbonate of potass.
lime	— Subborate of soda.
ammonia	— Carbonate of potass.
Phosphate of soda	— Muriate of ammonia.
Subborate of soda	— Carbonate of potass.
Nitrate of silver	— Muriate of soda.
Acetite of lead	— Citrate of potass.
Sulphate of mercury	— Muriate of soda.
Soap of potass	— Muriate of soda.
Soap of soda	— Sulphate of lime.

## 2. FROM COMPOUND AFFINITY.

Sulphate of baryta	with Carbonate of potass.
Sulphate of baryta	— soda.
potass	— Muriate of lime.
soda	— Muriate of lime.
Muriate of baryta	— Phosphate of soda.
	Subborate of soda.
	Carbonate of potass.
	soda,
	ammonia.
Muriate of lime	— Carbonate of ammonia.
Phosphate of soda	— lime.
Acetite of lead	— Sulphate of zinc.
Acetite of lead.	— Nitrate of mercury.

It is to be understood, that in the terms of mutual decomposition from simple affinity, and mutual decomposition from compound affinity, the following difference exists. That in simple affinity, when two bodies unite, in consequence of their *mutual* attraction alone, whether these bodies be themselves simple or compound, and even although, in the latter case, it be attended with decomposition, it differs from compound affinity in this particular; that in the latter there is more than one new combination, and when the new arrangement would not have taken place, in consequence of the attraction tending to produce either combination singly.

The doctrine of Berthollet has lately been called in question, and a system of chemical combination proposed by Mr. Dalton, and also by Dr. Wollaston, founded on the opposite principle to him, that bodies unite in proportions, rendered determinate by the immediate exertion of their mutual attractions.\*

As it respects the precipitation of metals from their solution, agreeably to the tables of affinity, an example of which is given in page 7, it appears that Mr. Sylvester has rendered it probable, that these precipitations are occasioned by the galvanic action of metals on each other. Volta has shown that metals differ in the avidity with which they absorb electricity, and that when two metals are placed in contact and separated, the one becomes *plus*, and the other *minus* electrified. It has also been shown, that when metals are in different states of electricity, and properly arranged, they decompose water, and produce all the other phenomena of galvanism. Mr. Sylvester, therefore, concludes, that it is the hydrogen evolved that produces the reduction of the metal.† If this opinion be correct, the order of affinity should be, not as it respects the metal for oxygen, or acid, but for electricity.

Certain substances only can be thrown down or precipitated. The agent that effects this change is called

\* See Murray's Supplement to the first edition of a System of Chemistry; also Phil. Trans. 1808.

† Nicholson's Journal, v. xiv. p. 94.

a *precipitant*, and the body thus separated is called a *precipitate*. By precipitation the earths and metallic oxyds, and such acids as are nearly insoluble in water, may be separated; while the alkalies and soluble acids cannot be precipitated. When a base is employed to precipitate a soluble acid, the substance thrown down is always a compound consisting of the acid united to the base employed. Accordingly, the acid is sometimes completely separated, and sometimes not, which depends on the energy of the base employed, and the degree of insolubility of the salt formed. In the case, however, of a neutral salt being used as a precipitant, the precipitate is composed of one of the ingredients of the precipitating salt, united to one ingredient of the salt in solution. Therefore such salts are employed as are known to form insoluble compounds with the acid or base which we wish to throw down. The separation is complete when the new salt formed is completely insoluble. Neutral salts perform their office much better than either the acid or base: thus sulphate of soda will precipitate barytes from its solution much better than sulphuric acid, and alkaline carbonates will throw down the earths with much more facility than the alkalies in a pure state. Hence it is, that this superiority is owing partly to the combined action of the acid and base.

Dr. Thomson justly remarks, that precipitations take place, not because the salts are insoluble in water, but because they are insoluble in the particular solution in which the precipitate appears. Now if this solution happens to be capable of dissolving any particular salt, that salt will not precipitate, even though it be insoluble in water. Hence the reason why precipitates so often disappear when there is present in the solution an excess of acid, of alkali, &c.

Precipitation is, therefore, effected by lessening the quantity of the solvent by evaporation, by diminishing its powers, as by reduction of temperature, or dilution; or, by the addition of some chemical agent. In the latter case we have seen, that the agent, or precipitant, either combines with the *solvent*, and precipitates the

*solvend*, or forms itself into an insoluble compound with some constituent of the solution. It may not be improper to enumerate a few of the precipitants: Thus tartaric acid is a precipitant for potash, sulphuric acid for barytes and strontian, oxalic acid for lime, phosphoric acid for magnesia, ammonia and prussiate of potash for yttria and glucina, hydrosulphuret of potash for zirconia, ammonia for alumina, sulphate of iron and nitrate of mercury for gold, muriate of ammonia for platinum, muriate of soda for silver and mercury, prussiate of mercury for palladium, iron for copper, succinate of soda, prussiate of potash, and tincture of galls for iron, zinc and oxymuriate of mercury for tin, sulphate of soda for lead, carbonate of potash, &c. for zinc, water and muriate of soda for bismuth, water and hydrosulphuret of potash for antimony, water for tellurium, hydrosulphurets for arsenic, nitrate of lead for chromic acid, prussiate of potash for uranium, muriate of barytes for sulphuric acid, nitrate of lead for sulphurous acid, muriate of lime for phosphoric, fluoric and oxalic acids, sulphuric acid for boracic acid, muriatic acid for benzoic and suberic acid, sulphate of iron for succinic acid, acetate of lead for moroxylic acid, acetate of barytes for mellitic acid, potash for tartaric acid, acetate of lime for citric and sacclactic acid, barytic water and lime water for carbonic acid, solutions of lead for sulphuretted hydrogen, &c. These and other reagents, or precipitants, will be described in the course of the work, in which their application to the purposes of analysis, or chemical investigation, will be particularly noticed. The combination of acids with alkalies, earths, and metallic oxyds form salts, which are either soluble, partially soluble, or insoluble. As a knowledge of these facts are interesting, the reader may find an extensive table in Thomson's System of Chemistry, vol. 3d. p. 672.

Different salts separate either spontaneously, or on evaporation, according to the order of their solubility. Those which are insoluble, of course precipitate, and those which are the least soluble crystallize first when the solution is evaporated. When two salts are mixed

together, on evaporation and crystallization, the resulting salts, thus formed, are much influenced by the proportions of the ingredients. One example of this kind, extracted from Berthollet's table, will be sufficient.

*Experiment 28.* Mix a solution of equal parts of *nitrate of lime* and *sulphate of potash*, a precipitate of **SULPHATE OF LIME** will be formed; on separating it by the filtre, and evaporating the liquor, the product of the *first* evaporation will be **NITRATE OF POTASH** and some sulphate of lime; the *second* evaporation will yield a little **SULPHATE OF POTASH**. But,

*Experiment 29.* If one part of *nitrate of lime* and two parts of *sulphate of potash* are used, **SULPHATE OF LIME** will be precipitated as before, and sulphate of lime and nitrate of potash will be the products of the *first* evaporation, and nitrate of potash, sulphate of potash, and sulphate of lime, the product of the *second*.

Crystallization is a species of *precipitation*, in which the parts of the solvend, on separating from the solution, assume certain determinate forms. Three *conditions* are necessary to crystallization, *viz.* that when acted upon by the attraction of aggregation, the *integrant* particles should have a tendency to arrange themselves in a determinate manner; that they be disaggregated, so far as to possess sufficient mobility to assume their particular arrangement; and that the causes disaggregating them be slowly and gradually removed. According to Mr. Haüy there are only three forms of the *integrant particles*.

1. The parallelopiped.
2. The triangular prism.
3. The tetrahedron.

It is by the union of these particles in particular ways that the great diversity of crystallizations take place. The *primitive forms* have been reduced to six:

1. The parallelopiped.
2. The regular tetrahedron.
3. The octahedron with triangular faces.

4. The six sided prism.

5. The dodecahedron terminated by rhombs.

6. The dodecahedron with isoscelles triangular faces.

Bodies in the act of crystallization always imbibe more or less water, which is a necessary constituent of the crystal; hence it is termed the *water of crystallization*. When the crystallized body is exposed to heat, and frequently to the air, it loses its water of crystallization, becomes opaque, and falls into powder. When a crystal undergoes this change in the air, it is said to *effloresce*; if a saline substance absorbs moisture and thereby becomes fluid, it is said to *deliquesce*.

## PART II.

### OF LIGHT.

*Experiment.* 1. Let the rays of *light* pass through a hole in a window shutter, in a darkened room, on a *glass prism*, placing it parallel to the horizon, with its axis perpendicular, so as to receive the beam of light; the light will thus be decomposed into seven parts, viz. RED, ORANGE, YELLOW, GREEN, BLUE, INDIGO, and VIOLET.

*Rationale.* As light consists of seven primitive colours, in this experiment it is resolved into its principles, in the order above stated. As none of these rays can be further decomposed, and as they always produce the same colour, they are called *original* or *primitive* colours. On turning the prism slowly upon its axis, the refracted light upon the opposite wall will first descend and then ascend between the ascent and descent; that is, where the *spectrum* is stationary the prism is to be fixed. The first effect is the *refraction* of light, or the light is bent out of its original course, because, according to the laws of optics, the light passes from one medium into another of a *different* density; it consequently assumes a new direction; hence it is said to be refracted. The refraction, therefore, is in the order of the experiment, and in passing through the prism, the light appears in its primitive colours.

*Remark.* The science of optics consists of a body of facts, which relate to the phenomena of the movement of light, its reflection and refraction, for upon the *reflexibility* and *refrangibility* of light, is founded the *telescope*, *microscope*, *spectacles*, and a number of other

optical instruments. See Adams's Philosophy, Newton's Optics, &c.

The decomposition of light is the cause of many natural and other phenomena. In the *rain bow*, *cascades* and *fountains*, if properly situated during the sun's shining; the *halo* which sometimes surrounds the *moon*; and the colours observed on *soap bubbles*, are all occasioned by the refrangibility of the rays of light. The appearance of the *sky* at certain times owes its phenomena to the same cause. The rays of light, are refrangible in the order in which they appear in the *solar spectrum*, the red is the least, and the violet ray the most refrangible. The analysis of light may be accomplished in the following manner:

*Experiment 2.* Let the *light* of the sun pass through a hole of the  $\frac{1}{10}$ th of an inch in a dark room; and placing a *screen* at the distance of six inches within the room, let the middlemost part of that light pass through a smaller hole in the screen; the object of which is to prevent, in a great measure, the indefinite light, or penumbra on the sides of the prismatic spectrum. Let that light fall perpendicularly upon a convex lens, at the distance of about ten feet, by which means an *IMAGE* well defined of the sun will be formed upon the screen placed at a proper distance from the lens: but, if a prism be situated close to the lens, so that the light, after having passed through the lens, may pass through and be refracted by the prism, then a *COLOURED SPECTRUM* well defined will be formed upon the screen.

Sir Isaac Newton demonstrated, that if the spectrum be divided into 360 parts, the rays of light would bear the following proportions to each other: viz. red 45, orange 27, yellow 48, green 60, blue 60, indigo 40, and violet 80.

*Experiment 3.* If the bulb of a sensible *thermometer* be moved, in succession through the different coloured rays, they will be found to communicate the *greatest heat* in the *RED RAYS*, next in the *GREEN*; and so on, in a diminishing progression, to the *VIOLET*.

*Rationale.* This experiment tends to show, that heat and light are not present, in a corresponding degree, in different parts of the solar spectrum; for, generally speaking, those rays *illuminate* most that have least heating power. Whether this is owing to the *respective affinities* of the particular ray for coloric, or whether it be owing to its *capacity* for heat, or to a certain state in which that phenomena ensues, or to any other cause, is at present not ascertained. But certain it is, that the experiments of Dr. Herschel have proved, that the rays towards the middle of the spectrum passes the greatest illuminating power, and those at the extremity the least.

*Remark.* It has been also ascertained, that there are *insensible* rays which possess considerable heat; for when the thermometer is removed entirely out of the confines of the red ray, but with its ball still in the line of the spectrum, it rises even higher than in the red rays, and continues to rise till removed, half an inch beyond the extremity of the red ray.

In making this experiment, the air thermometer should be preferred.

On the contrary, beyond the confines of the spectrum on the other side, or a little beyond the violet ray, the thermometer is not affected.

It is remarkable, that there are other rays, also invisible, of a different kind, which exert *all* the chemical effects of the rays of light, and sometimes with more power. If muriate of silver be exposed to these rays, it will, like in the solar rays, become changed from white to black. The rays of the prism, it must be recollected, have this power in a greater or less degree. Thus, the blue rays effect a change of the muriate of silver in fifteen seconds, which the red requires twenty minutes to accomplish. Hence it appears, that the solar beams consist of three distinct kinds of rays; of those that excite *heat* and produce *oxydizement*; of *illuminating* rays; and of *deoxydizing* rays.

Solar light, being a compound of three distinct kind of rays, when exposed to the prism is decomposed, on

account of the difference in the refrangibility of these rays. The *calorific* rays, or those which produce heat, are the least refrangible; the *deoxydizing* rays are the most refrangible; and the *colorific* rays, or those which give colour, possess a mean degree of refrangibility. Hence the rays in the middle of the spectrum have the greatest illuminating power, those beyond the red end the greatest heating power, and those beyond the violet end the greatest deoxydizing power; and the heating power on the one hand, and the deoxydizing power on the other, gradually increase as we approach that end of the spectrum where the *maximum* of each is concentrated. Dr. Herschel found, that the heating power of the violet, green, and red rays are to each other as the following numbers :

Violet = 16, green = 22.4, and red = 55.

Phosphorus introduced into the rays beyond the red extremity, is heated, smokes, and emits white fumes; but these are presently suppressed, on exposing it to the deoxydizing rays, which exist beyond the violet extremity.

There has, however been some objections against the deoxydizing theory, as there are a few exceptions to the doctrine; for an account of which consult the papers of Dr. Wollaston.

It has been supposed, that three of the prismatic colours, the red, yellow, and blue, were simple; and that the other four formed each of the contiguous ones; that is, the orange from the red and yellow, the green from the yellow and blue, the indigo from the blue and violet, and the violet from the indigo and red.

Colours are all formed in the solar light; the various tinges resulting from the absorption of some of the rays of light, and the reflection of others.\* Blue, red, and yellow, in dying, are the *fundamental colours*; by combining these, *on the stuffs*, rarely in the bath, the various hues are obtained. In order, in the next place, to consider the *theory of colours*, in the production of various

\* See a Theory on the Formation of Colours in the American Philosophical Transactions, by Dr. Conover.

hues, by the mixture of colourless fluids, the following experiments may be adduced, which were invented by Mr. *Tielebein*.

For this purpose the following articles are necessary.

No. 1. A solution of *acetate of lead*, prepared by dissolving two drams of the *acetate of lead* in twelve ounces of *distilled water*.

2. A solution of *carbonate of potash*, obtained by dissolving three ounces of the *carbonate of potash* in twelve of *water*, and proceeding as before.

3. A solution of *corrosive muriate of mercury*, consisting of twenty grains of the *corrosive muriate*, dissolved in twelve ounces of *water*.

4. A solution of two ounces of *sulphate of iron* in twelve of *water*.

5. *Acidulous solution of sulphate of iron*, composed of an ounce of *sulphate of iron*, and twelve of *water*, mixed with an ounce of the next solution, No. 6.

6. An ounce of *sulphuric acid*, mingled with twelve of *water*.

7. Dissolve one dram of *acetate of copper* in twelve ounces of *water*, and add one dram of *nitric acid*.

8. *Concentrated liquid ammonia*.

9. *Sulphurous acid*.

10. *Tincture of roses*, prepared by infusing red rose leaves in *sulphurous acid*.

11. *Tincture of red cabbage leaves*, prepared in the same manner.

12. *Tincture of galls*, prepared by digesting half an ounce of gall-nuts in twelve ounces of *water*, and adding one dram of *nitric acid* to the filtered solution.

13. Diluted solution of *prussiate of potash*.

14. One dram of *mercury* dissolved in an ounce of moderately strong *nitric acid*, with the addition of an ounce of *water*.

*Experiment 4.* Mix three parts of No. 1, *acetate of lead*, with one of No. 2, or solution of *carbonate of potash*, and a MILK WHITE will be produced.

*Rationale.* The acetate of lead and carbonate of potash are mutually decomposed; the acetic acid unites with the potash, forming acetate of potash, which re-

mains in solution, whilst the carbonic acid combines with the lead, and forms carbonate of lead, which is precipitated.

*Remark.* Whiteness is always compound; all the primary colours are necessary to its constitution; and its appearance is owing to a copious *reflection* of all the rays of light.

*Experiment 5.* If four parts of No. 14, *nitrated mercury*, and one of No. 2, or *carbonate of potash*, are added together; a **YELLOW** precipitate will be formed.

*Rationale.* In this experiment the nitric acid of the nitrate of mercury, unites with the potash, forming nitrate of potash, which remains in solution, and the carbonic acid of the carbonate of potash, combines with the mercury, and forms a carbonate of mercury, which is precipitated of a yellow colour. As the carbonate of potash used in the experiment is, more properly, a subcarbonate, the mercury is precipitated with an excess of base, forming a subcarbonate of mercury.

*Experiment 6.* To the *yellow precipitate* of the last experiment, add No. 6, *diluted sulphuric acid*, and the whole returns to its **LIMPID** state.

*Rationale.* In this case, the sulphuric acid decomposes the carbonate of mercury, carbonic acid is disengaged, and the mercury is taken up.

*Experiment 7.* If a few drops of No. 6, *diluted sulphuric acid*, be added to No. 10, or *tincture of roses*, a **CARMIN** colour will appear.

*Rationale.* The original colour is discharged on adding the diluted acid, which takes the place of the sulphurous acid, and consequently heightens the colour.

*Experiment 8.* If to the carmine colour, thus produced, *sulphurous acid* be added in a sufficient quantity, the colour will **DISAPPEAR**.

*Rationale.* In this case, the sulphurous acid reproduces the original colour, in consequence of uniting again with the colouring matter. This presents us with an additional proof of the theory of Berthollet on chemical attraction.

*Experiment 9.* If to a few drops of No. 6, *diluted sulphuric acid*, No. 11, or *tincture of cabbage* be added, a **BLOOD RED COLOUR** will be formed.

*Rationale.* On the principle, that acids have the quality of heightening the colour of some vegetable substances, as is the case with the colouring matter of the red cabbage, the application of the tincture of cabbage, as a test for acidity is founded. The acid unquestionably acts, by changing the affinities of the rays of light for the colouring matter into a new order, agreeably to the theory already noticed.

*Experiment 10.* On adding No. 9, the liquid will become again colourless, as in a former experiment.

*Experiment 11.* If three parts of No. 10, *tincture of roses*, be added to one of No. 1, or *solution of acetate of lead*, a GRASS GREEN colour will be produced.

*Rationale.* In this case a change in the colour, as well as a partial change in the bodies themselves ensues, and the new affinities for the rays of light are such, as to cause the *green ray*, according to Berthollet, to be reflected to our optics.

*Experiment 12.* Add No. 6, or *diluted sulphuric acid* to the product of the last experiment, and the mixture will become RED.

*Rationale.* Here a change again ensues, which is owing to the acid, and causes a corresponding change in the rays of light, the result being the production of a red colour.

*Experiment 13.* On adding No. 9, or *sulphurous acid* to the result of the last experiment, the fluid will return to its former LIMPID state.

*Rationale.* Here the sulphurous acid disposes a new arrangement of affinities for light, and the whole is changed into a limpid state.

*Experiment 14.* If three parts of No. 11, or *tincture of red cabbage leaves* be mixed with one of No. 1, or *solution of acetate of lead*, a LIGHT GREEN will be produced.

*Rationale.* The cause is the same as in some of the preceding experiments, as it respects the rays of light; but as the different shades of colour are produced by the absorption of some and the reflection of other rays, in such a manner as to constitute those colours, it follows, that several changes are necessary previously to

the formation of *mixed* colours. The production of *brilliant colours*, the blushing beauties of the *rose*, and the modest blue of the *violet*; the *pellucid stream*, the *green sea*, the *white froth*, the *dark pool*, the *azure sky*, the varying colours of the *pigeons' neck*, the *opal*, &c. are owing to the different refrangibility of light. Some rays, therefore, are absorbed, or enter into substances, whilst others are reflected; hence the diversity of colours. A red body, for instance, reflects the red rays, while it absorbs the rest; a green reflects the green rays, and perhaps also the blue and the yellow, and absorbs the rest, &c. Hence also in the compound colours, in the operations of dying, a *scarlet* is composed of red and yellow, *green* of blue and yellow, *violets*, *purples*, and *lilacs* of red and blue.\*

*Experiment 15.* Mix three parts of No. 7, *solution of acetate of copper*, with one of No. 8, or *concentrated liquid ammonia*, and an **ULTRAMARINE BLUE** will be obtained.

*Rationale.* In this experiment the acetate of copper is decomposed; the acetic acid unites with the ammonia forming an acetate of ammonia, at the same time an oxyd of copper is precipitated: this is then dissolved by another portion of the ammonia, and forms ammoniacet of copper, which is held in solution along with the acetate of ammonia.

*Experiment 16.* If three parts of No. 11, *tincture of red cabbage*, be mixed with one of No. 2, or *solution of carbonate of potash*, it will form a **DARK BLUE**; and if No. 6, or *diluted sulphuric acid* be now added, the colour will be changed to a **RUBY RED**.

*Rationale.* The sulphurous acid of the tincture unites with a portion of the potash, and another part of the carbonate of potash changes the tincture to a blue, which is again changed to red on the addition of sulphuric acid, in consequence of a neutral compound of acid and alkali being formed, and the *excess* of acid acting on the colouring matter of the cabbage.

\* See Berthollet on Dying, and Bancroft's Philosophy of Colours.

*Experiment 17.* If equal quantities of No. 5, *solution of sulphate of iron*, and No. 13, *solution of prussiate of potash*, be mixed, a BLUE COLOUR will result, and PRUSSIATE OF IRON be formed.

*Rationale.* In this case a double decomposition ensues; the sulphuric acid of the sulphate of iron unites with the potash, forming sulphate of potash, and the prussic acid combines with the oxyd of iron, and forms a blue precipitate, or prussiate of iron.

*Experiment 18.* If equal quantities of No. 7, *acetate of copper*, and No. 11, or *tincture of red cabbage leaves*, be added together, a VIOLET COLOUR will be produced.

*Rationale.* In this case the acetate of copper acts precisely as the acetate of lead, except that in the change, a violet colour is formed.

*Experiment 19.* When three parts of No. 11, are mixed with one of No. 4, *tincture of red cabbage*, and *sulphate of iron*, the result will be a PITCH BLACK colour.

*Rationale.* Here the action of sulphate of iron is different from that of acetate of lead or copper, in as much as the colour produced is of a perfect black. In this experiment *all* the rays of light are absorbed. From the nature of the cause, the fluid would remain black if no body was presented, which could change the existing affinities of the rays of light for the colouring matter thus altered. No part, or ray, of the light is suffered to be reflected, but *refracted* in; hence *blackness* is the consequence.

*Experiment 20.* Three parts of No. 12, *tincture of galls*, mixed with one of No. 4, or *solution of iron*, produces an INK BLACK. No. 6, or diluted *sulphuric acid*, again renders it limpid, and the addition of No. 13, turns it blue. •

*Rationale.* In this experiment the gallic acid of the *tincture of galls* unites with the iron of the sulphate of iron, and forms gallate of iron, which is *black*; on adding sulphuric acid this combination is destroyed, and sulphate of iron reproduced, which is *limpid*; and on adding prussiate of potash the sulphate is decom-

posed, and prussiate of iron formed, which is *blue*. During these changes the rays of incidental light obey their own laws.

*Remark.* The application of chemical tests, or reagents, is founded in a great degree upon the *colour* which they produce when added to liquids; for the bodies held in solution are detected by the reagent, only as it respects their *appearance* or *habits* when the particular reagent is added. These phenomena are governed by the same laws as in the experiments already given: hence, as the appearances under the same circumstances are precisely the same at all times, *chemical tests* have been justly called the "*compass* by which the chemist steers." Thus, if to an ore supposed to contain iron, we add muriatic acid, and dissolve it; and add to this solution either tincture of galls, or prussiate of potash, a black colour will be produced in the first case, and a blue one in the last, similar to the last experiment. We infer, therefore, the existence of iron.

While we are on the subject of colours, it may not be improper to introduce the following table.

*Colour of the Precipitates thrown down from Metallic Solutions, by various Re-agents.*

<i>Metals.</i>	<i>Prussiated alkalies.</i>	<i>Tincture of Galls.</i>	<i>Water impregnated with Sulphuretted Hydrogen.</i>	<i>Hydro-Sulphurets.</i>
Gold	Yellowish-white.	Solution turned green. Precipitate brown of reduced gold.	Yellow.	Yellow.
Platina	No precip.; but an orange coloured one by pruss. of mercury.	Dark-green, becoming paler.	Precipitated in a metallic state.	
Silver	White.	Yellowish-brown.	Black.	Black.
Mercury	White changing to yellow.	Orange yellow.	Black.	Brownish-black.
Palladium	Olive.* Deep orange.†		Dark-brown.	Dark-brown.
Rhodium	No precip.			No precip.
Iridium	No precipitate. Colour discharged.	No precipitate. Colour of solutions discharged.		
Osmium		Purple, changing to deep vivid blue.		

\* Chenevix.

† Wollaston.

*Colour of Precipitates from Metallic Solutions, &c. Continued.*

<i>Metals.</i>	<i>Prussiated Alkalies.</i>	<i>Tincture of Galls.</i>	<i>Water impregnated with Sulphuretted Hydrogen.</i>	<i>Hydro-Sulphurets.</i>
Copper	Bright red-dish-brown.	Brownish.	Black.	Black.
Iron. { 1. Green salts. 2. Red salts.	White, changing to blue. Deep blue.	No precipitate. Black.	Not precipitated.	Black.
Nickel	Green.	Grayish-white.	Not precipitated.	Black.
Tin	White.	No precip.	Brown.	Black.
Lead	White.	White.	Black.	Black.
Zinc	White.	No precip.	Yellow.	White.
Bismuth	White.	Orange	Black.	Black.
Antimony	White.	A white oxyd merely from dilution.	Orange.	Orange.
Tellurium	No precip.	Yellow.		Blackish.
Arsenic	White.	Little change.	Yellow.	Yellow.
Cobalt	Brownish-yellow.	Yellowish-white.	Not precipitated.	Black.
Manganese	Yellowish-white.	No precip.	Not precipitated.	White.
Chrome	Green.	Brown.		Green.
Molybdena	Brown.	Deep-brown.	Brown.	

*Colour of Precipitates from Metallic Solutions, &c. Continued.*

<i>Metals.</i>	<i>Prussiated Alkalies.</i>	<i>Tincture of Galls.</i>	<i>Water impregnated with Sulphuretted Hydrogen.</i>	<i>Hydro-Sulphurets.</i>
Uranium	Brownish-red.	Chocolate.		Brownish-yellow.
Tungsten				
Titanium	Grass-green, with a tinge of brown.	Reddish-brown.	Not precipitated.	Grass-green.
Columbium	Olive.	Orange.		Chocolate.
Tantalum				
Cerium		Yellowish.		Brown, becoming deep green.

*Experiment 21.* Make a decoction, or infusion of *madder* in *water*, and add a solution of *alum*; the colouring matter will be gradually precipitated in the form of a LAKE.

*Rationale.* The colouring matter of vegetables, being precipitated in a variety of cases, by the agency of certain saline and metallic solutions, it follows, that in this case the colouring matter is precipitated in combination with alumine, and forms a lake. The colour of the lake produced is owing, as in other cases, to the reflection of certain rays. If a small quantity of potash be added, the alumine or *earth of alum*, will be separated in a larger quantity.

*Experiment 22.* If to an infusion of cochineal, a solution of tin be added, the colouring matter will be

heightened, and precipitated in union with a portion of the metal, forming the **CARMINE** of the shops.

*Rationale.* In this as in the other experiments, the colouring matter itself, as well as the rays of light, are decomposed, so far at least as to produce a crimson colour, which is a combination of a *part* of the oxyd of tin with the colouring matter.

*Remark.* Other lakes may be obtained of different colours, by the substitution of different dye woods; thus alum decomposed by potash, in a decoction of quercitron bark, yields a bright yellow; with oxyd of tin all the shades, from a pale lemon colour to a deep orange; and with oxyd of iron a drab colour is produced from the same wood. Thus also, a combination of red oxyd of iron with the gallic acid and tan, is the principal black colour, which has therefore the same basis as common writing ink.

*Experiment 23.* Make a decoction of *cochineal*, and immerse into it a piece of *cloth*; on washing it the colouring matter will **DISAPPEAR**.

*Experiment 24.* To the remaining decoction add supertartrate of potash, and a portion of nitro-muriate of tin; now immerse a cloth in this mixture, and it will impart a permanent **SCARLET COLOUR**.

*Rationale.* A decoction of cochineal, therefore, will leave only a fugitive stain on a piece of cloth, which is evident in the first experiment; but in that portion of the decoction, which contains the supertartrate of potash and nitro-muriate of tin, the colouring matter is rendered *fixed*, or *permanent*. The nitro-muriate of tin and supertartrate of potash are here decomposed; a nitrate and muriate of potash is formed, whilst the tartaric acid of the tartrate combines with the tin, and precipitates the colouring matter on the cloth, at the same time the incidental light imparts colour to the precipitated colouring matter, which has thus entered the cloth. Other experiments of a like nature, together with observations on dying, with an examination of the theories and opinions of chemists, will be given in the course of the work.

*Remark.* It would be irrelevant to our plan to enter into a detail of the effects of light on vegetables and animals; a few experiments, however, on the agency of light on metallic oxyds and acids, may, with propriety, be introduced in this place.

*Experiment 25.* Take *muriate of silver*, wet it, and expose it to the light; in the course of a few hours the upper surface will be BLACKENED.

*Rationale.* The deoxydizing power of light has already been noticed. The light will exercise no power but at the surface, where the muriate will be found to be reapproaching to the metallic state. It appears, therefore, that oxygen is absolutely carried off from the oxyd in the state of oxygen gas, this gas being composed of oxygen, caloric, and light; and in this respect has a greater affinity for the oxygen than the metal.

*Experiment 26.* Cover white paper, or leather, with a solution of *nitrate of silver*, place it behind a painting on glass, and expose it to the solar light; the rays emitted through differently painted surfaces will produce distinct tints of brown or black, sensibly differing in intensity, according to the shades of the picture; and when the light is unaltered the colour of the nitrate becomes deepest.

*Remark.* This effect takes place on the same principle; and is a plan invented by Mr. Wedgwood for copying paintings upon glass, and making profiles of figures. For particulars, see the Journals of the Royal Institution, No. 9, p. 171.

*Experiment 27.* Into a solution of *muriate of gold* introduce a piece of charcoal, and submit the vessel with its contents to the rays of the sun. The metal will be reduced, and the charcoal GILT.

*Rationale.* In this experiment, as in the preceding, the effect is owing to the deoxydizing power of the sun's rays: the oxygen is taken off by the light, and the metal remains on the coal. The oxygen which oxydized the metal in the act of solution, being thus abstracted, it follows that the metal is no longer chemically combined with the acid.

*Experiment 28.* Expose a ribbon, wet with a diluted solution of *muriate of gold*, to the sun, the gold will be REVIVED as in the last experiment.

*Remark.* This experiment is stated by count Rumford, in his Philosophical Papers, vol. i. The count found that if magnesia was wetted with the solution of gold, and exposed in the same manner, it would change to a purple, and then to a crimson colour. If the ribbon, however, be first dried after it has been moistened, and then exposed, no change takes place.

*Experiment 29.* If a slip of *ivory* be immersed for a few hours in a solution of pure *nitrate of silver*, then taken out and exposed in water to the rays of the sun, it will in a few hours become *black*. On rubbing it the black will be changed into a METALLIC SURFACE, the silver being revived.

*Remark.* The effect is the same as in the other experiments. This process, invented by count Rumford, is for the purpose of *silvering ivory*. All metallic oxyds are affected, more or less, in the course of time, by the sun's rays.

Black oxyd of mercury, prepared by decomposing the sulphate of mercury by pouring ammonia on it, when exposed to the rays of light rapidly parts with its oxygen, and is converted into fluid quicksilver. Many other bodies are also affected by light.

*Experiment 30.* Expose concentrated *nitric acid* in a white bottle half filled, to the rays of the sun, at the end of some days the white acid will be converted into an orange coloured and fuming one, and the bottle will become filled with red vapours; this is the NITROUS ACID.

*Experiment 31.* Take the *acid*, thus coloured, and remove it to a dark place; in the course of time it will change into the *pale acid*, or NITRIC ACID.

*Rationale.* In the first experiment the light separated a part of the oxygen from the azote, as nitric acid is a compound of oxygen and azote, in consequence of which nitric oxyd or nitrous gas is evolved, part of it however remains in the acid, to which its colour is owing; but, when the light is withdrawn, as in the se-

cond experiment, the nitric oxyd is gradually decomposed, or rather oxygen unites with it, and converts it into nitric acid.

*Remark.* If oxygenized muriatic acid is exposed to the sun's rays, it suffers decomposition, and considerable quantity of oxygen gas may be easily obtained. See oxygen gas. Certain bodies have the property of absorbing the rays of light; of retaining them for some time, and of again evolving them unchanged, and unaccompanied with sensible heat. Thus according to Du Fay, a diamond exposed to the sun, and immediately covered with black wax, will shine in the dark on removing the wax at the expiration of several months. Bodies gifted with this property are called SOLAR PHOSPHORI. The *eyes of cats, owls*, and several other animals, are formed so as to collect light, to enable them to find food in the dark. This accounts for the light emitted by *snow*. Thus snow is a natural solar phosphori. So also is, occasionally, the *sea* when agitated; *putrid fish* have a similar property; and the *glow worm* belongs to the same class. These phenomena are independent of any thing like combustion; for artificial phosphori after being exposed to the light and placed in *vacuo*, will also emit it. *Light-wood* is also a phosphori; for some woods possess this property, at a period when they are about to undergo decomposition.

*Experiment 32.* If pieces of *sulphate of barytes* are made red hot, in a covered *crucible*, for a few minutes, and then pulverised and sifted; and this powder made into a paste with a little mucilage of gum arabic, and divided into cakes or pieces of the thickness of a quarter of an inch, and gradually exposed to a violent heat among charcoal, in a wind furnace, the BOLOGNIAN PHOSPHORUS will be formed. When this is exposed to the light, and then taken to the dark, it will emit light for some time.

*Rationale.* In this case, however, the light is emitted partly in consequence of its absorption, and partly from the decomposition of oxygen gas. When sul-

phate of barytes are exposed in contact with charcoal, as under the above circumstances, a partial decomposition of the sulphuric acid of the sulphate of barytes takes place. At a high temperature, the ignited charcoal possesses a greater affinity to the oxygen of sulphuric acid than the sulphur; the result of this union is carbonic acid. A part of the sulphur thus separated from the sulphuric acid, unites with the barytes, and forms sulphuret of barytes, which is known to have the property of absorbing oxygen to the reproduction of sulphuric acid. This effect then, may be partly considered a species of slow combustion, in which oxygen is absorbed, and caloric and light given out, the oxygen gas being decomposed.

*Experiment 33.* Put oyster shells into a crucible, calcine them by keeping them in a good coal-fire, for about an hour. To three parts of the lime, thus made, add one of flowers of sulphur, and place the whole in layers, in a crucible, tightly. Remove it to the fire, and keep it red-hot for about an hour and a half. When it is removed and cool, select the brightest part for use. This is the CANTON'S PHOSPHORUS. After exposure to light for a few minutes, and then put in the dark, light will be evolved as in the last preparation. This should be kept in a wide mouth vial, and well closed.

*Rationale.* A sulphuret of lime is formed in this process. It is necessary from some cause or other to employ the oyster shell. In this as in the former, oxygen gas is decomposed.

*Experiment 34.* Dissolve lime in nitric acid; when a neutral compound is formed, evaporate it to dryness, and expose it, well rammed in a crucible, to the action of heat, where it is to be kept till the whole mass becomes liquid. Pour this mass into an iron pot, previously heated, and the PHOSPHORUS OF BALDWIN will be formed. Preserve the mass in vials. After being exposed to the sun for a few moments, this preparation affords a beautiful light in the dark.

*Rationale.* This phenomena is owing to no other cause, than the previous absorption of light.

*Remark.* Several substances when exposed to an elevated temperature, are converted into solar phosphori. Such as all neutral salts with a base of *barytes*, *magnesia*, *carbonate of magnesia*, *sulphate and carbonate of lime*, *sulphate and carbonate of strontian*, *sulphate of potash*, *alumine earth*, *fluat of lime*, *zeolite*, some metallic oxyds, *phosphate of lime*, *cotton wool*, different combinations of earths, *linen and woollen*, *hair powder*, *saw dust*, *wax and oils*, *animal fats*, &c.

*Experiment 35.* If one part of powdered *muriate of ammonia*, and two of powdered *lime* be introduced into a red-hot crucible, and kept hot till the mixture becomes fluid, the PHOSPHORUS OF HOMBURG is produced. See to Accum, p. 167.

The preparation is to be poured into a heated iron pot, then broken into pieces, and preserved in a well stopped vial.

*Rationale.* In this process the *muriate of ammonia* is decomposed; the *muriatic acid* unites with the *lime*, forming *muriate of lime*, and the *ammonia* is disengaged in the state of gas. The *muriate of lime* is, therefore, a *Baldwin's phosphorus*.

*Remark.* If the substance obtained, after the preparation of liquid ammonia, by the decomposition of *sal ammonia* with *quicklime*, be melted with a sufficient degree of heat, *Homburg phosphorus* will also be formed. In this case the same substance, viz. *muriate of lime* is used; for in the other experiment, the *muriate of lime* is formed during the operation.

*Homburg's phosphorus* or *pyrophorus* which is the same, emits light when it is struck by a hard body. When a red-hot poker is dipped into the fused substance, and rubbed after it is cool with another piece of metal, it becomes luminous and evolves sparks and light.

*Flints* and other siliceous stones, *borax*, *sugar*, *bonnet-cane*, *tremolite*, *phosphate of lime*, *black-jack*, *gums*, *resins*, &c. give out light more or less by attrition. Some substances emit light in contact with acids. We have

stated already, that various animal and vegetable substances were solar phosphori. The shell fish called *pholas*, the *medusa phosphorea*, and other *mollusca*, the *fulgora*, or lantern fly, the *lampyris* or glow worm, the *scolopendra electrica*, the *cancer fulgens*, heat earth, the medullary substance of the brain of human beings; all emit light under certain circumstances. In the opinion of Dr. Holme,\* he believes that light is a *constituent part* of many animals, particularly of the marine fishes. This subject is treated at large in Thomson's Chemistry, vol. i. p. 413. But in many cases light is only emitted at the commencement of putrefaction. This phenomena has often been witnessed.

*Experiment 36.* Put four drams of the *flesh* of the herring, or mackarel, into a vial containing about two ounces of sea water, or of pure water holding in solution half a dram of common salt, or two drams of sulphate of magnesia; remove the whole to a dark room, in the course of three days a luminous ring will appear on the surface of the liquid; on shaking the vial, the whole becomes luminous.

*Rationale.* This experiment is in conformation of what has been said on this subject. Dr. Thomson concludes from this and other experiments, that light constitutes a part of these substances, and that it is the first of the constituent parts, which makes its escape when the substance containing it is to be decomposed.

*Remark.* When the liquids are frozen, the light disappears, but is again emitted as soon as they are thawed. A moderate heat increases the luminousness, but a boiling heat extinguishes it altogether. The light is extinguished also by water, lime water, water impregnated with carbonic acid gas, or sulphuretted hydrogen gas, fermented liquors, spirituous liquors, acids, alkalies and water saturated with a variety of salts; but light appears again when these solutions are diluted with water. The light produces no sensible effect on the thermom-

\* Phil. Trans. 1800. p. 161. See also a paper of Mr. Canton's in the same work, lix. 446.

eter. The absorption of light by vegetables, an important subject in vegetable physiology, enables us to explain the reason why plants become pale and white in the dark, and green in the light.

*Experiment 37.* Into a tea cup or plate, put one dram of fresh prepared *calcined magnesia*, and add at once half an ounce of sulphuric acid, and HEAT and LIGHT will be evolved.

*Rationale.* It would be more philosophical to conclude, that in this experiment, the phenomena was produced by the sudden conversion of latent into sensible heat, and at the same time light was evolved.

*Remark.* As to the relative intensity of light emitted by luminous bodies, various contrivances have been used to determine it. Instruments for this purpose are called *photometers*, of which the best are those of count Rumford, and Mr. Leslie. For particulars on this subject consult Rumford's Philosophical Papers, 1802. p. 270.

## PART III.

### OF CALORIC.

WE can only obtain a knowledge of what is understood by the terms *hot* or *cold*, through the medium of senses. The ideas of heat or cold are perceptions thus acquired, which indicate only a certain state in which we find ourselves, independent of any exterior object. Sensations, therefore, which are produced by external agents, as heat, in the instance before us, are attributable to *causes*, and these causes produce certain *consequences*. Hence it is, that we apply the terms hot or cold to the substances themselves. If a body communicates heat to the system, in a perceptible manner, we call it hot; but if it produces the contrary effect we call it cold. That which produces the sensation of heat is called *caloric*, or matter of heat; the *abstraction* of which, consequently, produced cold.

*Experiment 1.* If *steel* be struck with a *flint*, a considerable degree of **HEAT** will be produced, which is evident from the ignited particles thrown off.

*Rationale.* In the production of heat by percussion or collision, a temporary condensation of the body struck ensues, which causes the evolution of heat, and, in this instance, melts a portion of the steel, which is evident from the sphericity of the particles.

*Experiment 2.* If *air* be suddenly condensed in a *tube* by means of a *syringe*, with a piece of *spunk* attached to the end of the piston, on drawing it out, the **SPUNK** will be inflamed.

*Rationale.* Mr. Dalton some time since demonstrated, that when air is suddenly condensed, the temperature

was increased. In this experiment, the air suffers a considerable diminution of volume; in consequence of which, caloric is given out as *sensible* heat, and in so large a quantity as to inflame the spunk.

An instrument called the *condensing syringe*, sold in this city, for the purpose of procuring fire instead of the flint and steel, acts on this principle. The French chemists have discovered, that if a proper mixture of oxygen and hydrogen gases, be suddenly compressed they quit their æriform state, and produce water.

A number of interesting experiments on this subject, have been lately made by the French National Institute. Some time ago a soldier in the French army found, that heat was produced by the condensation of the air in an air gun.

*Experiment 3.* If a piece of *phosphorus* be put into the end of the piston of the condensing syringe, and the tube filled with *oxygen gas* and suddenly compressed, it will be immediately inflamed.

*Rationale.* In this experiment the phosphorus unites with the oxygen and forms phosphoric acid; the temperature of the oxygen gas, being increased by the compression, causes the phosphorus to be immediately inflamed.

*Experiment 4.* If two pieces of *stick* be rubbed very smartly against each other, they will *smoke*, and finally take FIRE.

*Remark.* The production of heat by friction, is not owing to the density of the bodies being increased, as is the case in the preceding experiments; for heat is produced by rubbing soft bodies against each other; the density of which, therefore, cannot be promulgated by that means. It is true, however, that heat is not produced by the friction of liquids; but then they are too yielding to be subjected to strong friction. It is not owing to the specific caloric of the rubbed bodies decreasing; for count Rumford found, that there was no sensible decrease, nor, if there were a decrease, would it be sufficient to account for the vast quantity of heat which is sometimes produced by friction. Neither is the caloric evolved during friction, owing to the com-

bination of oxygen with the bodies themselves, or any part of them. Considering these circumstances, therefore, the phenomena is neither produced by an increase of the density, nor by an alteration in the specific caloric of the substances exposed to friction, nor is it owing to the decomposition of oxygen gas of the atmosphere. This question is at present inexplicable. There is no reason, however, to conclude with count Rumford, that there is no such substance as caloric, but that it is a *peculiar kind of motion*. There is indeed an analogy between caloric and electricity; and the phenomena has been attempted to be explained on the principle, that electricity exists in those bodies; but such opinions require the authority of facts to render them admissible.

There are five sources, from which caloric may be obtained in a state of sensible heat. It *RADIATES* constantly from the *sun*; it is evolved during *combustion*; also in *percussion*, *friction*, and *mixture*, which will be noticed more fully in the course of the work. To which we may add a sixth source, viz. *electricity* and *galvanism*. By the first, if applied in *battery*, metals may be suddenly fused, and gases united, which we are unable to combine in any other mode. The same effects will take place, if *galvanism* be substituted.

*Experiment 5.* Rub a particle of *phosphorus* on paper, the friction produced will immediately inflame it.

*Rationale.* In this case a sufficient quantity of caloric is evolved, to occasion the phosphorus to burst into flame.

*Experiment 6.* If a *thermometer* be hung in the open air, and then introduced into a hole bored in the trunk of a tree, the mercury will rise many degrees.

*Remark.* This evidently shews, that caloric is as necessary for the support of vegetable, as it is for that of animal life: whether this effect is owing to the decomposition of some gas, the base of which is absorbed, and the caloric given out in a *free* state, or the conversion of latent into sensible heat, is a question yet to be determined; or whether, with Mr. G. F. Lehman, the heat of vegetables is the effect of certain necessary

*stimuli*, acting on them, as is supposed, occurs in the animal economy.\*

*Experiment 7.* Take a piece of wrought iron, and hammer it briskly on an anvil; it will evolve *sensible* heat, and finally become *ignited*.

*Rationale.* In this case, the wrought iron, which contains a large portion of *latent* caloric, suffers *percussion*, and gives out its *latent*, in the state of *sensible* heat.

*Experiment 8.* Place a pan of *snow* over a fire, and immerse a thermometer in it; notwithstanding the accession of heat, during the process of melting, the temperature will be found to be the same. When the *whole* becomes fluid, the temperature will *then* be raised.

*Rationale.* This is a case, in which caloric chemically combines with the snow: hence the thermometer is not raised; but when the whole is melted, the accession of heat is then shewn by the rise of the mercury, because the caloric which enters becomes *sensible*, or free heat.

*Remark.* As ice has the property of absorbing all the caloric with which it comes in contact, and, from the preceding experiments, communicates no part of it to the surrounding bodies till the whole is melted; it has therefore been employed as the means by which the *specific caloric* of substances may be calculated. The instrument for this purpose is called a *calorimeter*.

*Experiment 9.* If a piece of *ice* cooled  $20^{\circ}$  below the freezing point, be exposed to a *hot fire* with a *thermometer* stuck in it, the thermometer will rise very uniformly till it comes to  $32^{\circ}$ , and then make a full stop until the ice is all liquified: but, as in the preceding experiment, the instant all the ice is melted, the thermometer will begin to rise again, and continue to rise until it comes to  $212^{\circ}$ , the boiling point.

*Rationale.* As in the preceding experiment we learn, that the caloric, which is received by the ice, is not ap-

\* Mr. LEHMAN, in a very able and ingenious essay, has endeavoured to prove, that the vegetable is governed by the same laws as the animal kingdom.

preciable by the thermometer until the ice is liquefied; in this case, however, the thermometer rises from  $20^{\circ}$  to  $32^{\circ}$ , and at that degree remains stationary.

*Experiment 10.* When one part of *sulphuric acid* and four parts of *ice*, both at the temperature of  $32^{\circ}$ , be mixed; the mixture will indicate  $4^{\circ}$ .

*Rationale.* The fall of the thermometer is owing to the absorption of caloric from the sulphuric acid; the ice, therefore, is rendered fluid by the caloric which enters it.

*Experiment 11.* If an *amalgam of bismuth*, and another *amalgam of lead and mercury*, be mixed in a mortar, they will instantly become *fluid*.

*Rationale.* In this experiment there appears to be a mutual decomposition, or at least a new arrangement of component parts; and the change, which has thus taken place, indicates the absorption, or combination of caloric, causing the compound to assume a fluid state.

*Experiment 12.* Place in a glass vessel, containing about an ounce of a solution of *soda*, a small thermometer; add a sufficient quantity of *muriatic acid* to saturate the *soda*, and the mercury in the thermometer will rise.

*Rationale.* In this experiment, a compound of *muriatic acid* and *soda* is formed; and, at the instant of its formation, heat is given out as sensible heat, which proves that an alteration ensues in the capacity for caloric, during chemical changes. Other experiments of a like nature, will be hereafter noticed.

*Experiment 13.* If *carbonate of soda* be used in the same manner, with *sulphuric acid*, cold will be the result.

*Rationale.* In this case the carbonate is decomposed, carbonic acid gas is disengaged, and sulphate of soda formed; but the decrease of temperature is owing to the disengagement of carbonic acid.

*Experiment 14.* Dip the bulb of a thermometer in melted *rosin* so as to coat the glass with it, and suffer it to cool completely. If the flame of a taper be now applied to the bulb so as to melt the rosin, the mercury in the thermometer will not rise at the approach of the

taper, but will actually be seen to contract as the rosin becomes liquid.

*Rationale.* It is evident, that when solid bodies pass to the liquid state, their capacity for caloric is proportionably increased. In this experiment, therefore, when the heat is applied to melt the rosin, the rosin not only absorbs the heat which is presented to it, and which renders it soft, but also combines with the caloric of the mercury. It therefore falls.

*Experiment 15.* If 1 lb. of water at  $100^{\circ}$  be mixed with 1 lb. of water heated to  $200^{\circ}$ , the mixture will be found to give the exact mean temperature of  $150^{\circ}$ ; but 1 lb. of mercury at  $100^{\circ}$ , and 1 lb. of water at  $200^{\circ}$ , will produce a heat much higher than the mean temperature.

*Rationale.* From this fact we learn, that mercury has not so great a capacity for caloric as water: hence it is, that the difference in the capacity arises from certain causes, which are influenced by chemical affinity—that of one body having a superior affinity for caloric to another.

*Experiment 16.* If alcohol coloured red with cochineal, be introduced into a glass globe, having a long slender neck, up to a certain mark, and placed over a lamp; an EXPANSION will ensue which will increase until the fluid begins to boil.

*Rationale.* As caloric expands all bodies with one or two exceptions, in this case it dilates the alcohol, and the degree of expansion is shewn by the use of the fluid in the neck of the vessel: if it be taken to a cool situation, or the glass immersed in cool water, the fluid will descend, shewing that the expansion was occasioned by the caloric. Fluids with the least density, i. e. specific gravity, expand most with the same temperature. The expansion of mercury in a glass tube, forms the mercurial thermometer.

*Experiment 17.* Place the beak of a retort under water, and apply the heat of a lamp, bubbles of air will arise from the mouth of the retort.

*Rationale.* This experiment proves, that air as well as liquid bodies, is susceptible of expansion; for on applying the heat of a lamp, its volume is increased, which is shewn by the extrication of bubbles. A bladder, three fourths filled with air, when exposed to the fire, is dilated, and when removed to a lower temperature, returns to its former state.

It is on this property which air possesses, that the *trade winds* are accounted for; for the sun near the equator expands the atmosphere, which is then counteracted by the cold, and causes a current of air in a peculiar direction, to be formed. It is also this property that gave rise to the *air thermometer*; of which we have several kinds. The most important of these is *Leslie's Differential thermometer*. It is this also which constitutes the *pulse glass*.

*Experiment 18.* If an *iron bar* six inches long be ignited in a furnace, it will be found  $\frac{1}{20}$  of an inch longer than it was before.

*Rationale.* The iron bar in this case is expanded by the heat, not only in length but also in breadth; which on cooling however, returns to its former dimensions. To determine the minutest changes of expansion by heat, and the relative properties thereof, instruments have been used called *pyrometers*, which are calculated to shew the expansion from  $\frac{1}{50000}$  to  $\frac{1}{100000}$  of an inch.

A number of inferences may be made on this property, of the expansion of metals by heat. Suffice it to say, that it renders time-pieces erroneous, which however has been obviated by using a *grid-iron pendulum*, composed of different metals, so that the expansion of the one may counteract that of the other; that *harpsichords*, &c. are out of tune by change of temperature; and that bodies which are brittle, or which want flexibility, crack or break if suddenly heated or cooled.

*Remark.* Upon the expansive property of heat is founded its artificial measurement. The relative heat, or temperature of bodies, is therefore measured by certain instruments, called *thermometers* and *pyrometers*. The former consists of a hollow tube of glass, hermeti-

cally sealed and blown at one end in the shape of a hollow globe. The bulb and part of the tube are filled with mercury. When the tube, thus prepared, is immersed into a hot body, the mercury *expands*, and of course *rises* in the tube ; but when it comes in contact with a cold body, the mercury *contracts*, and therefore *falls* in the tube. To facilitate thermometrical observations, the tube is furnished with a scale of degrees, which vary in different thermometers. There are four thermometers used at present in Europe. These are Fahrenheit's, Reaumur's, Celsius', and Delisle's, differing only from each other in the number of degrees into which the space between the freezing and boiling points is divided.

The *pyrometer* of Wedgwood is formed of pieces of baked clay, and a rule or gauge. The degree of heat is shewn by the *contraction* which they undergo. High temperatures only are ascertained by this instrument. Each degree of this pyrometer is equal to 130 degrees of Fahrenheit's. Guyton has also contrived an instrument for the same purpose, which consists of a lever of platina moved by the expansion of a bar of the same metal, the whole being supported on a mass of baked clay. This property of alumina, of contracting when exposed to heat, has rendered it an exception to the general principle, that caloric expands *all* bodies.

*Experiment* 19. If a pound of water at  $172^{\circ}$  be mixed with a pound at  $32^{\circ}$ , the heat of the mixture will be  $102^{\circ}$ .

*Rationale.* If a given quantity of caloric occasions the ascent of the mercury through 20 degrees, it might be asked whether a second addition, equal to the first, would raise it through precisely 20 more ? This is the fact from the foregoing experiment. Here the hot water will be cooled  $70^{\circ}$ , and the cold will receive  $70^{\circ}$  of temperature ; consequently,  $172 - 70$ , or  $32 + 70$ ,  $= 102$ , will be the heat of the mixture. It appears, however, from the experiment of De Luc, that the ratio of expansion does not, strictly, keep pace with the

actual increments of temperature ; as, for instance, the expansion of mercury from 32 to 122, the first half of the scale, is to its expansion from 122 to 212, the higher half, as 14 to 15.

*Experiment 20.* If in an atmosphere at  $60^{\circ}$ , we place *iron filings* heated to redness, boiling water, and various other bodies of different temperatures, they will soon affect the thermometer in the same degree.

*Rationale.* This experiment shews, that uncombined caloric has a tendency to an equilibrium ; for the excess of caloric in the one body passes to the other, until a uniform temperature is the consequence. The same equalization of temperature is attained, though less quickly, when a heated body is placed in the vacuum of an air pump. The rate of cooling in air, is to that in *vacuo*, (the temperatures being equal,) nearly as five to two. Caloric indeed has the tendency to pervade all matter, till an equilibrium of temperature is established.

*Experiment 21.* Provide two tin *reflectors*, as described in Henry's Chemistry, 8vo. p. 28, twelve inches in diameter, and segments of a sphere of nine inches radius. Place these on a table at some distance apart, with their concave surfaces towards each other. In the focus of one let the ball of an air thermometer be situated ; and in that of the other suspend a ball of iron about four ounces in weight, and heated below ignition. The liquid in the air thermometer immediately descends.

*Rationale.* This is the celebrated experiment of professor Pictet, to shew the radiation of caloric. In this experiment the radiant caloric follows the same law as the solar light ; the angle of incidence being equal to the angle of reflection. The caloric flows first from the heated ball to the nearest reflector, from this it is transmitted, in parallel rays, to the surface of the second reflector, by which it is collected into a focus on the instrument.

*Experiment 22.* If the reflectors be placed in the same manner, and a flask of *boiling water* put before one of them, the same effect will ensue.

*Experiment 23.* If the apparatus remain, and a glass vessel filled with *ice*, or *snow*, be substituted for the heated ball, the course of the coloured liquor will be precisely in the opposite direction.

*Rationale.* At first view this experiment would appear to indicate the reflection of cold ; but it is in fact, only the reflection of heat, though in an opposite direction ; the ball of the thermometer being, in this instance, the hotter body.

*Remark.* The nature of the *surface* of bodies has an important influence over their power of radiating caloric. These varieties in the radiating power of different surfaces are attended, as might be expected, with corresponding variations in the *rate of cooling*.

*Experiment 24.* Take two *thermometers* of the same kind ; blacken the bulb of one of them with Indian ink, and expose them both to the sun. That which is blackened will ascend 10 degrees higher than the other.

*Rationale.* Radiant caloric is absorbed with different facility by different surfaces. Surfaces are endowed with various powers of reflecting caloric. In the case before us, the black ink acts in this way ; for it cannot be supposed, that the black coating is gifted with the power of retaining caloric, and preventing its escape ; because from experiments made, it appears that a similar coating would accelerate the cooling of a body to which it is applied. Colour, however, has considerable influence over the absorption of caloric, as is shewn by the experiments of Dr. Franklin.

*Experiment 25.* If pieces of *woolen cloth*, of equal dimensions, but of different colours, viz. black, blue, brown, and white, be laid on the surface of *snow*, they will sink in the snow in different proportion.

*Rationale.* It is evident, in this experiment, that the greater the quantity of caloric absorbed, and transmitted to the snow, the farther the cloth will descend.

In a few hours the black will have sunk considerably below the surface ; the blue almost as much ; the brown evidently less ; and the white will remain precisely in its former situation. The sun's rays, therefore, are absorbed by the dark coloured cloth, whilst they have not the power of penetrating the white. Hence the preference generally given to dark coloured clothes during the winter season, and to light coloured ones in the summer.

*Experiment 26.* If six pieces of *sheet copper*, of the same dimensions, be painted on one side, white, yellow, red, green, blue, and black, and the unpainted surfaces be placed on pieces of *cerate*, composed of wax and olive oil, and the whole exposed to the sun's rays, the same effect as in the preceding experiment will ensue.

*Remark.* The motion of caloric through bodies, it must be recollected, is of two kinds : through some bodies it moves with great celerity. In the one case it is said to be *transmitted* through the body, in the other *conducted* through it. See Thomson's Chemistry, vol. i. 310. As caloric, like light, is emitted from the sun with considerable velocity, at the rate of 200,000 miles in a second, it could never be accumulated, were it not retained by its affinity for that body. From this fact we may infer, that in every case, the rays of the sun only afford heat when they meet with an *opaque* body, and not when they pass through a transparent one, as air and water ; or when they are reflected by a white or polished one. On the principle before noticed, the Swiss peasants, when they want to sow their seed, spread black cloths on the surface of the snow, to absorb the sun's rays and facilitate its melting.

*Experiment 27.* Take a number of straight *wires* of equal diameters and lengths, but of different metals, for instance *iron*, *copper*, *gold*, *silver*, &c. cover each of them with a thin coat of wax or tallow, and plunge their extremities into water kept boiling, or into heated sand ; the wax or tallow will be melted off some of the metals sooner than others.

*Rationale.* Bodies which thus transmit caloric are called *conductors* of *caloric*. Different metals, as is seen in the last experiment, possess very different powers of conducting caloric. By the experiments of Dr. Ingenhaus we learn, that metals conduct heat in the following order: silver possesses the highest conducting power; next gold; then copper and tin, which are nearly equal; and, below these, platina, iron, steel, and lead, which are greatly inferior to the rest. According to the relative power which bodies possess, of conducting heat, they are said to be *good* or *bad conductors*; and those through which it does not seem to pass are called *non-conductors*. Thus it is, that some bodies are *warm*, or capable of preserving warmth; hence the different sensations excited by different bodies, when applied at the same temperature to our organs of feeling.

*Remark.* Next to metals, *stones* are the best conductors. Glass conducts heat very slowly; *wood* and *charcoal* still slower; and *feathers*, *silk*, *wool*, and *hair* are still worse conductors. As clothing used in the winter season is a bad conductor of heat, the importance of woollen cloth to preserve the warmth of the body, is obvious. *Hare's* fur and *eider-down* are the warmest; next to these, *beaver's* fur, *raw silk*, *sheep's* wool, *cotton wool*, and the scrapings of linen.

On the same principle also, we learn, that those skins are the warmest, which have the finest, longest, and thickest fur; and that the feathers of the *water-fowl*, with many other animals, are capable of confining the heat in winter, notwithstanding some of them partly live in the water. The *snow* which falls in the winter season, is doubtless designed by Providence as a garment to defend the earth from the piercing winds, so that nature is never wanting in that economy, which serves to shew the wisdom, power, and goodness of God, not only in forming, but in governing and supporting the physical world.

*Experiment 28.* Fill two large vials with *hot water*, at the same temperature; infold one in a piece of linen cloth, and cover the other completely with thick

fur. If in half an hour's time the contents of each be examined, the water in the first vial will be found to have lost several degrees of heat more than that which had been folded in fur.

*Rationale.* We learn by this experiment, the truth of our remark, that fur is a bad conductor of caloric. It is said, however, that clothes, as well as light spongy substances, such as furs and down, keep the body warm in consequence of atmospheric air which they infold within them.

*Experiment 29.* Pour a little *sulphuric ether* upon the surface of water, and inflame it by a slip of lighted paper. After the inflammation has ceased, introduce a thermometer, the temperature will be found to be the same as at first.

*Rationale.* This experiment is calculated to shew, that water is a bad conductor of caloric, and that when it is to be heated, the heat should not be applied at its surface. The heat, therefore, which resulted from the combustion, is carried off with the flame.

*Experiment 30.* Take two rods, one of *glass*, the other of *iron*, both of the same dimensions, and hold them towards the fire; the iron will become hot while the glass will scarcely be affected.

*Rationale.* This is obvious from the foregoing experiment: in this instance the iron rapidly conducts the heat to the hand, while the glass, being a *bad* conductor, scarcely transmits it. If two rods, the one of iron, the other of glass, of the same size, be coated at one end with wax, and the other extremity placed in a fire, the wax will be melted much sooner from the end of the iron rod, than from the glass one.

*Experiment 31.* Take a *glass tube*, eight inches in length, and about an inch in diameter. Pour into the bottom part, for about the depth of an inch, a little *water* tinged with *litmus*, and then fill up the tube with common water, pouring on the latter extremely gently, so as to keep the two strata quite distinct. When the tube is heated at the bottom, the cold affusion will ascend, and will tinge the whole mass. But if the upper

part of the tube be heated, the coloured liquor will remain at the bottom.

*Rationale.* In all cases where liquid and aëriform bodies are concerned, they are found to convey heat on a different principle from that observed in solids, namely, by an *actual change in the situation of their particles*. Hence in the above experiment, the caloric enters below, lessens the density of the fluid in contact with the under surface, which therefore rises and displaces the fluid immediately above, and causes a motion in the particles, which is continued until the liquor becomes of an uniform colour. But if the heat be applied to the surface, no effect of the kind takes place.

That water is a slow, though imperfect conductor of caloric, has been fully established by the experiments and inquiries of Dr. Thomson and Mr. Murray. Consequently, count Rumford's opinion, respecting the non-conducting power of water, is founded in error. The experiments and observations of Messrs. Thomson and Murray, may be found at large in their works on Chemistry. There are several experiments, tending to demonstrate the fact, that may be found by examining these authors; which, for want of room, have been omitted.

*Experiment 32.* If a *thermometer* be immersed in *liquefying ice* or *snow*, it will indicate  $32^{\circ}$ .

*Rationale.* The temperature of melting snow, or of thawing ice, is uniformly the same at all times, and in all places. During the thawing of ice or snow, the thermometer shews only  $32^{\circ}$ , the cause of which will be presently explained.

*Experiment 33.* Place a *thermometer* in *pounded ice*; the temperature will be  $32^{\circ}$ , and at the very same point in water, which results from the liquefaction of ice.

*Rationale.* Dr. Black was the first who proved, that whenever caloric combines with a solid body, the body becomes heated only until it is rendered fluid; or that whenever it has acquired the fluid state its temperature remains stationary. Whenever caloric becomes active, it produces heat; whenever it passes into a liquid state, it produces cold.

*Remark.* When certain bodies, as the metals, are exposed to a sufficient heat, the *attraction of aggregation* is lessened, the caloric acting as a *repulsive* power, and the body ceases to be solid: it appears, therefore, in a fluid state.

This phenomena is called *fusion*; and the body, thus changed from the solid to the fluid aggregate, is said to be *fused* or *melted*. Those bodies which cannot be rendered fluid by any degree of heat hitherto known, are called *fixed* or *infusible*. Fluidity is, therefore, by no means essential to any species of matter, but always depends upon the presence of a quantity of caloric. The caloric, necessary to accomplish this purpose, has been called the *caloric of fluidity*.

*Free caloric* is the same as *uncombined caloric*, *thermometrical caloric*, *caloric of temperature*, *interposed caloric*, &c. By *specific heat* is understood the relative quantities of caloric contained in equal weights of different bodies at the same temperature. *Latent heat* is synonymous with *caloric of fluidity*. *Capacity for heat* is a term made use of to express the property by which different bodies contain certain quantities of caloric at any temperature. *Absolute heat* implies the whole quantity contained in any body.

*Experiment 34.* Expose a pound of *water* at  $32^{\circ}$ , and a pound of *ice* at  $32^{\circ}$ , in a room, the temperature of which is several degrees above the freezing point, and uniformly the same during the experiment. Before the ice is melted, the water will arrive at the temperature of the room, several hours indeed before it takes place; and the melted ice will give, as before its liquefaction, the temperature of  $32^{\circ}$ .

*Rationale.* This experiment proves, that the ice during liquefaction absorbs a considerable quantity of caloric; for the ice must, during the time of the experiment, have been receiving caloric, because a hotter body can never be in contact with a colder one, without imparting heat to the latter. The caloric, therefore, which has entered the ice, though not appreciable by the thermometer, is in a latent state.

*Experiment 35.* If to a pound of water at  $172^{\circ}$  we add a pound of ice at  $32^{\circ}$ , put into a wooden bowl, the temperature will not be the arithmetical mean, but  $32^{\circ}$ .

*Rationale.* This experiment is designed to shew, that "the quantity of uncombined caloric that enters into a pound of ice, and becomes united, during liquefaction," is not the arithmetical mean of the two temperatures, but much below it, viz.  $32^{\circ}$ . All the uncombined caloric of the hot water, has therefore disappeared. By subtracting  $32^{\circ}$  from  $172^{\circ}$  leaves  $140^{\circ}$ , the quantity of caloric that combines with a pound of ice during liquefaction. It is, therefore, latent heat. As much caloric is absorbed by the pound of ice, as would raise a pound of water from  $32^{\circ}$  to  $172^{\circ}$ .

Other examples of the absorption of caloric, during the liquefaction of bodies, will be given in the course of the work; for, on the sudden transition of solids into fluids, is founded the well known production of cold by *frigorific* mixtures, which will also claim our attention in due time.

*Remark.* Dr. Black drew, from a number of experiments, the theory of latent heat; and has not only demonstrated the fact in the experiments already mentioned, but he has also shewn, that the fluidity of *melted wax, tallow, spermaceti, metals, &c.* is owing to the same cause. It is said, that the same law is applicable to *sulphur, alum, nitre, &c.*

*Experiment 36.* If water be cooled down below  $32^{\circ}$ , which may be effected if it be kept perfectly free from agitation, and then suddenly shook, it will immediately congeal, and the temperature will rise to  $32^{\circ}$ .

*Rationale.* In this experiment, the water is cooled down below the freezing point, without congealing; but on shaking it, it immediately freezes.

It is said, that this phenomena is governed by the same law, as is manifested in other cases, namely, that liquids, in becoming solid, evolve or give out caloric, or, in common language, produce heat.

*Experiment 37.* Expose to the atmosphere, when at a temperature below freezing, (for example, at  $25^{\circ}$  of Fahrenheit) two equal quantities of *water*, in one only

of which about a fourth of its weight of *salt* has been dissolved. The saline solution will be gradually cooled, without freezing to  $25^{\circ}$ . The pure water will gradually descend to  $32^{\circ}$ , and will there remain stationary a considerable time before it congeals.

*Rationale.* According to the general law, that a warmer body in contact with a colder one imparts caloric to the latter, it appears, that while the water remains stationary, it is yielding caloric to the atmosphere, equally with the saline solution. Dr. Crawford justly observes, that water, during congelation is acted upon by two opposite powers. It is deprived of caloric by exposure to a medium, whose temperature is below  $32^{\circ}$ , and it is supplied with caloric by the evolution of that principle from itself, viz. of that portion which constituted its fluidity. Consequently, the powers being equal, the temperature of the water must remain unchanged until the caloric of fluidity is all evolved.

*Experiment 38.* Into a round *tin* vessel, says Dr. Crawford, put a pound of powdered *ice*; surround this by a mixture of *snow* and *salt* in a large vessel; and stir the ice in the inner one, till its temperature is reduced to  $4^{\circ}$  of Fahrenheit. To the ice thus cooled, add a pound of water at  $32^{\circ}$ . One fifth of this will be frozen; and the temperature of the ice will rise from  $4^{\circ}$  to  $32^{\circ}$ .

*Rationale.* It is evident in this experiment, that the temperature of a pound of ice is raised to  $28^{\circ}$ , which is produced by the caloric evolved by the congelation of one fifth of a pound of water.

*Experiment 39.* Add to a saturated solution of *sulphate of potash*, or any *salt* insoluble in *alcohol*, an equal measure of *alcohol*; a precipitation, and a considerable degree of heat will be produced.

*Rationale.* In this experiment, the water has a stronger affinity for the alcohol, than for the salt: therefore the water and alcohol unite, the salt is precipitated, a contraction of bulk ensues, and the latent becomes sensible heat.

*Experiment 40.* *Water*, when heated until ebullition ensues, will indicate  $212^{\circ}$ ; *alcohol*  $176$ ; and *ether*  $98^{\circ}$  of Fahrenheit.

*Rationale.* Caloric, we have said, changes solid into fluid, and fluid into aëriform bodies. It is in fact this property, which ranks it among the most important agents in nature. It acts constantly in opposition to the attraction of aggregation, and according to the repulsive power, bodies appear in different states. Hence it is, that in this as well as in other operations, it places the particles of matter farther asunder, and causes them to assume a new state. When a heat of 212 degrees is given to water, that fluid takes the vapourized state; when alcohol is subjected to a temperature of 176° it boils; and when ether is exposed to 98° it is dissipated in ebullition. Therefore, every body, when of the same degree of chemical purity, and under equal circumstances of atmospheric pressure, has one peculiar point of temperature, at which it immediately boils. Steam has the same temperature as boiling water.

*Experiment 41.* If *water*, which has ceased to boil, be placed under the receiver of an air pump, and the air exhausted, ebullition will immediately commence.

*Experiment 42.* If *ether* be exposed in a similar manner, in *vacuo*, the same phenomena will result.

*Rationale.* These and other experiments of a like nature might be adduced to shew, that the boiling point of the same fluid varies, under different degrees of atmospheric pressure. In general liquids boil in *vacuo*, with about 145° less of heat than are required under a mean pressure of the atmosphere. These facts at once prove, that the particles of caloric are mutually repulsive, and that this repulsive power is communicated to other bodies. It is chiefly the pressure of the atmosphere, which counteracts this repulsive tendency.

*Experiment 43.* Place, over a lamp, a Florence flask, about three fourths filled with *water*; let it boil briskly, during a few minutes; and, immediately on removing it from the lamp, cork it tightly up: the water will now cease to boil; but, on cooling the upper part of the flask by a wet cloth, the boiling will be renewed.

*Rationale.* An imperfect vacuum is produced by the application of cold, which condenses the steam, and, as

water near the boiling points boils in vacuo, the ebullition is immediately renewed when the condensation of the steam takes place.

*Experiment 44.* Fill a retort one half or less with water, and make it boil over a lamp; when it has boiled briskly for a few minutes, cork the mouth as expeditiously as possible, and remove it from the lamp. When the ebullition begins to slacken, it may be renewed by dipping the retort in cold water.

*Rationale.* The theory of this experiment is the same as the preceding.

*Remark.* If the flask, or retort, be furnished with a stop cock, cemented to its mouth, the phenomenon will be more complete. After it boils rapidly the cock must be shut. Immediately the ebullition ceases. If the apparatus be removed, and the cock now opened, the accumulated vapour which repressed the ebullition, will then rush out with great violence, and the fluid will boil very rapidly. Considerable care, however, should be observed in this experiment. It is intended to shew the influence of pressure on ebullition. In the former experiments we stated, that if the upper part of the flask, or retort, be suddenly cooled after ebullition, the phenomenon of boiling would again be resumed; but if we immerse the flask, or retort, in hot water, it will be repressed or entirely destroyed. If a flask be provided with a very long neck, and tightly corked while it is boiling, and, after it has become cold, be suddenly reversed, the water in it will fall down with the apparent weight of a stone, because the resistance of the atmosphere is removed. On this principle is founded the water-hammer. Other experiments of this kind will be introduced hereafter.

It has been ascertained, that, notwithstanding the temperature of steam be no more than boiling water, according to the experiments of Mr. Watt, it still contains near 1000° more caloric, and it is this that preserves it in the form of steam.

*Experiment 45.* Fill a jar with water at the temperature of 104°, and invert into it a vessel of the same. Then introduce a little ether, by means of a small glass tube

closed at one end. The ether will rise to the top of the jar, and, in its ascent, will be changed into an aëriform state : or,

*Experiment 46.* Put a little *ether* into a small retort, tie a bladder to the beak of it, and apply heat. The ether will take the gaseous form and fill the bladder. If the bladder be now held in water, the ether will assume a liquid state, and the bladder will collapse. The bladder should first be gently warmed to ensure the success of the experiment : or,

*Experiment 47.* Attach a bladder to a vial, in which some *ether* had been put, and place the vial in *water* heated to about  $150^{\circ}$  or  $200^{\circ}$ ; the conversion of the ether into the aëriform state will immediately ensue : or,

*Experiment 48.* Introduce into a Florence flask *water* coloured with *cochineal*, having previously put in a tea spoonful of *ether*, and fill it with the coloured liquid. Then invert the flask in a shallow vessel of the same kind of coloured water, and by degrees pour boiling water upon its bulb; the ether will take the aëriform state and dispel the water. By pouring cold water on the flask, the ether will resume its original state.

*Rationale.* In all these experiments the same effect ensues, which is owing to the same cause, namely, that uncombined caloric changes liquids into the aëriform state, and that aëriform bodies are converted into the liquid, with some exceptions, however, by the abstraction of caloric, as we have formerly observed.

*Experiment 49.* Mix the filings of *zinc* and *tin*; no combination will ensue until heat be applied : or,

*Experiment 50.* Mix *soda* and *ice*, no action will ensue; but if heat be applied the ice will melt, and then dissolve the soda : or,

*Experiment 51.* *Potash* and *silex*, if mixed, have no action whatever on each other; but if submitted to a great heat, they melt and form a compound, called glass.

*Rationale.* These experiments are designed to shew, that uncombined caloric promotes the action of chemical affinity. Caloric serves not only to unite bodies

but also to separate them. It is, therefore, the most important instrument in the hands of the chemist: by it compositions and decompositions are effected. In some cases caloric acts as a solvent; in others, it separates bodies from each other, and, thus far, seems to be explicable on the principle of elective affinity.

*Experiment 52.* Melt sulphur in a crucible, and add the filings of iron; apply a heat sufficient to unite them, and a sulphuret of iron will be produced.

*Experiment 53.* Take the compound thus formed, and expose it to an intense degree of heat, and the sulphur will be dissipated.

*Rationale.* In these two experiments we find, that, in the first case, uncombined caloric, at a certain temperature, promotes chemical action, and forms the compound of sulphur and iron; and in the second, by subjecting the same compound to a higher temperature, a decomposition ensues; the sulphur is volatilized, except what portion is converted into acid, and the iron remains in the crucible. Hence caloric acts in a two fold capacity, that of composing and decomposing.

*Experiment 54.* Introduce two ounces of sulphate of soda, in powder, into a tea cup of cold water, stirring them together, and the water will only dissolve a portion of it. Now apply heat, and the whole will be taken up. If the solution be suffered to stand undisturbed until it cools, the salt will be observed to shoot into crystals.

*Rationale.* This experiment illustrates, that caloric promotes the solution of salts. Supposing, at the common temperature of the air, that the water dissolves only one half, but on applying heat the whole is taken up: when the temperature is reduced, it is evident that the water could not retain the whole quantity in solution, but that, from necessity, it must separate a part of the salt, which is accordingly separated in a crystalline form.

*Experiment 55.* Moisten the bulb of a thermometer with ether, which operation continue for a few minutes; the mercury will descend below the freezing point.

*Experiment 56.* Put some water into a small tube, having one of its extremities closed, and pour over that part which contains the *water* some *ether*; continue the operation for a few minutes, and the water will be frozen.

*Rationale.* The conversion of liquid into aëriform bodies, depends on the presence of caloric. On moistening the glass of the thermometer, a reduction of temperature necessarily ensues, as a concurring circumstance with the evaporation of the ether. The heat is therefore taken from the mercury, which, consequently, contracts; the degree of which is shewn by the mercurial column. The same theory precisely, is applicable to the second experiment.

*Remark.* The *cooling of rooms* by sprinkling them with water, the action of *butter coolers*, *buxaros*, or *water coolers*, the *cooling of wine* by wrapping the bottle in a wet cloth, the use of *tanned leather bags* by the blacks in Senegambia, the *wetting of the head and body with wet cloths* in use on the borders of the Persian Gulf, the method of making *ice artificially* in the East Indies, are all on the principle of the production of cold by evaporation.

*Experiment 57.* Add eight pounds of *iron filings* at  $300^{\circ}$  to one pound of water at  $212^{\circ}$ ; the temperature of the steam will remain the same.

*Rationale.* It is evident as the temperature remains the same, that the steam must contain, in a latent state, all the caloric which raised the temperature of eight pounds of iron filings from  $212^{\circ}$  to  $300^{\circ}$ .

*Experiment 58.* Place two cylindrical flat bottomed vessels of *tin*, five inches in diameter, and containing a small quantity of water at  $50^{\circ}$ , on a red hot iron plate, of the kind used in kitchens. In four minutes the water will begin to boil, and in twenty minutes the whole will be consumed.

*Rationale.* This is the celebrated experiment made by Dr. Black, in order to determine the quantity of caloric which becomes latent during the formation of steam.

In this experiment, the water received in four minutes  $162^{\circ}$  of temperature, or  $40\frac{1}{2}$  in each minute. If the same proportion be absorbed by the water during the twenty minutes, we may conclude, that  $40\frac{1}{2} \times 20 = 810$ , have entered the water, and are contained in the vapour.

*Experiment 59.* Mix 100 gallons of water at  $50^{\circ}$ , with one gallon of water at  $212^{\circ}$ . The temperature of the water will be raised about  $1\frac{1}{2}^{\circ}$ . Condense by a common still tub 1 gallon of water, from the state of steam, by 100 gallons of water, at the temperature of  $50^{\circ}$ . The water will be raised  $11^{\circ}$ .\*

*Rationale.* From this experiment it appears, that 8lbs. of water, condensed from steam, would raise the temperature of 100 gallons of cold water  $9\frac{1}{2}$  more than 8 pounds of boiling water; and, by an easy calculation, it appears, that the caloric imparted to the 100 gallons by the steam, if it could be condensed in 1 gallon of water, would raise it to  $950^{\circ}$ . A pound of water, therefore, from this data, in the state of steam, contains more caloric than a pound of boiling water, in the proportion of 950 to 212.

*Remark.* On account of the large quantity of caloric latent in steam, it renders its application useful for practical purposes. Thus water may be heated at a considerable distance, and steam conveyed through pipes, either for warming manufactories, rooms, baths, &c. Steam may also be applied to the purpose of heating or evaporating water, besides other operations, which will be noticed in the course of the work. Dr. Black remarks, that steam is the most faithful carrier of heat that can be conceived; as it will deposit it only on such bodies as are colder than  $212^{\circ}$ . Its application to the steam engine is the most important use of which steam may be made.

*Experiment 60.* Mix by degrees, in a Florence flask, four parts of *sulphuric acid* and one of *water*, HEAT will be evolved.

\* Henry, 8vo. p. 424.

*Rationale.* In this experiment heat is produced, which is owing to a condensation that takes place. Here we are presented with the fact, that in some operations heat is given out in an uncombined state, becoming *sensible* heat; for the bulk of the acid as well as the water, on mixture, becomes considerably less than before. In all cases of mixture either *heat* or *cold* is produced; if a *contraction* of bulk is the consequence *heat* is evolved; if an *expansion*, *cold* is the result; or, in other words, the *compound* has a greater or less *capacity* for caloric than the separate ingredients.

*Experiment 61.* If to a portion of *alcohol*, *sulphuric acid* be added by degrees, the same effect will ensue.

*Rationale.* This is owing to the same circumstances as stated in the rationale of experiment 60.

*Experiment 62.* Pour a small quantity of *water* upon *muriate of ammonia* in a wine glass; shake the mixture, and *COLD* will be produced.

*Rationale.* Dr. Black has clearly demonstrated that all matter is subject to the following law, viz. that "whenever a body changes its state, it either combines with, or separates from, caloric." Therefore, the cold produced by the solution of this or other crystallized salts, is owing to the water which was combined with them in a state of solidity, suddenly taking a liquid form, and *absorbing* caloric to preserve it in a state of fluidity; consequently the sensation of cold is the consequence. The same bodies have at all times the same capacity for caloric, unless a change takes place in the *state* of these bodies.

*Remark.* The number of freezing mixtures is considerable. The substances, which may be employed for experiments of this kind, may be arranged in the following order; for which we are indebted to Pepys, Walker and Lowitz.

## TABLE OF FREEZING MIXTURES.

<i>Mixtures.</i>	<i>Thermometer sinks.</i>
Muriate of ammonia - 5 parts Nitrate of potash - 5 Water - - - 16	From 50° to 10°.
Muriate of ammonia - 5 parts Nitrate of potash - 5 Sulphate of soda - 8 Water - - - 16	From 50° to 4°.
Sulphate of soda - 3 parts Diluted nitric acid - 2	From 50° to 3°.
Sulphate of soda - 8 parts Muriatic acid - 5	From 50° to 0°.
Snow - - - 1 part Muriate of soda - 1	From 32° to 0°.
Snow or pounded ice - 2 parts Muriate of soda - 1	From 0° to -5°.
Snow or pounded ice 1 part Muriate of soda - 5 Muriate of ammonia & Nitrate of potash - 5	From -5° to -18°.
Snow or pounded ice 12 parts Muriate of soda - 5 Nitrate of ammonia - 5	From -18° to -25°.
Snow and Diluted nitric acid	From 0° to -46°.
Muriate of lime - 3 parts Snow - - - 2	From 32° to -50°.

TABLE OF FREEZING MIXTURES CONTINUED.

<i>Mixtures.</i>				<i>Thermometer sinks.</i>
Potash	-	-	4 parts	From 32° to —51°.
Snow	-	-	3	
Snow	-	-	2 parts	From —10° to —56°.
Diluted sulphuric acid			1	
Diluted nitric acid	-		1	
Snow	-	-	1 part	From 20° to —60°.
Diluted sulphuric acid			1	
Muriate of lime	-		2 parts	From 0° to —66°.
Snow	-	-	1	
Muriate of lime	-		3 parts	From —40° to —73°.
Snow	-	-	1	
Diluted sulphuric acid			10 parts	From —68° to —91°.
Snow	-	-	8	
Nitrate of ammonia	-		1 part	From 50° to 4°.
Water	-	-	1	
Nitrate of ammonia	-		1 part	From 50° to 3°.
Carbonate of soda	-		1	
Water	-	-	1	
Sulphate of soda	-		6 parts	From 50° to 10°.
Muriate of ammonia	-		4	
Nitrate of potash	-		2	
Diluted nitric acid	-		4	
Sulphate of soda	-		6 parts	From 50° to 14°.
Nitrate of ammonia			5	
Diluted nitric acid			4	
Phosphate of soda	-		9 parts	From 50° to 12°.
Diluted nitric acid			4	
Phosphate of soda	-		9 parts	From 50° to 21°.
Nitrate of ammonia			6	
Diluted nitric acid	-		4	
Sulphate of soda	-		5 parts	From 50° to 3°.
Diluted sulphuric acid			4	

In using the saline substances, in order to produce the effects before stated, they should be reduced to powder, and contain their full quantity of water of crystallization. Some other circumstances should be attended to, which will naturally recur to the operator.

*Experiment 63.* Into a cup placed upon a hearth put three or four ounces of *spirits of turpentine*, and pour into it (from a bottle fastened to a stick of some length to prevent accident) a mixture of *nitric and sulphuric acids*, in the proportion of an ounce of the former and a quarter of an ounce of the latter ; instant *flame* will be produced.

*Rationale.* In this experiment we are presented with an additional proof of our former position, namely, that the compound of these articles has *less capacity* for caloric than they possess in a separate state ; consequently, a part of their *combined* caloric is liberated, and produces the inflammation. The sulphuric acid appears to promote the action very considerably. If the temperature of the turpentine be raised, the effect is more instantaneous. The nitric acid, as well as the sulphuric acid, is decomposed ; a part of its oxygen combines with a part of the carbon of the turpentine, forming carbonic acid ; another part unites with the hydrogen forming water ; whilst the other portion is disengaged in union with the azote of the nitric acid in the state of nitric oxyd, or nitrous gas. The sulphuric acid also suffers decomposition ; sulphurous acid gas is evolved ; and oxyd of carbon remains behind.

*Remark.* It has been asserted, that the sulphuric acid acts only in this experiment by depriving the spirit of turpentine of any water it might contain.

*Experiment 64.* Pulverise a portion of *charcoal*, dry it, and place it in a cup ; pour on it some concentrated *nitric acid*, and *FLAME* will be produced.

*Rationale.* In this experiment the nitric acid is decomposed ; a part of its oxygen unites with the carbon forming carbonic acid, whilst the other portion is evolved in union with the azote in the form of nitric oxyd gas.

*Experiment 65.* Into a tube containing about twelve cubic inches, throw up, over water, about half its capacity of *nitric oxyd gas*, and then the same quantity of *oxygen gas*; a considerable diminution will take place, and SENSIBLE HEAT be given out.

*Rationale.* Some gases when presented to each other have no action, but only exist in the state of mechanical mixture; others again when brought into contact exert a chemical change; their individuality is destroyed; and a new compound is formed. If they suffer no change, no alteration takes place in their specific gravity. In this experiment the affinity is altered; for as soon as the oxygen gas is presented, both gases quit the aëriform state, and unite into a compound called nitric acid, which immediately unites with the water; at the same time *caloric* is given out. In consequence of this property which nitrous gas possesses, of absorbing oxygen, Dr. Priestley has recommended it in eudiometry to determine the purity of the atmosphere. See Atmospheric Air.

## PART IV.

### OF GASES IN GENERAL.

Gas is a generic name given by Van Helmont to elastic aëriform fluids, and is now generally adopted. The term *air*, which was used by Dr. Priestley, seems rather to imply, that elastic fluids are only modifications of common or atmospheric air, the contrary to which is known to be true. It is not necessary to remark, that pneumatic chemistry is considerably indebted to Dr. Priestley, for its present flourishing state.

Elastic fluids have been divided into two genera, *gases*, and *vapours*; the former signify such elastic fluids as retain their elasticity in all known temperatures; the latter those elastic fluids which lose their elasticity by cold, and become liquid, &c. This distinction may have its use; but there is no great reason to believe the difference is not in kind, but in degree only; and that all the gases would lose their elasticity provided the temperature could be sufficiently reduced. The gases may be considered simple or compound; an enumeration of which may be seen in the general contents of the book; to which some add aqueous, alcoholic, and ethereal vapour.

A few remarks on the nature of simple gases, gaseous mixtures, &c. may, with propriety, be here noticed.

Newton, in the 23d prop. of the second book of the Principia, says that an elastic fluid consists of particles that repel one another by a force which varies in the simple inverse ratio of the central distances. A fluid, however, so constituted would exhibit the same mechanical properties as atmospheric air. A gas consists of a *ponderable base* united with *caloric*, and sometimes with light (as oxygen gas) with an affinity too powerful to be overcome, or destroyed, except by

chemical action, or a relative change in affinities. The repulsive power, which always tends to separate the particles of bodies, consequently acts in opposition to the attraction of aggregation, in the case with gases preserves them in an aëriform state. On this power there have been several speculations; at this era of science, it is considered to be a peculiar matter called caloric, or the matter of heat. Some imagined it to be magnetical; others electrical, but these opinions have been exploded.

The mode in which caloric exists in this class of bodies may be shewn by experiment. Introduce into a tubulated retort some dry *muriate of soda*, attach to it a globular vessel having two openings, from one end of which let a tube come and pass into water; then place a thermometer in the globe, and add to the salt half its weight of concentrated sulphuric acid. Apply heat, and gas will come over. It will be found, that the mercury in the thermometer will rise only a few degrees; but the water in the tube, into which the pipe enters, will acquire a considerable accession of heat. In this case, therefore, caloric first combines with muriatic acid, as it is disengaged from the salt, and exists chemically united, as it is not appreciable by the thermometer; but in coming to the water, the gas is absorbed, partly decomposed, and caloric is given out in a free state, as *sensible* heat. By *compound gases* we understand an elastic fluid, which arises from a chemical union of the elements of two or more elastic fluids, or of one elastic fluid and another inelastic body, as carburetted hydrogen, in which carbon and hydrogen are united, or as in nitric oxyd, in which azote and oxygen are combined.

By *gaseous mixtures* we mean the union of two or more gases. Some gases when mixed, *chemically* combine with each other; others are merely diffused through the whole space.\*

With respect to the classification of gases, some writers have applied the terms *respirable* and *nonrespi-*

\* See page 13.

*rable, supporters and non supporters* of combustion, &c. and in this manner have divided them. Some gases effect *no positive* change in the blood, while others, according to Dr. Beddoes and professor Davy, produce some *positive* change. As to the weights, specific gravities, constituent principles, &c. of the gases, they will be found under their proper heads.

The *pneumatic apparatus* is a reservoir or cistern too well known to require description; it is for the purpose of collecting, transferring, and experimenting on the gases. It may be made of wood, tin (painted or japanned) or sheet iron painted with a thick coat. Wood, however, is preferable. See a plate in Lavoisier's and Henry's Chemistry. It is obvious, that as some gases are absorbed by water, that that fluid would not answer for all gases.\* For collecting and experimenting on these a mercurial apparatus is indispensably necessary. A trough about 12 inches long, three inches wide, and four deep, is sufficient for all private experiments. As to the method of collecting and transferring gases from one vessel to another, the operation is too simple to need description; nor need we notice the *bell glasses* or *air holders* necessary in pneumatic chemistry. For a particular account of these and other apparatus for conducting experiments on the gases, I would refer the student to that excellent manuel, Henry's Epitome of Chemistry, a work designedly calculated to instil the first principles into the mind of the new beginner.

Agreeably to our plan, the *preparation* of the gases separately will be considered under distinct sections, and in the subsequent part their *characteristic properties* will claim our attention.

\* See page 15.

## SECTION I.

## OF THE PREPARATION OF OXYGEN GAS.

*Experiment 1.* Put into a retort a small quantity of *oxygenized muriate of potash*, and apply the heat of a lamp. When the salt begins to melt, OXYGEN GAS will be obtained in abundance.

*Rationale.* In this process a decomposition of the oxygenized muriate of potash takes place; its oxygen is extricated in combination with caloric, forming oxygen gas, while the simple muriatic acid united to the potash, in the state of muriate of potash, remains in the retort.

*Experiment 2.* Introduce into an *earthen*, or coated glass retort, or iron mattrass, a portion of *nitrate of potash*, and expose the apparatus to the action of a strong heat, until the retort becomes red hot. A gas will be obtained, which is OXYGEN GAS.

*Rationale.* In this experiment the nitric acid of the nitrate of potash is partially decomposed. The greatest part of the oxygen of the nitric acid unites to caloric, and forms oxygen gas. The other part remains with the potash in the state of nitrous acid. The residue in the distilling vessel is therefore nitrite of potash. Care should be taken to lessen the heat towards the end of the process, otherwise azotic gas will also come over.

*Remark.* This method of obtaining oxygen gas, I would recommend for extensive experiments in preference to any other. In my class, where a number of experiments are made, I found it more expeditious in the end.

*Experiment 3.* If *black oxyd of manganese* be exposed in the same manner, and with the same apparatus, to a strong heat, OXYGEN GAS will be given out.

*Rationale.* Black oxyd of manganese is an ore of manganese, in which a quantity of oxygen exists in a combined state. On exposing it, therefore, to a red heat, the affinity of the two is partially destroyed; its

oxygen unites with caloric in the state of oxygen gas, while the metal re-approaches the metallic state. A gray oxyd of manganese, however, remains in the vessel.

One pound of oxyd of manganese, will afford about 1400 cubic inches of oxygen gas.

*Remark.* If sulphuric acid be previously added to the manganese, the gas is produced by a less heat and in a larger quantity; a glass retort and an Argand's lamp may then be used.

*Experiment 4.* If red oxyd of mercury (*mercurius precipitatus per se*) be treated in the same manner as in the preceding experiment, OXYGEN GAS will be the result.

*Rationale.* This oxyd of mercury is formed by exposing mercury to a heat of about 610° Fahr.

If the temperature be raised to about 1000° the attraction of oxygen is changed; oxygen gas is given out, and the mercury is revived.

*Experiment 5.* If red oxyd of lead be heated, with or without sulphuric acid, OXYGEN GAS will be produced.

*Rationale.* In this experiment also, the heat destroys the former affinities; consequently, oxygen gas is given out, and, if sulphuric acid be used, a sulphate of lead remains in the retort.

*Experiment 6.* Fill a glass bell with water, introduce the leaves of vegetables under it, and place the bell inverted in a flat dish of water. Expose the apparatus to the rays of the sun, and very pure OXYGEN GAS will be disengaged.

*Rationale.* In this experiment the water is said to be decomposed; the hydrogen combines with the plant, to the nourishment and support of which it contributes, while the oxygen is set at liberty. Dr. Manners informed me that he exposed a plant to the action of the sun's rays under water, which contained carbonic acid, and that he obtained a large quantity of oxygen gas. In this case, the carbonic acid, as well as the water, underwent a decomposition; the carbon and hydrogen were absorbed, and the oxygen, not only of the water, but also of the carbonic acid, was liberated.

*Experiment 7.* Expose under water, in the same manner as in the former experiment, a portion of the *green matter* which collects on stagnant waters, to the rays of the sun; oxygen gas will be disengaged in abundance.

*Rationale.* The *conferva*, or green matter, of stagnant pools, Dr. Priestley discovered would afford, when exposed to the sun's rays, a large quantity of *empyreal* or *oxygen gas*. It has been supposed by some philosophers, that this matter is the product of spontaneous generation.

In this as in the preceding experiment, the water is decomposed; its hydrogen is absorbed, and the oxygen is given out in the state of gas.

*Experiment 8.* Expose the *leaves of vegetables* to the sun's rays under water; *oxygen gas* will be emitted: expose the same leaves under lime water, and *no gas* will be disengaged; now remove the leaves, wash them, and expose them again in pump water, and gas will be given out as at first.

*Rationale.* This experiment I give on the authority of my friend Dr. Manners, which experiment he instituted to prove that water is *not* decomposed as is generally supposed, but the carbonic acid, with which it is impregnated; for, when the leaves were exposed in water, either distilled or boiled, he obtained not a particle of gas. When lime water was used, the effect was the same. See an Essay in the Memoirs of the Columbian Chemical Society, by Dr. Manners.

Dr. Woodhouse made a number of experiments, I think in 1806, on this subject, an account of which was published in Nicholson's Journal, and also in Woodhouse's edition of Chaptal's Chemistry; wherein he endeavoured to prove, that water was not decomposed by vegetables, but that in every case in which oxygen gas was formed, carbonic acid was present. Consequently he inferred, that the emission of oxygen was from the decomposition of carbonic acid, and not from the water. The professor instituted these experiments after Mr. Sennebier had made his on the same subject.

Mr. Sennebier proved, that if water be previously boiled, of course deprived of its air, the leaves do not emit a particle of oxygen gas ; that those kinds of water which yield most air, contain in them the greatest quantity of carbonic acid gas ; and that leaves do not emit any oxygen when plunged in water totally destitute of carbonic acid gas.\* If these conclusions be correct, which we have no reason to doubt, the theory of the decomposition of water by plants, is fallacious. Berthollet infers, that oxygen is given out partly from the water, and partly from the carbonic acid.

*Remark.* All plants do not emit oxygen gas with the same facility. There are some which yield it the moment the sun's rays come upon them, as the leaves of the *jacoboea* or rag wort, of *lavender*, *peppermint*, and some other aromatic plants. Green healthy plants afford more air than white or yellow ones. Green fruits also furnish oxygen gas. The *nastutium indicum*, in the space of a few hours, gives out more air than is equal to the bulk of all its leaves. Several essays have appeared on this subject. See an interesting one by Mr. G. F. Lehman, "On the emission of Oxygen gas by plants," in the Memoirs of the Columbian Chemical Society, vol.i.

*Experiment 9.* Put concentrated oxygenized muriatic acid into a bottle, and fit to it a bent glass tube, one end of which pierces the cork of the bottle, and the other end reaches under a bell or receiver, filled with and inverted in a basin of water, care being taken that the tube does not touch the acid ; expose the whole to the rays of the sun, and OXYGEN GAS will pass over into the receiver.

*Rationale.* This experiment is founded on the property, of the decomposition of oxymuriatic acid by light, for the production of oxygen gas is the effect of that decomposition. The oxygenized muriatic acid is, therefore, changed into the common muriatic acid.

\* See Thomson, v. 355.

## SECTION II.

## PREPARATION OF CARBONIC ACID GAS.

*Experiment 1.* Into a glass in which *marble*, or *chalk* has been put, pour *sulphuric*, *nitric* or *muriatic acid*, a decomposition will ensue, and CARBONIC ACID GAS be disengaged.

*Rationale.* In this experiment the marble, or chalk, (carbonate of lime) is decomposed; the sulphuric, nitric, or muriatic acid unites with the lime, forming the sulphate, nitrate, or muriate of lime, and the carbonic acid is disengaged in a gaseous state.

*Experiment 2.* Into a jar containing *oxygen gas*, introduce a piece of *ignited charcoal*; when the combustion has ceased, the remaining air will be found to be CARBONIC ACID; and if the charcoal be sufficient, the whole of the oxygen gas will be converted into carbonic acid gas.

*Rationale.* The charcoal by combustion in oxygen gas unites with the oxygen; the result is carbonic acid, a compound of carbon and oxygen. This experiment should be made over mercury.

*Experiment 3.* If the vapour of *water* be passed over *charcoal*, heated to redness in a gun barrel; and the gas collected, it will be found to be CARBONIC ACID, with HYDROGEN and CARBURETTED HYDROGEN GASES.

*Rationale.* In this experiment the water is decomposed; its oxygen combines with a part of the carbon forming carbonic acid, whilst its hydrogen is liberated partly in a free state, and partly in combination with carbon, forming the carburetted hydrogen gas.

*Experiment 4.* Put into an *iron matrass* some *marble* or *chalk*, apply a considerable degree of heat, and CARBONIC ACID GAS will be obtained.

*Rationale.* In this case the decomposition of the carbonate of lime takes place, on account of the action of caloric, which at a high temperature breaks the affinity of the carbonic acid and lime; it unites with the first and

leaves the lime in that state which is generally called *quicklime*.

*Experiment 5.* If a tube be attached to the bung of a barrel, in which the *vinous fermentation* has commenced; or if the air of a brewer's vat, in which fermentation is going on, be collected and examined, it will be found to be CARBONIC ACID.

*Rationale.* During the vinous fermentation, the carbon of the vegetable matter is partly carried off in union with oxygen forming carbonic acid, whilst the other portion of carbon remains behind in combination with hydrogen, and forms spirit, which exists in beer, cyder, and liquors of this kind, in union with water and mucilaginous matter.

*Experiment 6.* Mix together equal parts of *red lead* and *charcoal*, and expose the mixture to the action of a strong heat, in an earthen retort; CARBONIC ACID GAS will come over.

*Rationale.* In this case the red lead or oxyd of lead, is decomposed by the charcoal; the oxygen is abstracted, the lead revived, and carbonic acid formed.

*Experiment 7.* Melt in a crucible a portion of *nitrate of potash*; when melted throw in by degrees some *charcoal powder*; an immediate deflagration will ensue; and if the gas be collected, it will be found to be principally CARBONIC ACID.

*Rationale.* In this case the nitric acid of the nitrate of potash is decomposed: the carbon unites with the oxygen forming carbonic acid, whilst the azote is set at liberty. A portion of the carbonic acid is disengaged, and another portion remains with the potash of the decomposed nitre, in the form of subcarbonate of potash.

*Remark.* The sources of carbonic acid are immense, and widely diffused. The chief are the following:

1. The atmosphere always contains a small portion, which varies in the immediate vicinity of places where the processes of respiration and combustion are going on, though somewhat less than might be expected. The general average is estimated at about one hundredth part.

2. Almost every natural spring, as it rises from the earth, contains a small portion of this air; and some waters hold so large a portion as to give them, when exposed to the air, a very brisk, frothy appearance, and a very sensible taste, and decidedly acid properties. The celebrated springs of Spa, Pyrmont, and Seltzer, and the Balltown in the United States, are of this kind.

3. Every process in which coal, wood, or any other carbonaceous substance is burnt, is one which generates this acid gas. The same may be said of the processes of respiration.

4. The vegetation of plants under some circumstances generates carbonic acid.

5. The spontaneous decomposition of vegetable and animal matter, produces this gas in abundance.

6. But the largest store of carbonic acid that exists, is that enormous quantity which is solidified in all the immense beds of lime-stone, chalk, and calcareous stones with which every part of the globe abounds. Many of these contain 40 per cent. or even more of their weight of this acid.

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### SECTION III.

#### OF THE PREPARATION OF GASEOUS OXYD OF CARBON.

*Experiment 1.* To one part of chalk, previously exposed to a low red heat for ten minutes, add an equal quantity of perfectly dry filings of zinc; let the mixture be introduced into an earthen, or iron retort, and exposed to a heat gradually increased. As soon as the retort becomes of a dull red colour, gas will be disengaged in great abundance. This gas is the CARBONIC OXYD, or GASEOUS OXYD of CARBON.

*Rationale.* This combination of carbon and oxygen contains a less proportion of oxygen than is found in carbonic acid. In this process, therefore, a decomposition of the carbonic acid of the chalk takes place, in

its nascent state. The zinc robs the carbonic acid, as it is liberated by the action of heat, of a part of its oxygen at a high temperature, and becomes to a certain degree oxydized. The carbonic acid, by being thus deprived of a part of its oxygen, is converted into a new inflammable gas.

*Remark.* In the commencement of the process carbonic acid gas is obtained; but when the heat is increased, the decomposition of the remaining acid ensues. This gas is said to hold the same relation to pure hydro-carburets and carbonic acid gas which nitrous gas, or nitrous oxyd, does to pure azote and nitrous acid.

Carbonic oxyd gas may also be obtained by several other processes. If tin filings be mixed with charcoal, and treated in the same manner, the like result will ensue; or, if equal quantities of scales of iron separated in forging (black oxyd of iron) and charcoal powder previously heated to redness be mixed, and exposed to the action of heat, the same effect will take place. The gas procured in this way, is a mixture of about one part of carbonic acid gas, and four of gaseous oxyd of carbon; the former may be separated by suffering the gas to stand over lime water, which will absorb it, and form a carbonate of lime. By employing oxyd of zinc, red oxyd of copper, semi-vitreous oxyd of lead, black oxyd of manganese, and the rest of the metallic oxyds capable of enduring a red heat, with charcoal, carbonic acid gas, and carbonic oxyd gas will be obtained. Carbonic acid gas transmitted over ignited charcoal, also forms it.

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## SECTION IV.

### OF THE PREPARATION OF HYDROGEN GAS.

*Experiment 1.* Introduce into a flask about an ounce of iron or zinc filings, and pour over them a few ounces of

water ; then add *sulphuric acid*, and HYDROGEN GAS will be evolved.

*Rationale.* According to the Lavoisierian theory of chemistry, the water in this case is decomposed, and the acid promotes the chemical action. All metals before solution are oxydized, which must take place either before, or in the act of solution ; therefore, when iron or zinc filings, is presented to diluted sulphuric acid, the water is decomposed ; its oxygen goes to oxydize the metal, which is then dissolved by the acid ; whilst the hydrogen is evolved in the state of gas. The oxygen is therefore the bond of union between the metal and the acid.

*Experiment 2.* Let a gun barrel, having its touch-hole screwed up, pass through a furnace ; adjust to its upper extremity a retort charged with water, and let the other extremity terminate in a tube introduced under a receiver in the pneumatic trough. When the apparatus is thus disposed and well luted, bring the gun-barrel to a red heat ; and, when thoroughly red hot, make the water in the retort boil ; the vapour, when passing through the red hot tube, will afford HYDROGEN GAS abundantly.

*Rationale.* In this experiment the oxygen of the water combines with the iron at a red heat, forming an oxyd ; and the caloric applied combines with the hydrogen of the water, and forms hydrogen gas.

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## SECTION V.

### OF THE PREPARATION OF SULPHURETTED HYDROGEN GAS.

*Experiment 1.* Put some *sulphuret of iron* (made by melting three parts of iron filings and one of sulphur) into a flask ; pour a little diluted *sulphuric acid* upon it,

and SULPHURETTED HYDROGEN GAS will be disengaged.

*Rationale.* In this experiment the water is decomposed; a part of the oxygen oxydizes the iron, which is dissolved by the acid; the hydrogen then, acting upon the sulphur, dissolves a portion of it, and forms sulphuretted hydrogen or hepatic gas. A portion of sulphuric acid is also formed.

*Experiment 2.* Into a flask introduce some *sulphuret of potash*, and pour on it diluted *muriatic acid*; apply heat, and SULPHURETTED HYDROGEN GAS will be disengaged.

*Rationale.* Sulphur in a separate state, has no action on water, yet if it be united to an alkali, this combination decomposes water whenever it comes in contact with it, though the alkali itself has no attraction either for oxygen or hydrogen. A part of the sulphur unites with the oxygen forming sulphuric acid, which then combines with a part of the alkali and produces sulphate of potash, whilst the hydrogen of the water, thus set at liberty, unites with a portion of the sulphur, and forms sulphuretted hydrogen which is disengaged in union with caloric in the state of gas. The muriatic acid unites with the other portion of alkali, forming muriate of potash. If sulphuret of potash be thrown into water of the common temperature, it will be decomposed; sulphate of potash, undecomposed sulphuret, and hydrogenated sulphuret will exist. If an acid be added, or the temperature raised, the latter would be decomposed, and sulphuretted hydrogen gas be disengaged.

*Experiment 3.* If a mixture of *sulphur* with *vegetable matter*, as *sugar*, *oil*, or powdered *charcoal*, be exposed to a strong heat, SULPHURETTED HYDROGEN GAS will be obtained.\*

*Rationale.* The hydrogen, which exists in vegetable substances, or probably from water in its decomposition by heat, unites with the sulphur, and produces sulphuretted hydrogen. Gas obtained by this means, would be impure, containing more or less of carburetted hydrogen.

*Experiment 4.* If sulphur be exposed to hydrogen gas, in a gas holder, a portion will be dissolved by the gas, and the whole converted into SULPHURETTED HYDROGEN GAS.

*Rationale.* This experiment proves, that hydrogen is susceptible of holding sulphur in solution; which forms hepatic air.

*Experiment 5.* If sulphur be melted in a tube, and hydrogen gas passed through it, SULPHURETTED HYDROGEN GAS will be formed.

*Rationale.* This is also a case of the simple solution of sulphur in hydrogen gas.

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## SECTION VI.

### OF THE PREPARATION OF LIGHT CARBURETTED HYDROGEN GAS.

*Experiment 1.* Fill a wide mouth bottle with water, and keep it inverted in some stagnant water, with a funnel in its neck; then with a stick stir the mud at the bottom just under the funnel so as to let the bubbles of air which rise from the mud enter into the bottle; when, by thus stirring the mud in various places, and catching the air in the bottle, it is filled: the gas thus obtained is the LIGHT CARBURETTED HYDROGEN.

*Rationale.* Hydrogen is capable of containing carbon in solution: in this case we have a compound of the two. Nature produces it ready formed in marshes and ditches, on the surface of putrid water, in burying-places, common sewers, and in those situations where putrid animal and vegetable matters are accumulated. It is also generated in the intestinal canal of living animals.

*Experiment 2.* If shavings of wood, or saw dust, be put into a retort, and distilled with a heat gradually in-

creased until the retort becomes red hot; a great quantity of gas will be liberated, which, when caught over lime water and washed, will be found to be the LIGHT CARBURETTED HYDROGEN.

*Rationale.* When wood is subjected to destructive distillation, it is resolved into its elementary principles, and the product obtained shews that it contains hydrogen, carbon, and oxygen. When the heat arrives at a certain temperature, a part of the charcoal unites with part of the oxygen, which forms carbonic acid, whilst the hydrogen combines with another part of the charcoal, and forms the light carburetted hydrogen gas. The flame of burning wood is supposed to be this gas in the state of combustion.

*Experiment 3.* If charcoal be moistened with water, and exposed in an earthen retort to a heat gradually raised, a gas will come over consisting partly of carbonic acid gas, and partly of LIGHT CARBURETTED HYDROGEN GAS.

*Rationale.* In this case the water is decomposed, and carbonic acid and carburetted hydrogen gases are produced. The former may be separated by lime water.

*Experiment 4.* If charcoal be exposed to the solar rays, concentrated by a lens, in hydrogen gas, the same combination will take place.

*Experiment 5.* Expose some pit coal in a small earthen, or iron retort, to the action of a strong heat; a gas will come over, which when passed through lime water, will be pure LIGHT CARBURETTED HYDROGEN GAS.

*Rationale.* As the coal receives the heat, a vast quantity of gas is liberated, not however perfectly pure. This gas is formed, it is supposed, by the decomposition of water in the coal; for at the same time, some carbonic acid passes over, which is produced from the oxygen of the water and carbon of the coal. The gas obtained from pit coal has been substituted for oil in lamps, and has been used successfully to light up rooms, for an account of which see Thomson's Che-

mistry, vol. i. p. 51. and Parke's Chemical Catechism, 8vo.

During the operation much bituminous matter is distilled.

*Experiment 6.* If *acetite of potash* be distilled, a gas will be obtained which possesses the properties of the LIGHT CARBURETTED HYDROGEN GAS.

*Rationale.* In this experiment, the acetous acid is decomposed; its oxygen unites with a part of the carbon, forming carbonic acid, which attaches itself to the alkali, whilst the hydrogen and part of the carbon are dissipated in a gaseous state.

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## SECTION VII.

### OF THE PREPARATION OF HEAVY CARBURETTED HYDROGEN GAS.

*Experiment 1.* If four parts of *concentrated sulphuric acid* and one of *alcohol* be mixed together in a retort, and a moderate heat applied, a large quantity of gas will pass over, which is the HEAVY CARBURETTED HYDROGEN GAS, or the OLEFIANT GAS of the Germans.

*Rationale.* By the action of sulphuric acid on the alcohol, a decomposition ensues. A part of the acid itself is decomposed: the oxygen of the acid appears to combine with a portion of hydrogen forming water, whilst the carbon of the alcohol is separated; the other portion of hydrogen, being now disengaged, combines with a part of the carbon, and forms the heavy carburetted hydrogen gas, at the same time some sulphureous acid passes over, from which it is to be separated. From the property which the gas possesses of forming an oil with oxymuriatic acid gas, the Dutch chemists have given it the appellation of olefiant gas, and Dr. Thomson calls it heavy hydrocarburet, or hydrocarbonate.

*Experiment 2.* Pass through a red hot earthen tube in the state of vapour, alcohol or sulphuric ether, and a gas will be obtained similar to the preceding.

*Rationale.* During this operation, the heat acts as a *divellent power*; the hydrogen of the alcohol, or ether, takes the gaseous form, which unites with carbon obtained from the same source, and produces the HEAVY CARBURETTED HYDROGEN GAS.

*Remark.* There are several species of the gas called carburetted hydrogen, a full account of which may be seen in Thomson's Chemistry. What is called the light carburetted hydrogen contains  $28\frac{1}{2}$  per cent. hydrogen, and  $71\frac{1}{2}$  carbon, and the heavy carburetted hydrogen, called also the super carburetted hydrogen, and olefiant gas, is composed of 83 per cent. of carbon, and 17 of hydrogen.

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## SECTION VIII.

### OF THE PREPARATION OF ARSENIURETTED HYDROGEN GAS.

*Experiment 1.* Mix a small quantity of *metallic arsenic* with a few *zinc* or *iron* filings, and add to the mixture some diluted *sulphuric acid*, ARSENIURETTED HYDROGEN GAS will be obtained.

*Rationale.* In this experiment, the water is decomposed; the oxygen unites with the zinc or iron, which is afterwards dissolved, and the hydrogen combines with a portion of the arsenic, forming the arseniuretted hydrogen gas.

*Experiment 2.* If an alloy composed of 15 parts of *tin* and one of *arsenic*, be digested in *muriatic acid* ARSENIURETTED HYDROGEN GAS will be evolved.

*Rationale.* In this process, recommended by Stromeyer, the water in the muriatic acid is decomposed; hydrogen is evolved, which dissolves a portion of arse-

nic, forming the gas in question, whilst the muriatic acid unites with the tin into a muriate of tin.

*Experiment 3.* If *liquid arsenic acid* be digested with zinc, an effervescence will ensue, and ARSENIURETTED HYDROGEN GAS will be evolved.\*

*Rationale.* In this experiment the water of the liquid arsenic acid is decomposed; its oxygen as well as a *part* from the arsenic acid goes to the zinc and oxydizes it, which is then taken up by the arsenic acid, forming arseniate of zinc, whilst the hydrogen of the water, thus disengaged, unites with a portion of the arsenic, and forms arseniuretted hydrogen.

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## SECTION IX.

### OF THE PREPARATION OF PHOSPHURETTED HYDROGEN GAS.

*Experiment 1.* Put four ounces of *water* into an eight ounce retort, and add a little solution of *pure pot-ash*, and give it a boiling heat with a lamp. When it boils, drop a small piece of phosphorus into it, and immerse the beak of the retort into a vessel of water. Bubbles of PHOSPHURETTED HYDROGEN GAS will pass over, and on coming in contact with the atmosphere, will take fire.

*Rationale.* In this case the phosphorus unites with the potash, forming a phosphuret, which decomposes the water: the oxygen of which unites with a part of the phosphorus and converts it into phosphoric acid; whilst the hydrogen of the water, thus set at liberty, dissolves the other portion of phosphorus, and produces the phosphuretted hydrogen gas. Phosphate of potash remains in the retort.

\* Reese's Cyclopediæ, article Arsenic.

*Experiment 2.* If a small quantity of *phosphuret of lime* be thrown into water, bubbles of PHOSPHURETTED HYDROGEN GAS will be evolved.

*Rationale.* In this case the water is decomposed by the phosphuret of lime: a part of the phosphorus is converted into the phosphoric acid by the oxygen of the water, which unites with the lime into a phosphate of lime; the other part of the phosphorus combines with the hydrogen of the decomposed water, and forms the phosphuretted hydrogen gas.

*Experiment 3.* If 20 grains of *phosphorus*, cut very small, and mixed with 40 grains of fine granulated zinc, and 2 drachms of concentrated *sulphuric acid* be added thereto, PHOSPHURETTED HYDROGEN GAS will rise to the surface, and take fire.

*Rationale.* In this case the zinc seizes the oxygen; and the hydrogen, the other constituent of the water, unites with a portion of the phosphorus, forming the phosphuretted hydrogen gas, whilst the oxyd of zinc is taken up by the sulphuric acid, and forms sulphate of zinc.

*Experiment 4.* If to a piece of *phosphuret of lime*, put in water, a few drops of concentrated *muriatic acid* be added, a disengagement of PHOSPHURETTED HYDROGEN GAS will immediately ensue.

*Rationale.* In this experiment, like in the preceding, the water undergoes a decomposition; the muriatic acid promotes the action, probably by separating the hydro-phosphuret, like in the case with hydro-sulphuret of potash.

*Experiment 5.* If *phosphorus* be exposed to an atmosphere of *hydrogen gas*, a portion will be dissolved in that air, and form the PHOSPHURETTED HYDROGEN GAS.

*Rationale.* In this case a direct combination of phosphorus with hydrogen takes place; if the phosphorus be melted, while in the hydrogen gas, the combination will be facilitated. The gas formed in this way contains less phosphorus than that produced by the phosphuret of lime; it has therefore been called *phosphorized hydrogen gas*. It is this gas which is often seen ho-

vering on the surface of burial-grounds, marshes, &c. known by the name of *will-o-the-wisp*.

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## SECTION X.

### OF THE PREPARATION OF AMMONIACAL GAS.

*Experiment 1.* Introduce a mixture of two parts of *muriate of ammonia* and one part of *lime (quick-lime)* both in powder, into a retort, and apply the heat of a lamp; a gas will be produced, which is the AMMONIACAL GAS.

*Rationale.* In this experiment the muriate of ammonia, being a compound of muriatic acid and ammonia, is decomposed by the lime; the muriatic acid unites with this earth, forming muriate of lime, which remains in the retort, and the ammonia combines with caloric, and forms ammoniacal gas.

*Experiment 2.* Introduce into a retort, or flask adapted to a syphon, a portion of *liquid ammonia*, and apply the heat of a lamp; AMMONIACAL GAS will be produced.

*Rationale.* As the liquid ammonia is nothing more than a solution of ammoniacal gas in water, it is obvious, that on the application of heat, the ammonia is disengaged in the form of gas.

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## SECTION XI.

### OF THE PREPARATION OF SULPHUROUS ACID GAS.

*Experiment 1.* Pour on to a small quantity of *mercury*, put into a retort, a portion of *sulphuric acid*; apply heat, and SULPHUROUS ACID GAS will be formed.

*Rationale.* In this experiment the mercury abstracts a part of the oxygen of the sulphuric acid, as the latter is a compound of sulphur and oxygen, and becomes converted into an oxyd; the sulphuric acid having thus lost a portion of its oxygen, is transformed into the sulphurous acid.

*Experiment 2.* Place in an earthen dish some *sulphur*; set fire to it, and when it is completely inflamed, cover it with a large bell glass perfectly dry; remove the whole on a dish and surround it with mercury. The sulphur will burn for some time. When the vapour has subsided, the air in the glass will be found to contain SULPHUROUS ACID GAS.

*Rationale.* This is a case of the slow combustion of sulphur. During the process, the sulphur absorbs the oxygen contained in the atmospheric air; the oxygen not being sufficient to oxygenate the sulphur completely, the result is an imperfect aëriform acid.

*Experiment 3.* If *sulphite of potash* be exposed in a retort to the action of heat, SULPHUROUS ACID GAS will be disengaged.

*Rationale.* In this case the heat decomposes the salt, which is a compound of sulphurous acid and potash, and unites with the acid forming sulphurous acid gas.

*Experiment 4.* If concentrated *sulphuric acid* be added to the *sulphite of potash*, and heat applied, SULPHUROUS ACID GAS will be produced.

*Rationale.* In this experiment, the sulphuric acid decomposes the sulphite; it unites with the alkali forming sulphate of potash, whilst the sulphurous acid is liberated.

*Experiment 5.* Moisten *charcoal* with *sulphuric acid*, and expose it to distillation; SULPHUROUS ACID GAS and carbonic acid gas will be obtained.

*Rationale.* In this case the charcoal decomposes the sulphuric acid; it unites with a part of the oxygen and forms carbonic acid; at the same time the remaining compound of sulphur and oxygen is disengaged in the state of sulphurous acid gas, the sulphuric acid being partly deoxydated.

*Experiment 6.* If a mixture of *sulphur* and the *oxyds* of *lead*, *mercury*, *tin*, or *manganese*, be subjected to heat, SULPHUROUS ACID GAS will be produced.

*Rationale.* In this experiment the sulphur attracts the oxygen of the metallic oxyds, and becomes converted into sulphurous acid gas, while the oxyds are partially restored to the metallic state.

## SECTION XII.

### OF THE PREPARATION OF NITRIC OXYD GAS.

*Experiment 1.* If to a portion of *copper* filings, put into a retort, *nitric acid* be added, and heat applied, NITROUS GAS, or NITRIC OXYD GAS, will be obtained.

*Rationale.* In order the better to obtain this gas, the acid should be diluted, and the first portions of the gas suffered to escape. In this experiment the water undergoes no change, but the acid suffers a partial decomposition : nitric acid, being a compound of oxygen and azote, when presented to the metal, is decomposed ; a part of the oxygen unites with the metal, thereby oxidizing it, which is then dissolved by another portion of the acid, forming nitrate of copper, at the same time another part being thus deprived of some of its oxygen, assumes a gaseous form, constituting the nitric oxyd, or nitrous gas, which exists as a permanently elastic fluid at the common temperature of the atmosphere.

*Remark.* Other metals beside copper may be used for procuring nitrous gas, such as lead, mercury, silver, iron, zinc, &c.

*Experiment 2.* Pour *nitric acid* on powdered *tin*, a violent action will immediately ensue, and a copious disengagement of NITROUS GAS take place.

*Rationale.* It is evident, that as the metals possess different degrees of affinity for oxygen, the phe-

nomena is more or less rapid. In this experiment considerable heat is produced, during the oxydizement of the metal, and the extrication of the nitrous gas. The rationale of this is similar to the preceding.

*Experiment 3.* If *copper wire*, or strips of this metal, be introduced into a retort, and the same quantity of *nitrate of potash* added, and to this half its weight of *sulphuric acid*; on applying heat, NITROUS GAS will be obtained.

*Rationale.* In this process nitrate of potash is decomposed: the sulphuric acid unites with the alkali, forming sulphate of potash, whilst the nitric acid is disengaged, which acts immediately on the copper, and causes, by its decomposition as in a former experiment, an evolution of nitrous gas.

*Experiment 4.* If coarsely powdered *manganese* be put into an earthen tube, open at both ends, then placed in a furnace, and heat be applied until the manganese is red hot, and ammoniacal gas passed over it from a retort attached to one end, NITROUS GAS will be given out at the other end of the tube.

*Rationale.* *Ammonia* consists of hydrogen and azote: in this case, when it comes in contact with the heated oxyd of manganese, its hydrogen combines with a portion of the oxygen given out, and forms water, whilst another part unites with the azote, and constitutes nitrous gas.

Care should be taken, in making the experiment, not to suffer the ammoniacal gas to pass through undecomposed.

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## SECTION XIII.

### OF THE PREPARATION OF AZOTIC GAS.

*Experiment 1.* If a paste made of *sulphuret of potash*, or *sulphuret of iron*, be exposed to atmospheric air in a bell glass over water, the air will gradually diminish,

as will appear from the ascent of the water, until only about three fourths of its original bulk remain. The remaining air is AZOTIC GAS, OR NITROGEN GAS.

*Rationale.* Atmospheric air is composed of oxygen gas and azotic gas. On presenting the sulphuret, the former is absorbed, and the sulphuret is converted into a sulphate. The remaining air is the azotic gas. If carbonic acid gas existed in the air, its separation from the azote may be accomplished by means of lime water. It is this property which some of the sulphurets possess, that has recommended them in eudiometry to ascertain the quantity of oxygen gas in the atmosphere. The water, with which the sulphuret is moistened, likewise undergoes a decomposition; some sulphuretted hydrogen gas is therefore formed.

*Experiment 2.* If to *lean muscular flesh* cut in pieces and put into a retort, *nitric acid* diluted with double its weight of water be added, and the heat of a lamp applied; a gas will pass over, which will be found to be AZOTE OR NITROGEN.

*Rationale.* Animal substances are quaternary compounds, consisting of azote, carbon, hydrogen, and oxygen. On adding nitric acid and applying heat, the equilibrium of the respective affinities is destroyed, and azotic gas is evolved. That the nitric acid, although composed of azote as a necessary constituent, does not afford the nitrogen is obvious, from its saturating the same quantity of alkali after as well as before the experiment.

*Experiment 3.* If *oxygenated muriatic acid gas* be received in a vessel containing *liquid ammonia*, NITROGEN GAS will be formed.

*Rationale.* The oxymuriatic acid gas as well as the ammonia, are reciprocally decomposed; the oxygen of the former unites with the hydrogen of the latter and forms water, whilst the azote, the other constituent of the ammonia, is set at liberty; the oxymuriatic being reduced to the common muriatic acid.

*Experiment 4.* If *phosphorus* be inflamed in a jar of *atmospheric air*, until the combustion ceases, the air remaining will be found to be NITROGEN GAS.

*Rationale.* In this experiment the *phosphorus* robs the air of its *oxygen* and forms with it *phosphoric acid*, which appears in white fumes. When these subside, the remaining air will be tolerably pure azote. It is said that the azote holds a portion of phosphorus in solution forming phosphuretted azotic gas.

*Remark.* Fourcroy asserts, that azotic gas left in contact with charcoal has the property of dissolving a portion of it. The gas has been called CARBURETTED AZOTIC GAS.

In the same manner, azote unites with phosphorus and sulphur, forming the PHOSPHURETTED and SULPHURETTED AZOTIC GASES.

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## SECTION XIV.

### OF THE PREPARATION OF NITROUS OXYD GAS.

*Experiment 1.* Introduce into a retort a portion of *nitrate of ammonia*, and apply the heat of a lamp; the salt will soon liquefy, and NITROUS OXYD GAS or GASEOUS OXYD OF AZOTE will be disengaged.

*Rationale.* When the temperature has arrived between 340 and 480 degrees, the salt melts and a rapid decomposition ensues. In this experiment, therefore, the nitric acid, as well as the ammonia is decomposed; for at a temperature of 480° the attractions of hydrogen and nitrogen, and that of nitrous gas for oxygen in nitric acid are diminished, while on the contrary, the attraction of the hydrogen and ammonia for the oxygen of the nitric acid, and that of the remaining nitrogen of the ammonia for the nitrous gas of the nitric acid, are increased; consequently, a change of affinities ensues. The hydrogen of the ammonia unites with

the oxygen of the nitrous acid and forms water : the nitrogen of the ammonia then combines with the liberated nitrous gas, and forms nitrous oxyd.

After the gas is prepared it is suffered to remain over water before it is used. The peculiar stimulating effects of this gas when taken into the lungs, which has excited great attention in the literary world, will be noticed hereafter.

*Experiment 2.* If *nitrous gas* be exposed to *alkaline sulphites*, a part of its *oxygen* is absorbed, and the gas is converted into the NITROUS OXYD.

*Rationale.* In this experiment the sulphite is converted into the sulphate of potash by the absorption of oxygen from the nitrous gas, which is thus changed into the nitrous oxyd.

*Experiment 3.* If *nitrous gas* be presented to *sulphuretted hydrogen gas* NITROUS OXYD will be formed.

*Rationale.* In this experiment the hydrogen unites with a portion of oxygen and forms water, and with azote it produces ammonia. Sulphur is deposited. The remaining oxygen and azote form the nitrous oxyd.

*Experiment 4.* Expose *sulphuret of potash* to *nitrous gas*, and the latter will be changed into NITROUS OXYD.

*Rationale.* In this case a part of the oxygen is abstracted by the sulphur, which is acidified, whilst the remaining gas is converted into the nitrous oxyd. If the sulphuret be a hydro-sulphuret, the sulphuretted hydrogen will undergo decomposition.

*Experiment 5.* If the *nitrous gas* be collected, which has been obtained by the action of *nitric acid* upon *copper*, and exposed to a solution of *sulphate of iron*, the nitrous gas will be absorbed, and the remaining gas will be found to be NITROUS OXYD.

*Rationale.* In the decomposition of nitric acid by copper, or any of the metals, it appears, that besides nitrous gas, a portion of nitrous oxyd is generated. Dr. Priestley first announced the fact. As the nitrous differs from the nitric oxyd, or nitrous gas, only in the proportion of azote and oxygen, it would appear, that in preparing nitrous gas, these elementary principles arrange themselves in two different orders; the first

constitutes the nitric and the latter the nitrous oxyd. The proportion of the latter, however, is inconsiderable to the former. When impure nitrous gas is exposed to a solution of sulphate of iron, Mr. Davy found that the nitrous gas was wholly absorbed, leaving the nitrous oxyd behind. This solution forms Mr. Davy's test for oxygen, in eudiometry, and is far preferable to Dr. Priestley's mode of using the nitrous gas.

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## SECTION XV.

### OF THE PREPARATION OF MURIATIC ACID GAS.

*Experiment 1.* Into a tubulated retort introduce two parts of very dry *muriate of soda*, and pour on it very gradually one part of concentrated *sulphuric acid*. A violent action will ensue, and MURIATIC ACID GAS becomes disengaged.

*Rationale.* Muriate of soda is a compound of muriatic acid and soda.

On adding sulphuric acid, it is decomposed. The muriatic acid is given out in the state of gas, and a compound remains in the retort of sulphuric acid and soda.

*Experiment 2.* If *muriatic acid* be exposed to a moderate temperature in a retort, a gas will come over, which is the MURIATIC ACID GAS.

*Rationale.* In this process the application of heat disengages the muriatic acid gas from its combination with water, in which it exists in the state of acid, without distilling the water.

*Experiment 3.* If *muriatic acid* be put into a cylindrical glass, and about one third or one fourth by measure of *sulphuric acid* be added, a violent effervescence will ensue, and MURIATIC ACID GAS be evolved.

*Rationale.* This experiment proves that the affinity of sulphuric acid for water, is greater than that of muriatic acid; consequently, the one displaces the other.

## SECTION XVI.

## OF THE PREPARATION OF OXYGENIZED MURIATIC ACID GAS.

*Experiment 1.* Introduce into a retort one part of *black oxyd of manganese* and three or four of concentrated *muriatic acid*; apply heat and gas will be obtained. This is the OXYGENIZED MURIATIC ACID GAS.

*Rationale.* In this experiment oxyd of manganese is partly deoxydated; a portion of its oxygen unites with the muriatic acid, which is changed into oxygenized muriatic acid, and which takes the gaseous form. The oxyd of manganese, being thus partly deoxydized, is dissolved by another portion of the muriatic acid, into a muriate of manganese.

*Experiment 2.* To eight parts, by weight, of *muriate of soda*, and three of powdered *oxyd of manganese*, put into a tubulated retort, add gradually four parts of *sulphuric acid*, diluted previously with three of *water*. On applying a gentle heat OXYGENIZED MURIATIC ACID GAS will be produced.

*Rationale.* In this case the muriate of soda is decomposed by the sulphuric acid, which unites with the soda, for which it has a greater affinity, forming sulphate of soda, whilst the muriatic acid seizes the oxygen of the oxyd, in the same manner as in the preceding experiment, and forms with it oxygenized muriatic acid gas.

*Remark.* The *disinfecting apparatus* of Morveau is formed of the above materials placed in a suitable glass vessel. Most of the metallic oxyds will answer as well as the manganese, but the latter is much cheaper, and generally yields more oxygen.\*

\* As the disinfecting apparatus of Morveau has been used in hospitals, for the purpose of destroying contagion, or at least for purifying the atmosphere, the reader may find a description of the apparatus, and the mode of using it, in a work entitled, "Observations on the Means of preserving the Health of Soldiers and Sailors, and on the Duties of the Medical Department of the Army and Navy; with remarks on Hospitals and their Arrangement," by EDWARD CUTBUSH, M. D. Surgeon in the Navy of the United States.

*Experiment 3.* To an ounce measure of *liquid muriatic acid*, contained in a gas bottle, add three or four drachms of *hyper oxymuriate of potash*, and OXYMURIATIC ACID GAS will be evolved. If the heat of a lamp furnace be applied, the action of the acid is promoted. By immersing the gas bottle in a vessel of warm water, the same effect will ensue.

*Rationale.* The production of oxymuriatic acid gas by the decomposition of hyper oxymuriate of potash by muriatic acid, depend upon the superior affinity of the muriatic acid for the alkali, in consequence of which the oxymuriatic acid is expelled, and muriate of potash is formed.

*Remark.* This process was first pointed out by Mr. Cruikshank. This philosopher infers, that the gas obtained by this means contains one part of oxygen and 1.3 of muriatic acid, or 56.5 of muriatic acid, and 43.5 of oxygen in the hundred. According to Mr. Chenevix the gas procured by this process is a mixture of hyper oxymuriatic acid and oxymuriatic acid gas.

*Experiment 4.* If *nitric acid* be added to *muriate of soda* and heat applied, the salt will be decomposed, and an acid gas consisting partly of OXYMURIATIC ACID GAS will be obtained.

*Rationale.* In the first place a part of the nitric acid goes to decompose the muriate of soda, with the base of which it forms nitrate of soda, whilst the muriatic acid unites with a part of the oxygen of the remaining portion of nitric acid and forms oxymuriatic acid. The azote of the nitric acid still in union with oxygen, constitutes nitric oxyd, or nitrous gas, with which the oxymuriatic is contaminated.

*Experiment 5.* If *oxygenized muriate of potash* be put into a cup, and *sulphuric acid* added, an action will ensue, and OXYMURIATIC ACID GAS will be disengaged. If heat is applied, the decomposition is more rapid.

*Rationale.* In this experiment the oxymuriate of potash is decomposed; the sulphuric acid takes the place of the oxymuriatic acid, and the latter assumes a gaseous form.

## SECTION XVII.

## OF THE PREPARATION OF FLUORIC ACID GAS.

*Experiment 1.* Put one part of powdered *fluat*e of lime (Derbyshire spar) into a *leaden* or *tin* retort, and pour over it two or three parts of concentrated *sulphuric acid*. When heat is applied, a violent action will ensue, and FLUORIC ACID GAS will pass over.

*Rationale.* The fluat of lime is decomposed by the sulphuric acid; the fluoric acid is separated in the state of gas, whilst the sulphuric acid unites with the lime, forming sulphate of lime. It is this acid which has the property of corroding glass; hence the use of a leaden or tin retort, as it does not act upon either of the metals, and hence also its utility in etching on glass.

*Experiment 2.* If *water*, impregnated with *fluoric acid gas*, be exposed to a moderate heat, FLUORIC ACID GAS will pass over.

*Rationale.* In this case the heat destroys the union of the gas with the water; hence the former is disengaged.

## PART V.

### OF THE PROPERTIES OF THE GASES.

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#### SECTION I.

#### OF OXYGEN GAS.

*Experiment 1.* If *oxygen gas* be introduced into a bell glass over water, or mercury, and ignited charcoal brought in contact, combustion will immediately commence and scintillating sparks will be thrown out in all directions.

In showing this experiment the red hot charcoal should be attached to a copper wire.

*Rationale.* In this experiment the oxygen gas is decomposed, as it consists of oxygen, caloric, and light; the carbon, at the temperature of ignition, having a greater affinity for oxygen than caloric, combines with the oxygen, and forms carbonic acid, which takes the gaseous state, whilst heat and light are set at liberty. If a certain quantity of charcoal be burnt, or enough to decompose all the oxygen gas, the remaining air will be found to be unfit for combustion, or respiration, and susceptible of separation by lime water: if this be introduced, or the jar removed to a dish containing lime water, the gas will be absorbed, the lime water will put on a milky appearance, and carbonate of lime will be produced.

*Remark.* Oxygen gas, according to Dr. Thomson, is a *simple supporter of combustion*. The term supporter is used to denote the property which some airs possess, particularly oxygen gas, of aiding and promoting

combustion. For the theories on combustion see Lavoisier's and Thomson's Chemistry.

Respecting the combustion of charcoal, it may not be improper to add, that in all cases, whether it be burnt in oxygen gas or in atmospheric air, carbonic acid gas is generated; and as this gas is deleterious to animal life, it is important that proper ventilators should be used in every situation in which it is burnt.

*Experiment 2.* Introduce into a bell glass of *oxygen gas* a piece of roll *sulphur*, previously inflamed, attached to a copper wire; the *sulphur* will burn with a beautiful blue flame. Fumes will arise, which will gradually subside.

*Rationale.* In this experiment the oxygen gas is decomposed; the sulphur unites, in combustion, with the oxygen, and forms both the sulphurous and sulphuric acids; these acids being composed of sulphur and oxygen. The water under the air holder will be found to have an acid taste, and to exhibit the properties of acids in general. Oxygen is the principle of acidity.

*Remark.* When sulphur is burnt in contact with nitrate of potash, as in the sulphuric acid manufactories, it is *completely* oxygenated; for there the oxygen is furnished by the nitric acid of the nitrate, which is decomposed.

*Experiment 3.* Fill a bell with *oxygen gas*, and introduce a piece of phosphorus placed in a little cup; set it on fire by means of a crooked *iron wire* previously ignited, and a brilliant flame will be produced.

*Rationale.* In this experiment the phosphorus unites with the oxygen, forming phosphoric acid, which appears in a white smoke, and the light heat of the gas, as well as of the phosphorus (for these bodies exist in phosphorus) are set at liberty.

*Remark.* On account of this property, phosphorus has been used in eudiometry, to measure the quantity of oxygen gas in the atmosphere. Forty grains of phosphorus absorb generally sixty-five of oxygen. On the mode of using it, see Thomson's Chemistry. Mr.

Henry has proposed the following method to shew the combustion of phosphorus in oxygen gas.

*Experiment 4.* Fill a bell shaped receiver, having an opening in the top, to which a compressed bladder is firmly tied, with *oxygen gas*; and, as it stands inverted in water, press a circular piece of pasteboard, rather exceeding the jar in diameter, over its mouth. When an assistant has set fire to the *phosphorus* cover it instantly with the jar of *oxygen gas*, retaining the pasteboard in its place, till the jar is immediately over the cup. When this has been skilfully managed, a very small portion only of the gas will escape; and the inflammation of the phosphorus will be extremely brilliant. The expanded gas rises into the flaccid bladder, and is thus prevented from escaping into the room, and proving disagreeable by its suffocating smell.

*Experiment 5.* If fine *iron wire*, or thin harpsicord wire, be twisted in a spiral form, to the end of which a little flax or tow dipped in *sulphur* has been put, and to the other end a cork fixed, which fits the mouth of a bottle, then set on fire, and introduced into the bottle, previously filled with *oxygen gas*, the wire will burn with a most brilliant light and throw out a great number of sparks.

*Rationale.* This experiment proves that the metals are combustible, and that in the present instance, the iron decomposes oxygen gas. During the combustion, oxygen is absorbed by the metal, which is therefore changed into an oxyd, and heat and light are set at liberty. The iron, by thus uniting with oxygen, increases in weight, and loses the properties of metallic iron. It is always necessary, in order to effect the decomposition of the gas, that the iron should be ignited, or that combustion some where should commence the process, otherwise the affinity of oxygen and caloric would still remain in equilibrio.

*Remark.* Watch springs, and steel made sharp pointed, will, if properly managed, shew the same experiment. Before my class, I have exhibited the phenomena with perfect satisfaction by using the watch

spring, and also by exposing it, in an ignited state, to a stream of the gas, issuing from the *hydro-pneumatic blow pipe*.

All the metallic substances, with the exception of gold, silver, and platina, have the property of decomposing oxygen gas.

*Experiment 6.* If *metallic arsenic* be put into a copper ladle, having previously affixed to it a piece of wood or charcoal, then set on fire by means of the blow pipe, and quickly introduced into *oxygen gas*, a beautiful white flame will be produced, and the *arsenic* be consumed.

*Rationale.* In this case the arsenic, a simple combustible body, decomposes the gas, and is converted, by its combining with oxygen, into an acid, the arsenious acid, which is found floating on the water (if the experiment be made over water) in the form of a white powder: heat and light are, therefore, disengaged.

*Experiment 7.* Make a small ball of the turnings of zinc and put in it a small piece of *phosphorus*, put it into a copper ladle, or attach it to a *copper wire*, set it on fire and introduce it into *oxygen gas*; the zinc will be inflamed and produce a beautiful green flame surrounded by a white one.

*Rationale.* The oxygen in this case converts the zinc into an oxyd of zinc.

*Experiment 8.* If the filings, or turnings, of zinc, copper, antimony, iron, or steel, be exposed to a current of oxygen gas from a *gasometer*, they will burn with great rapidity.

*Experiment 9.* Take the *metal* obtained from potash, or *potassium*, heat it and introduce it under a bell glass of oxygen gas, a rapid combustion will ensue, and potash be reproduced.

*Rationale.* As potash is found to be a compound body, consisting of a peculiar metal united with oxygen, in the state of an oxyd, agreeably to Mr. Davy, it follows, that potash is reproduced in this experiment. The potassium unites with the oxygen, and heat and light are, of course, set at liberty.

*Experiment 10.* If a little Homburg's *pyrophorus* be introduced into *oxygen gas*, immediate FLASHES like inflamed gun powder will ensue.

*Rationale.* This effect is also owing to the decomposition of oxygen gas.

*Experiment 11.* A lighted *wax taper* let down into a vessel of *oxygen gas* burns with great splendour ; if it be blown out and again let down, the snuff is instantly rekindled.

*Rationale.* The first part of the experiment proves, that oxygen gas is a better supporter of combustion than common air, which is a compound of oxygen and azotic gases, and the second, that ignited carbon (of the wick) is immediately inflamed in oxygen gas.

*Experiment 12.* If a piece of *dry coal* be fastened to a copper wire ignited, and immersed into oxygen gas, it will burn and throw out brilliant sparks.

*Experiment 13.* *Nitrate of lime* and *charcoal* mixed, set on fire and introduced into the gas, will burn with an orange red colour.

*Experiment 14.* *Boracic acid* and *charcoal*, in the proportion of one part of the former and three of the latter, treated in the same manner, affords a green.

*Experiment 15.* *Nitrate of strontian* and *charcoal* produces a rose coloured flame.

*Rationale.* In these cases, the colours are produced by the different substances, which constitutes their *habits* when exposed, under certain circumstances, to oxygen gas.

*Experiment 16.* If two lighted tapers be placed in two jars of the same dimensions, the one containing *atmospheric air*, and the other *oxygen* ; it will be found that the taper will burn considerably longer in the *oxygen gas* than in the *atmospheric air*.

*Rationale.* As oxygen gas is a supporter of combustion, and atmospheric air only a supporter of combustion as it contains oxygen, it follows that the taper would burn for a longer time in the one than in the other.

*Experiment 17.* If a *bi d*, mouse, or other small animal be put into a vessel of *oxygen gas*, it will be found to live six times longer than in the same bulk of atmospheric air.

*Rationale.* This is a proof that oxygen gas supports, eminently, animal life. Condorcet, accordingly, named it *vital air*. The reason why oxygen gas thus maintains animal life is readily explained, when we consider, that animal heat is attributable to the decomposition of oxygen gas by the blood in the lungs; or that the process of respiration which is a compound action of inspiration and expiration, causes the air to come in contact with the disoxygenated blood, that oxygen gas is decomposed analagous to combustion, and that oxygen is absorbed, forming the red blood, and heat is thus set at liberty from it.

*Remark.* Dr. Priestley and many other philosophers have shewn, that animals live much longer in the same quantity of oxygen gas than of common air. Count Morozzo placed a number of sparrows, one after another, in a glass bell filled with common air and inverted over water.

	H.	M.
The first sparrow lived	3	0
The second	0	3
The third	0	1
He filled the same glass with oxygen gas and repeated the experiment.		

	H.	M.
The first sparrow lived	5	23
The second	2	10
The third	1	30
The fourth	1	10
The fifth	0	30
The sixth	0	47
The seventh	0	27
The eighth	0	30
The ninth	0	22
The tenth	0	21

He then put in two together; the one died in 20 minutes, but the other lived an hour longer. These experiments, therefore, shew, that a considerable difference exists between atmospheric air and oxygen gas as it respects the vitality or the support of animal life.

Dr. Higgins having caused a young man to breathe pure oxygen gas for several minutes, his pulse, which was at 64, soon rose to 120 beats in a minute.\* Pure oxygen gas has been used also with success in cases of suspended animation. Water impregnated with it has been found a valuable remedy in several diseases.

*Experiment 18.* If a little dark coloured blood be passed up into a jar partly filled with *oxygen gas*, and standing over mercury; or if a vial be filled with oxygen gas, and a portion of blood added and well shook, the gas will be in part absorbed, and the colour of the blood will be changed to a bright and florid red.

*Rationale.* Blood, being found to contain subphosphate of iron united with eight other ingredients, when exposed to oxygen gas changes its colour, (if it be dark) to a red, which is owing to the absorption of oxygen. For particulars, see Thomson's Chemistry.

*Remark.* All the operations of nature, whether of the animal, the vegetable, or the mineral kingdoms, are so governed by invariable laws, as to co-operate with each other. It is thus by reciprocal changes, which are governed by uniform laws, that revolutions are brought about; and it is thus also, that the economy of nature is produced from those operations, which consist in regular and harmonious changes, and altogether bespeaks the handy work of an artist acquainted with his materials.

Oxygen gas is a component part of atmospheric air in the proportion of twenty-two parts in a hundred. It has never been procured in a separate state. Oxygen gas, or the combination of oxygen with caloric and light, is its most simple form. The gas is permanently elastic, compressible, transparent, inodorous and insipid. The specific gravity is 0.00135. We have seen that it sup-

ports inflammation and is necessary for respiration, in which processes it is decomposed. Oxygen is also a principal constituent in water, in all acids, and metallic oxyds, and in almost all animal and vegetable substances. Oxygenizement is a process in which the oxygen unites with certain bases, forming either oxyds or acids, in the formation of which certain affinities ensue.

#### PRIMARY COMPOUNDS OF OXYGEN.

- |  |   |
|--|---|
| A. Binary.                                     | 2. Sulphurous acid.   |
| <i>a. a.</i> With nitrogen.                    | 3. Sulphuric acid.  |
| 1. Atmospheric air.                            | <i>e. e.</i> With phosphorus ;  |
| 2. Nitrous oxyd.                               | 1. Oxyd of phosphorus.  |
| 3. Nitric oxyd.                                | 2. Phosphorous acid.  |
| 4. Nitric acid.                                | 3. Phosphoric acid.   |
| <i>b. b.</i> With hydrogen, wa-<br>ter.        | B. Ternary, with carbon and<br>hydrogen.  |
| <i>c. c.</i> With carbon.                      | <i>a. a.</i> Oxyds. Hydrocarbon-<br>ates, alcohol, ether, oil,<br>vegetable substances. |
| 1. Incombustible coal,<br>plumbago.            | <i>b. b.</i> Acids. Vegetable acid.   |
| 2. Charcoal, (carbonous<br>oxyd.)              | C. Quaternary. With hydro-<br>gen, carbon, and nitrogen.                                |
| 3. Gaseous oxyd of<br>carbon, (carbonic oxyd.) | <i>a. a.</i> Oxyds. Animal sub-<br>stances.   |
| 4. Carbonic acid.                              | <i>b. b.</i> Acids. Animal acids.   |
| <i>d. d.</i> With sulphur.                     |   |
| 1. Oxyd of sulphur.                            |   |

It has been supposed that oxygen gas is a principal agent in putrefaction. Dr. Manners placed a quantity of fresh meat, dried as much as possible, in order to free it from moisture, under mercury, so as to exclude it entirely from atmospheric air ; in three days he discovered that the putrefactive process had taken place. Dr. Thomas D. Mitchell has since repeated the experiment, with precisely the same result, from which they drew the following conclusion. That external oxygen, or oxygen gas of the atmosphere, has no influence whatever in the putrefactive process ; and that putre-

faction ensues, in consequence of the equilibrium of the component parts of animal substances being destroyed by the loss of *vitality*, in which also some new products are formed. Dr. Manners observes, that contrary to the common opinion, no ammonia, sulphuretted hydrogen, nor oxygen gas was formed, in the process of putrefaction, *excluded from external air* ; but that carbonic acid gas was given out.

This subject, however, will be noticed under its proper head.

## SECTION II.

### OF CARBONIC ACID GAS.

*Experiment 1.* Carbonic acid gas extinguishes flame, for if a lighted taper be let down into a vessel of this air, it will be immediately extinguished. The smoke, if the vessel be shaken, will have an undulating motion.

*Experiment 2.* Into three tubes of the same dimensions, introduce *atmospheric air*, *carbonic acid gas*, and *oxygen gas*, in each tube ; plunge successively, and with swiftness, a lighted taper into each of them. In the tube containing atmospheric air, the taper will burn as usual ; in that which contains carbonic acid gas, it will be extinguished, and in the oxygen gas it will burn with increased splendour.

*Experiment 3.* If a candle be placed in a jar of *common air*, and a jar of *carbonic acid gas* be poured, as you would water, into it, the flame will be immediately extinguished.

*Rationale.* These experiments are designed to prove, that carbonic acid gas is not a supporter of combustion ; that although it contains oxygen, yet it is already combined with carbon, with an affinity too great to be overcome in this manner. Hence it extinguishes flame.

*Remark.* As the extinguishing of flame is a prominent character of carbonic acid gas, commonly called fixed air, and as this gas is often found in vaults, cellars, wells and the like, it may be always ascertained by letting down a lighted taper.

*Experiment 4.* Into a jar of the gas put a mouse, it will die in a few minutes.

*Remark.* This gas is, therefore, fatal to animal-life. Many accidents have been produced by this gas. In the burning of coal, in the fermentation of wine, cyder, beer, &c. it is generated. The celebrated lake of Averno, where Virgil placed the entrance of hell, affords so large a quantity of carbonic acid gas, that birds cannot fly close over it with impunity.

If *butterflies* and other insects be destroyed in this gas, for cabinet specimens, the colour will be better preserved than if they were suffocated by the burning of sulphur. It is this gas in combination with soda, &c. that constitutes the aerated waters, known by the name of *artificial mineral waters*. It is found in mineral springs, and it is often the solvent of iron, forming the natural aerated or carbonated chalybeate waters, of which the United States abound.

*Experiment 5.* Let the gas, issuing from a mixture of carbonate of lime, and sulphuric acid, or carbonic acid gas, be conveyed into a bottle, by means of a syphon, with its mouth uppermost. Place a lighted taper into another jar, or bottle, containing atmospheric air, and pour in the contents of the first mentioned jar, and the candle will be instantly extinguished.

*Rationale.* This experiment proves that carbonic acid gas is heavier than common air; for, in the first place, when the carbonic acid gas comes in contact with the air of the bottle, it displaces it; and in the second, on pouring the gas into the bottle, in which the lighted candle had been placed, the gas will descend and extinguish the flame, shewing that by its superior gravity it displaces atmospheric air.

*Remark.* It is on this account that carbonic acid gas occupies the lowest situations; hence it is found at the bottom of wells, mines, cellars, and the like. The spe-

cific gravity of this air, according to the experiments of Kirwan, is 1.500, that of air being 1.000 ; or it is to air as 3 to 2.

*Experiment 6.* Let a jar containing *carbonic acid gas* stand a few hours over water. It will be found, that the *bulk* of the gas is considerably diminished.

*Rationale.* In this experiment carbonic acid gas is absorbed by the water, which thus acquires a very brisk and pleasant taste.

*Remark.* If pressure be employed, water may be impregnated with upwards of three times its own bulk of carbonic acid gas. The specific gravity of this saturated water is 1.0015. Various kinds of apparatus are employed to effect a combination of carbonic acid gas with water, but the most common of these is the Nooth's apparatus, which has lately been improved by Parker and Magellan. By using this machine, however, water cannot be made to absorb more than half its own bulk of the gas. The apparatus consists of three pieces, all of glass, furnished with a valve and stop cocks. Different machines have been invented for the same purpose. Some of the aerated alkaline waters prepared in this city, I have found to contain between two and three times their bulk of gas. This can only be effected by using powerful pressure by means of apparatus.

It is owing to the presence of carbonic acid, that cyder, perry, ale, champaign and other wines owe their briskness.

*Experiment 7.* Into water saturated with *carbonic acid gas*, pour a little of the *tincture of litmus*, or immerse into it a slip of *litmus paper*, or mix it with the *infusion of cabbage* ; the blue colour of the paper, or infusion, will be changed to red.

*Remark.* This experiment fully proves, that this gas, in combination with water, exhibits the characteristic properties of acids.

*Experiment 8.* Expose water saturated with *carbonic acid gas* to the atmosphere ; it will be found, in the course of a short time, that the water will have lost its carbonic acid.

*Remark.* It is on this account that beer, cyder, per-ry, &c. when exposed to the air become vapid: hence also the reason why natural and artificial aerated waters on exposure to the air lose their properties.

*Experiment 9.* Expose aerated water under the receiver of an air pump, and exhaust the air. When a vacuum is produced, the gas will escape from the water so rapidly as to present the appearance of ebullition.

*Rationale.* The affinity which subsists between water and carbonic acid gas is, by removing the pressure of the atmosphere, destroyed; hence the gas is disengaged with considerable rapidity.

*Experiment 10.* If water containing *carbonic acid gas* be mixed with *lime*, *barytes*, or *strontian water*, or if a stream of *carbonic acid gas* be made to pass into either of these solutions, the fluid, though perfectly transparent before, will become turbid.

*Rationale.* If either of these waters come in contact with carbonic acid, they immediately unite with it, and form a new combination, which will be either a carbonate of lime, carbonate of barytes, or a carbonate of strontian.

*Experiment 11.* Pass the *air* given out during respiration, through *lime water*, which may be effected by means of a glass tube or quill. The lime water will grow turbid, and a precipitation of carbonate of lime take place.

*Rationale.* This experiment is designed to shew, that the respiration of animals is another source of carbonic acid. If an animal be confined in oxygen gas over lime water, the water will also become turbid. This effect is explained on the principle, that in respiration, a portion of the carbon of the blood in contact with atmospheric air in the lungs, combines with a part of the oxygen, and is thrown out in the form of carbonic acid gas, which is absorbed by the lime water, in the same manner as in the preceding experiment.

*Experiment 12.* Suspend two pieces of *fresh meat* in *common air*, and in *carbonic acid gas*; it will be found, that the meat hung in the carbonic acid gas will be preserved untainted sometime after the other has begun to putrefy.

*Rationale* In this experiment, which is intended to prove that carbonic acid gas retards the putrefaction of animal substances, several circumstances are to be taken into consideration.

1. The antiseptic quality of carbonic acid.
2. The reason why it is so.

It is a fact stated by some writers on this subject, that those substances which contain most oxygen are good to prevent putrefaction; and as carbonic acid contains a large quantity of it, it is considered a better preservative.\*

*Experiment 13.* If water saturated with carbonic acid gas be applied to the roots of plants, it will promote their growth.

*Rationale.* In this case the carbonic acid is decomposed. The carbon unites with the vegetable, which becomes a component part of it, while the oxygen, the other constituent of carbonic acid, is disengaged in a free state: hence it is, that carbonic acid gas exerts powerful effects on living vegetables. It is said that carbonic acid gas, applied as an atmosphere to plants, proves injurious to their health.

*Experiment 14.* Fill a tube with a solution of caustic potash, and introduce a portion of carbonic acid gas, the gas will be diminished, and, if the quantity be sufficient, will form carbonate of potash.

*Rationale.* In this experiment the gas is decomposed; the carbonic acid itself unites with the alkali, and forms a compound consisting of carbonic acid and potash.

*Remark.* The combination of carbonic acid with alkalies, earths, and metals, constitutes a class of salts, called carbonates: if the base of the salt be in excess, it is a sub-carbonate, if both unite into a neutral compound, it forms a carbonate, but if the carbonic acid is in a superabundance, the salt is a super-carbonate.

Carbonic acid, formerly called *fixed air*, *aerial acid*, *mephitic acid*, *calcareous acid*, &c. contains 28 per cent. of carbon, and 72 of oxygen.

*Experiment 15.* Into a tube of glass introduce a bit of phosphorus and some carbonate of lime; seal the tube

\* See an ingenious essay on this subject by Dr. Mitchell, in the Memoirs of the Columbian Chemical Society.

hermetically and apply heat, and CHARCOAL will be deposited.

*Rationale.* This process was used by Mr. Tennant to effect the decomposition of carbonic acid, which takes place in the following manner: The substances introduced into the tube are phosphorus, and carbonate of lime, or lime and carbonic acid. And the substances found in it, are phosphorus, lime, oxygen, and carbon. Hence, therefore, the carbonic acid of the carbonate is decomposed; its oxygen unites with the phosphorus, for which it has a greater affinity, forming phosphoric acid, and with lime phosphate of lime, whilst the carbon, the basis of carbonic acid, is separated in the form of charcoal.

These experiments, which were first instituted by Mr. Tennant, were afterwards repeated and confirmed by Dr. Pearson, and Messrs. Fourcroy, Vauquelin, Sylvestre, and Brogniart.

*Remark.* Count Mussin-Puschkin effected the decomposition of carbonic acid, by boiling a solution of carbonate of potash and phosphorus together.

### SECTION III.

#### OF GASEOUS OXYD OF CARBON.

*Experiment I.* If gaseous oxyd of carbon, properly prepared, be introduced into a bladder furnished with a stop cock and pipe, with a small aperture, and set fire to, as it is compressed out it will BURN with a blue flame.

*Rationale.* This gas is therefore inflammable, and during its combustion, it forms, with the oxygen of the air, carbonic acid; hence it unites with another dose of oxygen, and has its properties changed.

*Remark.* This gas does not explode like other inflammable gases with common air, but burns silently

with a lambent blue flame. It detonates, however, in the following manner:

*Experiment 2.* To 100 measures of the gaseous oxyd, add 45 of oxygen gas, and fire them over mercury in a detonating tube; and the gas, after the detonation, will be found to have decreased from 145 to 90 measures.

*Rationale.* In this experiment carbonic acid is produced, which constitutes the 90 measures left in the tube.

*Experiment 3.* When a stream of this gas is burnt, in the same manner as *hydrogen* is (to shew the formation of water) no WATER will be formed.

*Remark.* This experiment shows that the gaseous oxyd contains no hydrogen, which is always essential in the constitution of water.

*Experiment 4.* If a mouse, or other small animal, be immersed in a jar of this gas, it will destroy it in a short time.

*Remark.* This gas is, therefore, deleterious to animal life. When respired for a few minutes it produces giddiness and fainting.

*Experiment 5.* Let a mixture of *gaseous oxyd* and *hydrogen gas*, in equal quantity, be made to pass through an *ignited tube*, the tube will become lined with charcoal.

*Rationale.* At a high temperature, hydrogen decomposes the gaseous oxyd of carbon; it combines with the oxygen and forms water, at the same time charcoal is deposited.

*Experiment 6.* If a vial be filled with a mixture of two measures of *carbonic oxyd gas*, and two and two-third measures of oxymuriatic acid gas, then closed with a ground stopper, and allowed to remain for 24 hours with its mouth inverted under mercury, on drawing the stopper under water, two-thirds of the gas are immediately absorbed, and all the rest by agitation in lime water (except  $\frac{1}{6}$ th of a measure of azote.\*)

*Rationale.* In this experiment the gases act upon each other at the common temperature of the atmosphere; that oxymuriatic acid gas gradually parts with

\* Nicholson's Journal, 1802, v. p. 205.

a portion of its oxygen to the carbonic oxyd, which is therefore converted into carbonic acid. And if proper mixtures be employed, the whole will be converted into carbonic acid and muriatic acid.

*Remark.* The substance known by the name of *carbonic oxyd*, or *gaseous oxyd of carbon*, was confounded with carburetted hydrogen, till the celebrated Dr. Priestley drew the attention of philosophers in a dissertation which he published in defence of the doctrine of phlogiston. Our countryman, Dr. James Woodhouse, professor of chemistry in the university of Pennsylvania, repeated his experiments, and confirmed his theories. Other experiments were made on the American continent. But the true nature of this gas was pointed out by Mr. Cruikshank, of Woolwich, Great Britain. In France also a number of experiments were made at the instance of the National Institute. See *Nicholson's Journal*, vol. v. p. 201. *Ann. de Chim.* xxxix. 88, and xlii. 121. See also the observations of the Dutch Chemists, *Ann. de Chim.* xliii. 113.

Carbonic acid is composed of about

69 Carbonic oxyd  
31 oxygen.

---

100

But 100 carbonic acid are composed of 28 carbon and 72 oxygen. Consequently,

Carb. ox. carb. ox. oxygen.

$28 + 72 = 69 + 31.$

Carb. ox. carb. ox.

$28 + 41 = 69$ ; or 69 parts of gaseous oxyd of carbon contains 28 parts of carbon, and 41 of oxygen. Hence it is composed of

41 carbon.

59 oxygen.

---

100. Therefore 146 parts of oxygen, are sufficient to form 100 parts of carbon into 246 of carbonic oxyd gas.

Carbonic oxyd is lighter than common air, in the proportion of 966 to 1000. One hundred cubical inches weigh 30 grains.

Berthollet is of opinion, that there are two different species of inflammable gases containing carbon. The first species is composed of carbon and hydrogen; the second, of carbon, hydrogen, and oxygen. The first he calls carburetted hydrogen, the second *oxycarburetted hydrogen*. Under the latter term he includes the gas obtained by exposing charcoal to a strong heat, the gas obtained by distilling sugar, carbonic oxyd gas, &c.

## SECTION IV.

### OF HYDROGEN GAS.

*Experiment 1.* If a bottle, or jar, be filled with *hydrogen gas* and exposed to the air with its mouth upwards, it will be found, that on letting down a lighted candle, the gas will have escaped, for the candle will burn with its usual splendour.

*Experiment 2.* If a tube twelve inches long and  $\frac{1}{4}$ th of an inch diameter be filled with *hydrogen gas*, it will be five minutes in losing one half of its gas.\*

*Experiment 3.* Fill another bottle, or jar, with the gas, and let it remain with its mouth downwards, and in this situation let a lighted taper be immersed: it will be immediately extinguished.

*Rationale.* As hydrogen gas is lighter than common air, as its specific gravity, according to Kirwan, is 0.0843, that of air being reckoned 1.000, it follows, that on letting the jar remain with its mouth upwards, the gas will be displaced by atmospheric air. In the second place we are furnished with a proof of this fact, for on immersing a lighted taper it is extinguished.

\* Nicholson's Journal, vol. viii. 148.

*Remark.* It is on account of the levity of this gas that it has been used in the construction of *aeronautic vessels*, or balloons, for ascending in the atmosphere. Although hydrogen gas, as we shall see hereafter, is inflammable, yet it is so only in contact with a supporter of combustion; hence it extinguishes flame; it being of itself a non-supporter.

*Experiment 4.* If a *mouse* be introduced into a vessel of gas, it will die in a few minutes.

*Remark.* Hence, hydrogen gas is deleterious to animal life. A mouse put into a jar of this gas by Dr. Gilby, of Birmingham, lived 30 seconds without inconvenience; but in 1 minute and 33 seconds it was dead. Scheele, of Sweden, Fontana, Pilate de Rozier, Mr. Watt, and more lately professor Davy, have inhaled it, but with disagreeable consequences.

*Experiment 5.* Fill a bladder with *hydrogen gas*, having a stop cock attached to it, and adapt the bowl of a tobacco pipe to the end of it; prepare a lather of soap, and form bubbles with the gas; these instead of descending will ascend. If a lighted taper be applied to these bubbles, they will take fire and burn with noise.

*Experiment 6.* If a mixture of *atmospheric air* and *hydrogen gas* be used instead of the latter, and the same experiment with the soap be made, it will, on presenting the taper, take fire and explode.

The theory of these phenomena will be given directly.

*Experiment 7.* Into a jar of the gas introduce a lighted taper, it will be extinguished.

*Rationale.* It is a fact, that two combustible bodies presented to each other without the presence of a supporter of combustion, will, if the one be on fire, extinguish the other: hence the lighted taper is extinguished. Hydrogen gas is, therefore, unfit for a supporter of combustion. The same effect may be shewn in the following manner:

*Experiment 8.* Pass up into a tube over mercury, a portion of *hydrogen gas*, and then introduce a piece of phosphorus and tinder; if the phosphorus be melted,

which may be accomplished by means of a heated wire, it will not take fire.

*Experiment 9.* Let a jar containing a given quantity of *hydrogen gas* stand over water ; no sensible diminution will take place.

*Remark.* This experiment shews, that no hydrogen gas is absorbed by the water. If water, however, be deprived of all its air by boiling, 100 cubic inches of it will imbibe 1.53 inches of the gas, at the temperature of  $60^{\circ}$ . By artificial pressure water may be made to absorb about the third part of its bulk of that gas. The taste of the water is not sensibly altered.

Mr. Paul, who first formed this compound, informs us, that it is useful in inflammatory fevers, and in nervous complaints, but it is injurious in dropsy.

*Experiment 10.* In a strong bottle capable of holding about four ounces of water, mix equal parts of *common air*, and *hydrogen gas*. On applying a lighted candle the mixture will burn, not silently as in a former experiment, but with a sudden and loud explosion. If a larger bottle be used, it should be wrapped round with a handkerchief, to prevent the glass from doing any injury, in case the bottle should burst.

*Remark.* In this case the hydrogen unites with the oxygen of the air, and forms water. If oxygen gas itself be used in the place of common air, the effect will be greater.

*Experiment 11.* If a bell glass, furnished with a capillary tube, be filled with *hydrogen gas* ; on immersing the glass into water, the gas will be evolved out of the tube, which, if inflamed, will exhibit a beautiful light, forming the philosophical candle.

*Remark.* If the hydrogen be pure, the flame is of a blue colour ; but if any substance is held in solution, the flame is tinged of different colours according to the substance. The temperature necessary for the inflammation of hydrogen is about  $1000^{\circ}$ . It is on this principle that *artificial fire works* are constructed, which consists of jets, tubes, &c. bent into different directions, and formed into various figures, which are

pierced with holes of different sizes. The *philosophical lamp*, invented by Volta, formed of hydrogen gas and the agency of electricity, which may be lighted an hundred times without the least inconvenience, is a useful application of this principle.\*

*Experiment 12.* Procure a tin apparatus, called an *air pistol*, which is usually in the form of two cones, attached at the base with two apertures, the touch-hole and muzzle; fill it with a mixture of *hydrogen* and *oxygen gases*, about in equal parts, and inflame the hydrogen by holding a taper to the touch-hole, a violent explosion will ensue.

*Remark.* This effect of the combination of hydrogen with oxygen, may be shewn in several ways, in all of which water is formed. When 4 measures of hydrogen gas are mixed with ten measures of common air, the mixture detonates with equal violence; and if the experiment be made in glass tubes, eight measures only will remain after the combustion.

*Experiment 13.* If an electric shock be passed through a mixture of two parts in bulk of *hydrogen gas* and five parts of *atmospheric air*, in a detonating tube, an explosion will ensue, the volume of the gases be diminished, and the water will rise in the tube.

*Remark.* In this case, the hydrogen unites with the oxygen of the atmospheric air, by the electric spark, and forms water; if the gas be pure and the proportions correct, all the oxygen will be dissolved or combined with the hydrogen. In order to ascertain the purity of hydrogen gas, Mr. Berthollet has recommended this mode. Thus, when the bulk of a mixture of four parts of hydrogen gas and ten parts of air is diminished after explosion to eight parts, the hydrogen gas may be considered as pure; if only to nine, it contains some foreign ingredients. On this principle is also founded the *eudiometer* of Volta.

If 300 parts of common air, and 200 of pure hydrogen gas (which are measured by a scale on the tube,) be introduced into the eudiometer, and the electric

\* For an account of this apparatus, see Adams's Lectures.

spark made to pass through them; after explosion they will be found only 305 measures. There will, therefore, have been a diminution of 195 measures, of which one third may be estimated to be oxygen. Therefore, 65 of oxygen have been lost by 300 of air, or 21 and a fraction *per cent*.

The following rule may be adopted, in order to ascertain the purity of air. Add to three measures of air under examination, two measures of pure hydrogen gas, and inflame them by electricity. Observe the diminution when the vessel has cooled; and, by dividing its amount by three, we obtain very nearly the quantity of oxygen gas which has been condensed. That water is formed by the detonation of hydrogen, is evident from the following experiment:

*Experiment 14.* Into a bell-glass introduce oxygen gas, and into a bladder furnished with a stop cock with a pipe at the end bent like an S put hydrogen; let the bell-glass stand over mercury, and introduce the pipe from the bladder, turn the cock and press the gas; on setting fire to it it will burn in the oxygen until it is consumed. Water will be condensed on the sides of the glass; or,

*Experiment 15.* Let the inflamed gas, as it comes from the bladder, come in contact with iron, or in a glass bottle; water will be formed, and condense on the colder body.

*Remark.* Various other modes have been adopted to exhibit the some phenomena. See WATER.

*Remark.* From the experiments of Mr. Biot it appears, that if a proper mixture of hydrogen and oxygen gases be suddenly compressed in a condensing syringe, the gases will quit their aeriform state and form water. In an apparatus constructed for the purpose, an extremely brilliant light was seen to be emitted.\*

The combustion of hydrogen and oxygen gas, is successfully applied for the purpose of exciting an intense degree of heat by the *blow pipe*. The construction of this instrument may be seen in the *Annales de Chimie*, *American Philosophical Transactions*, and the *Philadelphia*

\* Nicholson's Journal, xii. 219.

edition of the *Conversations on Chemistry*, we therefore beg leave to refer the reader to these works.

*Experiment 16.* Into a glass bottle put iron filings and sulphuric acid with five or six parts of water; and fit a cork into the neck, through which a glass tube is passed, having its upper extremity drawn out to a capillary bore. By setting fire to the hydrogen gas, which escapes from this extremity, a continued current or jet of flame is produced, which is allowed to pass into a tube either of glass, earthen-ware, or metal. If the tube be not too large, the flame becomes smaller as it is depressed, when the tube covers the flame to a considerable depth, very clear sounds are produced. But, on the contrary, if the tube be too narrow, the flame will be extinguished, and in proportion as the tube is enlarged, the sound diminishes, so that there is a certain limit at which it totally ceases. The same happens when the tube is too long. The sounds may be raised at pleasure by either using tubes of various figures or dimensions, or made of different substances.\*

*Rationale.* In this experiment a sound like that of the Aeolian harp is produced. That the percussion of glass, by a rapid stream of gas, should produce a sound, is not extraordinary; but the sound here is so peculiar, that no other gas has a similar effect. Perhaps it is owing to a brisk vibratory motion of the glass occasioned by the successive formation and condensation of small drops of water on the sides of the glass tube, and the air rushing in to replace the vacuum formed.

*Experiment 17.* If flowers, or any other figures be drawn on a ribbon or silk with a solution of *nitrate of silver*, and the silk moistened with water, be then exposed to the action of *hydrogen gas*, the silver will be revived, and the figures finally fixed upon the silk will become visible and shine with metallic brilliancy.

*Experiment 18.* By proceeding in the same manner, and using a *solution of gold in nitro muriatic acid*, silks may be permanently gilt at a most insignificant ex-

\* Nicholson's Journal, 8vo. i. 129. and iv. 23.

pense, and will exhibit an appearance the most beautiful that can be conceived.

*Experiment 19.* Immerse a slip of white silk in a solution of *nitro muriate of gold* in distilled water, and dry it in the air. Silk thus prepared will not be altered by *hydrogen gas*; but if another piece of silk be dipped in the solution and exposed, while wet, to the same current of *hydrogen gas*, instant signs of metallic reduction will appear, the colour will change from yellow to green, and a brilliant film of reduced gold will soon glitter on its surface.

*Experiment 20.* If a piece of silk be immersed in a solution of *nitrate of silver*, and dried in a dark place, and then submitted to hydrogen gas, the silver will not be reduced; but, if exposed, while wet, to a stream of the same gas, the surface will quickly be coated with reduced silver; various colours, such as blue, purple, red, orange, and yellow, will accompany the reduction, and the threads of the silk will look like silver wire.

*Experiment 21.* Dissolve some *muriate of tin* in pure water, then dip a piece of white silk in the solution and dry it in the air; if this be now immersed in *hydrogen gas*, no change will be observed; but if it be exposed, while wet, to the same current of gas, the reduction will soon commence, attended with a great variety of beautiful colours, as red, yellow, orange, green, and blue, variously intermixed.

*Rationale.* In all these experiments the metallic oxyds, which are united with the acids in the form of salts, are decomposed by the hydrogen; which unites with the oxygen of the oxyd and forms water. The revivification of metals, in the above, as well as in other experiments, for which we are indebted to Mrs. Fulham, affords a doctrine on which both the phlogistic and antiphlogistic theories have been supported.

*Remark.* According to a modern idea it has been asserted, that hydrogen in these cases unites with the metal itself; that it was the phlogiston of the older chemists; and that in every instance where a metal was oxydized, it was given out; but that in the reduction of a metal, it was absorbed. But these opinions,

however ingenious, are vague and hypothetical ; which, therefore, require some direct experiments to establish the existence of the principle of phlogiston.

*Experiment 22.* If a small tube, or cylinder, be filled with *hydrogen gas*, and a piece of fresh made charcoal be brought in contact with it, the volume of the gas will be diminished.

*Remark.* Charcoal, having the property of absorbing hydrogen gas, is rendered useful for a variety of purposes. Its action as an antiseptic may depend in a great measure on the absorption of hydrogen. Coal thus containing hydrogen, when brought in contact with atmospheric air, forms water by the combination of this gas with oxygen.

This gas, formerly called *inflammable air*, and by some chemists *phlogiston*, and known also to miners by the name of *fire-damp*, was discovered about the beginning of the 18th century. The following are the *primary compounds of hydrogen*.

A. Binary.

- a. With oxygen ; water.
- b. With azote ; ammonia.
- c. With sulphur ; sulphuretted hydrogen.
- d. With phosphorus ; phosphuretted hydrogen.

B. Ternary.

- a. With carbon and oxygen.
  - 1. Oxyds ; hydrocarbonates, vegetable substances.
  - 2. Acids ; vegetable acids.

C. Quaternary.

- With carbon, azote, and oxygen.
  - 1. Animal oxyds.
  - 2. ——— acids.

## SECTION V.

## OF SULPHURETTED HYDROGEN GAS.

*Experiment 1.* If a bottle filled with *sulphuretted hydrogen gas*, be inverted in a basin of water; an absorption will take place, more especially if agitation be used.

*Rationale.* This is a direct combination of sulphuretted hydrogen gas with water; this solution has been called by some *hydrothionic acid*, as it exhibits some of the properties of acids.

*Remark.* According to the experiments of Dr. Henry, 100 cubical inches of water, at the temperature of  $50^{\circ}$ , are capable of absorbing 108 inches of sulphuretted hydrogen. It is the solution of sulphuretted hydrogen in water, that imparts to those waters called mineral, such as Harrowgate, the smell of fetid eggs.

*Experiment 2.* To water, holding *sulphuretted hydrogen gas* in solution, add *infusion of litmus*, or the *infusion of violets*; these reagents will become red.

*Remark.* Hence the solution, in this respect, produces the effect of an acid.

*Experiment 3.* If *water* impregnated with *sulphuretted hydrogen*, be exposed to the air, it will become covered with a pellicle of *sulphur*.

*Rationale.* In this experiment the sulphuretted hydrogen parts with its sulphur, which is deposited, whilst the hydrogen is disengaged partly in a free state. It would appear, however, that oxygen is the decomposing cause; in that case water would be produced.

*Experiment 4.* If to a similar solution of *gas* in *water*, *nitric acid* be added; *sulphur* will instantly be precipitated.

*Rationale.* The oxygen of the acid unites with the hydrogen of the sulphuretted hydrogen, and forms water, while the sulphur is precipitated. Hence nitric acid has been used as a *test* for sulphur in hepatic waters.

*Experiment 5.* Set fire to a portion of the gas as it escapes from the gas holder, and a flame of a bluish red colour will be produced.

*Rationale.* This gas is, therefore, like hydrogen, inflammable, and in this experiment is decomposed by the oxygen of the atmosphere; the products of combustion being water, from the union of oxygen with the hydrogen, and sulphuric and sulphurous acids from that of the oxygen and sulphur.

*Experiment 6.* Mix equal parts of *sulphuretted hydrogen gas* and *oxygen gas* over water, and apply a lighted taper; a smart detonation will take place, and both gases will disappear.

*Rationale.* Part of the oxygen unites to the hydrogen of the sulphuretted hydrogen gas, and forms water, whilst another part of the oxygen unites with the sulphur, and generates sulphurous acid.

*Experiment 7.* When three parts of *sulphuretted hydrogen gas* are mingled with two of *nitric oxyd gas*, or *nitrous gas*, the mixture will burn with a yellowish green flame.

*Rationale.* In this experiment the nitrous gas acts as a supporter of combustion; its oxygen converts the hydrogen into water, a part of the sulphur is deposited, and azotic gas remains in the vessel.

*Experiment 8.* If *carburetted hydrogen gas* be passed through melted *sulphur*; it will be decomposed, and *sulphuretted hydrogen gas* obtained.\*

*Rationale.* In this experiment the charcoal, held in solution in the carburetted hydrogen, is deposited, whilst the hydrogen dissolves the sulphur, forming the sulphuretted hydrogen gas.

*Experiment 9.* If equal parts of sulphuretted hydrogen gas and atmospheric air be introduced into a bell glass, that of sulphuretted hydrogen first, a diminution will ensue, sulphur will be precipitated, and azote left behind.

\* Ann. de Chim. xxi. 55.

*Rationale.* In this case the oxygen of the common air unites with the hydrogen, for which the hydrogen has a greater affinity than for the sulphur, and form water, whilst the sulphur is precipitated and the azote of the atmospheric air remains in the vessel.

*Remark.* On this principle we account for the deposition of sulphur in certain situations; foras soon as atmospheric air comes in contact, it decomposes the sulphuretted hydrogen (for the hydrogen is generally the solvent of the sulphur) and causes the sulphur to be deposited. Hence also, the reason why sulphur is precipitated in the neighbourhood of *hepatic waters*.

*Experiment 10.* Take a tube closed at one end; fill it with *sulphuretted hydrogen gas*, and invert it over a concentrated *solution of potash*; the gas will be absorbed, and the alkali will acquire the colour and odour of sulphuretted hydrogen.

*Rationale.* The gas is absorbed by the alkali, and a peculiar compound is formed. If the alkali is saturated with the gas, it will be converted into a *hydro-sulphuret of potash*. In this state, it forms with the potash, a triple compound; on exposing it to heat, the gas will be evolved.

*Remark.* The alkalies and some of the earths will combine with sulphuretted hydrogen. These compounds are colourless if kept in close vessels, but on exposure to air, they become coloured, which is produced by the absorption of oxygen. The hydrogen unites with the oxygen and forms water, whilst the sulphur is deposited, which darkens the sulphuret.

*Experiment 11.* If *sulphuretted hydrogen* and *sulphurous acid gas*, be mixed together over mercury, they mutually decompose each other, and *sulphur* is deposited: or,

*Experiment 12.* If a watery solution of *sulphuretted hydrogen* be mixed with another of *sulphurous acid gas*, they decompose each other, and *sulphur* is precipitated.

*Rationale.* In these experiments the hydrogen possesses a stronger affinity for oxygen than sulphur; consequently, it takes it from the sulphurous acid, and forms

water, whilst the sulphur of the sulphuretted hydrogen as well as of the sulphurous acid is deposited.

*Experiment 13.* If into a jar containing fresh prepared *sulphuretted hydrogen gas*, standing over mercury, we add by degrees *ammoniacal gas*, dense fumes will appear, the gases will vanish, and a new compound will be formed.

*Rationale.* In this experiment, the gases quit their aeriform state; the sulphuretted hydrogen combines with the ammonia, and forms a saline compound, called *hydroguretted sulphuret of ammonia*.

*Experiment 14.* If *oxygenized muriatic acid gas* be mingled with *sulphuretted hydrogen gas*, over water, at the instant the gases come in contact with each other, their bulk will be diminished, and the vessel become lined with *sulphur*.

*Rationale.* A part of the oxygen of the oxymuriatic acid gas unites with the hydrogen of the sulphuretted hydrogen gas, forming water, whilst another portion of oxygen combines with a part of the sulphur and produces sulphuric acid; at the same time the other portion of the sulphur is precipitated, and muriatic acid gas remains.

*Experiment 15.* If the *electric spark* be passed through *sulphuretted hydrogen gas* in a tube over water, the volume of the gas will be diminished and *sulphur* be precipitated.

*Remark.* It is evident that the electric fluid changes the original compound, so that the hydrogen is diminished, and the sulphur precipitated.

*Experiment 16.* Write on paper with a solution of *acetate of lead*, or a solution of *silver, bismuth, mercury, or tin*, or moisten a slip of paper with either of these solutions, and expose it to the action of *sulphuretted hydrogen gas*, the paper will instantly become blackened.

*Remark.* Writings performed with these solutions are invisible when dry, but become visible when immersed in a bottle filled with this gas. Whether this gas is applied in a state of gas, or in water impregnat-

ed, the effect is the same, as in the following experiment.

*Experiment 17.* To a solution of *acetate of lead*, add water impregnated with *sulphuretted hydrogen*; the lead will be precipitated of a deep brown colour.

*Remark.* Hepatic water precipitates all metallic solutions, excepting those of iron, nickel, cobalt, manganese, titanium, and molybdenum. It is therefore a useful chemical reagent. Sulphuretted hydrogen gas tarnishes silver, mercury, and other polished metals, and instantly blackens white paint.

The putrid smell, arising from house drains, sewers, &c. which has the property of tarnishing silver spoons, is a mixture of this gas with putrid effluvia.

*Rationale.* In the experiments before given, the decomposition of metallic solutions by sulphuretted hydrogen is explained in the following manner: metallic solutions are formed in the first place by the union of oxygen with the metal, forming an oxyd, which is then taken up by the particular acid forming the metallic salt. When any of the metallic solutions before named, are brought under certain circumstances, in contact with sulphuretted hydrogen, the hydrogen abstracts the oxygen from these bodies, and causes them to re-approach the metallic state, whilst the sulphur in its turn unites with the metal thus regenerated, and converts it into a sulphuret.

*Remark.* On this principle some of the *sympathetic inks* are formed, and also the effect on metallic *cosmetics* is accounted for. Ladies, who have been in the habit of using some of these preparations, have become dark tawnies by bathing in waters holding sulphuretted hydrogen gas in solution.

*Experiment 18.* If *sulphuretted hydrogen gas* be passed over ignited *charcoal*, it will be decomposed, and converted into *carburetted hydrogen gas*.

*Rationale.* Here it is evident the sulphur is disengaged, and the charcoal takes its place.

*Remark.* *Sulphuretted hydrogen gas*, called also *stinking sulphurous air*, and *hepatic air* was first investigated

by Scheele. Its specific gravity, according to Kirwan, is 1.106, that of air being 1.000. It is composed of

20.8 sulphur,  
17.6 hydrogen,

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38.4

Hence 100 parts of hydrogen are combined in the gas with 118 parts of sulphur. See *Ann. de Chim.* xxxii. 267. According to Thenard 100 parts contain 29 of hydrogen, and 71 of sulphur.

Sulphuretted hydrogen forms the link by which *colorific acids* are joined to the acids strictly so called. The Germans have, therefore, given it the name of *hydrothionic acid*. As an instrument of chemical analysis it is usually employed in two states. 1. Dissolved in water, in which state it is called liquid sulphuretted hydrogen. 2. Combined with alkalies, by causing a current of sulphuretted hydrogen to pass through an alkaline solution, till the liquid is saturated. The liquid is then heated to expel the excess of gas. In that state it is called an *alkaline hydro-sulphuret*.

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## SECTION VI.

### OF LIGHT CARBURETTED HYDROGEN GAS.

*Experiment 1.* If a bladder be filled with *light carburetted hydrogen gas*, and inflamed in the same manner as directed in the experiments on hydrogen gas, it will burn with a deep blue colour.

*Rationale.* As this gas is a solution of carbon in hydrogen, it follows, that in combustion, the carbon unites with oxygen and forms carbonic acid, and the hydrogen by combining with the same principle, generates water.

*Experiment 2.* If soap bubbles be made with this gas, they will not ascend as those of *hydrogen*, but will fall to the ground.

*Remark.* A jar filled with carburetted hydrogen gas, held inverted for a few minutes, exchanges its contents for common air. The specific gravity of light carburetted hydrogen gas, is said to be greater than that of hydrogen gas, or that of common air: 100 cubic inches weigh from 16 to 21 grains.

*Experiment 3.* If six measures of *light carburetted hydrogen gas*, be exploded over mercury by the electric spark with four measures of oxygen gas, the volume will be augmented to  $12\frac{1}{2}$  measures. On throwing up lime water, the bulk will be diminished; the residue will probably amount to  $10\frac{1}{4}$  on which *nitrous gas* will have no effect. If two measures of the remaining gas be fired with one of *oxygen*, and the volume should be reduced to one; we may conclude, that the whole residuary gas would require about  $5\frac{1}{4}$  measures of *oxygen* to saturate it, and produce 5 measures of *carbonic acid gas*.

*Rationale.* This is an experiment, stated originally by Mr. Cruikshank, in which the decomposition of light carburetted hydrogen gas is effected by means of oxygen gas. A part of the oxygen converts the carbon into carbonic acid, whilst the other part converts the hydrogen into water.

*Experiment 4.* If one measure of *light carburetted hydrogen gas*, be mixed, over water, with two measures of *oxymuriatic acid gas*, and the vessel be suffered to remain inverted for twenty-four hours with its mouth corked; and the cork be afterwards removed under water, the water will rise and occupy about .43 parts of a measure, the diminution being 2.57 measures. On mixing the residuary gas with lime water .09 parts more become absorbed.

*Rationale.* In this experiment a mutual decomposition ensues. In consequence of the oxygen given out by the oxymuriatic acid gas, we have no less than four new compounds. 1. Part of the oxygen unites with the hydrogen and forms water. 2. Part combines with the charcoal and forms carbonic acid. 3. A still less quantity unites with another portion of charcoal,

and produces gaseous oxyd of carbon. The oxymuriatic acid is reduced to the state of common muriatic acid gas.

*Experiment 5.* When a stream of *carburetted hydrogen gas* is burnt under a long funnel-shaped tube open at both ends, *water* will be formed which will condense on the glass.

*Rationale.* This experiment is to shew the formation of water in the combustion of this gas, which arises from the union of the hydrogen with oxygen.

*Experiment 6.* If a stream of the gas be burnt in a vessel of *oxygen gas*, *carbonic acid*, as well as *water*, will be produced.

*Rationale.* In this case the carbon of the gas unites with the oxygen, and forms carbonic acid.

*Experiment 7.* Let the *oxygen gas*, after the combustion, be removed to a vessel of *lime water*; a considerable absorption will ensue.

*Rationale.* In this experiment the carbonic acid, which was formed in the combustion, unites with the lime of the lime water, and forms carbonate of lime.

*Remark.* Carburetted hydrogen, formerly called *heavy inflammable air*, was occasionally collected and experimented on by Dr. Priestley; but it was not known until lately, that there were several varieties of this gas. One hundred cubic inches of the gas, obtained from wetted charcoal according to Mr. Cruikshank, weighed 14.5 grains, and required 66 cubic inches (22.4) grains of oxygen to saturate them. The compound yielded 40 cubic inches, or 19 grains of carbonic acid, and 9 grains of water. Hence this gas consists of nearly 4 of carbon, and 1.3 of hydrogen.

In order to ascertain the quantity of the ingredients, in the carburetted hydrogen gases obtained from different sources; they may be known by firing them in a detonating tube over mercury, with a known quantity of oxygen gas, and observing the nature and quantity of the products, which are carbonic acid and water.

Kind of gas.	Measures of oxygen gas required to saturate 100 measures.	Measures of carbonic acid produced.
Pure hydrogen gas	50 to 54	
Gas from charcoal,	60	35
———— coal	170	100
———— stagnant water	200	100
Olefiant gas	284	179

Now since, for the formation of each measure of carbonic acid gas, in the foregoing experiments, an equal volume of oxygen gas is required, we may learn, by deducting the number in the third column from the corresponding one in the second, what proportion of oxygen has been allotted to the saturation of the hydrogen of each hydro-carburet. Thus, for example, in burning the gas from coal, 100 measures of oxygen have been employed in forming carbonic acid; and the remaining 70 in saturating hydrogen. But 70 measures of oxygen are sufficient to saturate 140 of hydrogen gas and a quantity of hydrogen must therefore be contained in 100 measures of gas from coal; which expanded to its usual elasticity would occupy 140 measures.

## SECTION VII.

### OF HEAVY CARBURETTED HYDROGEN.

*Experiment 1.* Introduce into a glass tube three parts of *fresh prepared heavy carburetted hydrogen gas*, and add to it gradually four parts of *fresh prepared oxygenized muriatic acid gas*. After each addition of the gas shake the mixture; an absorption will take place, caloric will be liberated, and the tube will become filled with white vapours. When the gases have totally disappeared, an oil of a pearl gray colour will be deposited.

*Rationale.* In this experiment the gases are decomposed; the oxygen of the oxymuriatic acid gas unites

with the hydrogen and carbon and forms an oil, of an agreeable and penetrating odour, and of a sweetish taste; which, on exposure to the air, becomes yellow. The oxymuriatic is, of course, converted into common muriatic acid.

*Experiment 2.* If equal parts of *oxygen gas* and *heavy carburetted hydrogen gas*, are introduced into a detonating tube, and the *electric spark* passed through them, a momentary expansion will ensue; the tube will become lined with a fine black soot of *charcoal*; and *light carburetted hydrogen gas* will remain.

*Rationale.* This experiment proves that the heavy carburetted may be converted into the light carburetted hydrogen gas, by the agency of oxygen gas and the electric spark; for the oxygen unites with a part of the hydrogen and forms water, whilst a portion of carbon is deposited, and the remaining hydrogen and carbon, being in proper quantities, constitutes the light carburetted hydrogen gas.

*Remark.* We have already observed, that there are two species of carburetted hydrogen gas, and that these differ in the proportion of their component parts. Dr. Henry calls the carburetted hydrogen gas, a *hydro-carburet*, and Mr. Watt named it *hydro-carbonate*; but the gas we have just noticed differs from that to which Dr. Henry has given the name of hydro-carburet, in containing different proportions of the hydrogen and carbon.

The *olefiant gas*,\* or more properly *super-carburetted hydrogen*, called also, *oily carburetted hydrogen*, which was first examined by a society of Dutch chemists, is composed of

83 carbon  
17 hydrogen.

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100.

Besides possessing the mechanical properties of common air, this gas has a disagreeable odour. It does not

\* From "oil making."

support combustion, nor animal life. Its specific gravity is 0.905, that of air being 1,000. It burns with a dense white flame, and with very great splendour. If it is *fully* decomposed with oxygen gas, by employing one hundred cubic inches with three hundred inches of oxygen, according to Mr. Dalton, there is formed a quantity of carbonic acid equal to 200 inches. The remaining 100 of oxygen, united with the hydrogen and formed water. As the olefiant gas contains more carbon than the other species of carburetted hydrogen, the propriety of the new term will appear obvious. A brief view of the ingenious experiments and observations on this gas, as well as the gas obtained from *moist charcoal, wood, peat, pitcoal, from oil and spirits* (which are carburetted hydrogen gases) by Dr. Wm. Henry, may be seen in Thomson's Chemistry, vol. i. page 48 to 65.

The gas obtained by distilling *pitcoal* he remarks, is a mixture of the light carburetted hydrogen with some carbonic oxyd and olefiant gas; and the gases obtained from oil and wax by distillation contain more or less of the latter. The passing of *ether, camphor, or alkohol*, through red hot tubes, instead of furnishing the light carburetted hydrogen gas alone, affords a portion of olefiant gas.

When applied to the purpose of illumination, the hydrocarburet from coal, from lamp oil, or from wax, produces as much light in an Argand lamp as oil in substance does; this is attributed to the olefiant gas which it contains.

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## SECTION VIII.

### OF ARSENIURETTED HYDROGEN GAS.

*Experiment 1.* If a jar of *arseniuretted hydrogen gas* be exposed with its mouth upwards, the gas will be displaced by the *atmospheric air*.

*Remark.* The specific gravity of this gas, the barometer at 30 inches, is 0.5293, that of air being 1.000 : hence 100 cubic inches of it weigh 16.4.

*Experiment 2.* If an *animal* be immersed in a vessel of this gas, it will die in a few minutes.

*Remark.* This gas is, therefore, deleterious to animal life.

*Experiment 3.* Immerse a *lighted taper* into the gas, perfectly free of *atmospheric air*, it will instantly be extinguished.

*Remark.* This gas is a non supporter of combustion, consequently it extinguishes flame ; that although combustible, yet, like other inflammable gases, it requires a supporter of combustion.

*Experiment 4.* If a lighted taper be applied to the gas, as it comes from the syphon, it burns with a blue flame ; and, if the combustion be effected in a narrow glass vessel, the arsenic is deposited.

*Rationale.* In this experiment, whilst the hydrogen unites with oxygen and forms water, the arsenic combines with another portion of oxygen, and forms arsenious acid, which is deposited.

*Experiment 5.* If two parts of this gas and three of oxygen gas, are brought in contact with a lighted taper, an expansion takes place, and *water* and *arsenious acid* are formed.

*Rationale.* In this, as in the former experiment, the oxygen goes to convert the hydrogen into water, and the arsenic into arsenious acid, commonly called the white oxyd of arsenic.

*Remark.* Equal parts of these gases do not explode so loudly, but give a more vivid flame. Two parts of this gas and one of oxygen leave a small residue. According to the experiments of Stromeyer, it requires for combustion 0.72 parts of its bulk of oxygen gas.

*Experiment 6.* Mix equal parts of this gas with *sulphuretted hydrogen gas*, no action will ensue, but if *oxymuriatic acid gas* be now added, the bulk diminishes, and yellow flakes are deposited.

*Rationale.* In this experiment a part of the oxygen of the oxymuriatic acid gas, unites with the hydrogen and forms water, whilst another part unites with the arsenic, which then combines with a part of the sulphur, forming a sulphuretted oxyd of arsenic, of a yellow colour.

*Remark.* Hence these two gases furnish us with a delicate test for detecting the presence of arsenical hydrogen.

*Experiment 8.* If concentrated *nitric acid* be suddenly agitated with the *gas*, an evolution of red fumes, and an explosion accompanied with flame ensue.

*Rationale.* In this experiment the arsenic quits the hydrogen and decomposes the nitric acid, in consequence of which nitric oxyd is evolved, and the arsenic is partly converted into arsenic acid. If the nitric acid, previously to its being used, be diluted with water, the arsenic, according to Trommsdorf, will be oxydized, and the hydrogen will remain pure.

*Remark.* This gas, called also *arsenical hydrogen gas*, was discovered by Scheele, and afterwards noticed by Proust, and lately experimented upon by Trommsdorf. According to Stromeyer, it is composed of 106 parts arsenic and 2.19 hydrogen. These proportions, however, do not accord with its specific gravity, as stated by Trommsdorf.

Mr. Davy has lately announced the existence of three other gases, which are metallic compounds, or hydrogurets, viz. *telluretted*, *potassuretted*, and *boruttet hydrogen gas*. These are nothing more than hydrogen gas holding in solution the metals called *tellurium*, *potassium*, and *boracium*. All these gases, which are but little known, are said to contain their own bulk of hydrogen gas.

## SECTION IX.

## OF PHOSPHURETTED HYDROGEN GAS.

*Experiment 1.* If a jar of *phosphuretted hydrogen gas* be placed over *water*, at the temperature between  $50^{\circ}$  and  $60^{\circ}$ , according to Raymond, about one fourth of its bulk will be absorbed.

*Rationale.* The water absorbs the gas, and assumes, if the solution be complete, an orange colour. If the temperature of  $212^{\circ}$  is applied, the whole of the gas will be disengaged, and the water remains behind in a state of purity.

*Remark.* Water impregnated with this gas has a bitter and disagreeable taste, and a strong unpleasant odour.

*Experiment 2.* Expose a solution of *phosphuretted hydrogen gas*, in water, to the atmosphere; *oxyd of phosphorus* will be deposited, and the *hydrogen* will escape.

*Rationale.* In this case the decomposition is effected in consequence of the disengagement of hydrogen, and the absorption of oxygen by the phosphorus, which is deposited in the form of an oxyd.

*Experiment 3.* Pass electric shocks through *phosphuretted hydrogen gas*; its volume will be increased and a decomposition take place.

*Rationale.* In this experiment the water, which is contained in the gas is decomposed; its oxygen unites with the phosphorus and forms phosphoric acid, and the hydrogen is evolved.

*Experiment 4.* If the gas, as it passes from the retort, through water, be suffered to come in contact with the *atmosphere*, the bubbles will burst with a slight explosion, and produce flashes of fire in the circumambient air. A circular dense white smoke will rise like a ring, enlarging as it ascends, and forming a sort of *corona* extremely beautiful.

*Experiment 5.* If a wide mouth phial be filled with

the *gas* over mercury, it will take fire when suffered to escape into the air by inclining the phial. This experiment, however, must be made with caution.

*Rationale.* In the combustion of phosphuretted hydrogen gas, a decomposition of this, as well as the oxygen gas of the atmosphere takes place. The phosphorus unites with the oxygen and forms phosphoric acid, which is disengaged in white fumes, and the hydrogen, by combining with another portion of oxygen, produces water. It is to the water which is carried off with the phosphoric acid, in which it is enveloped, that the white appearance of the *corona* is attributed.

*Experiment 6.* If *phosphuretted hydrogen gas* be conveyed into a receiver of *oxygen gas*; at the instant they come in contact, a brilliant flash of fire takes place, accompanied with a report.

*Rationale.* The same thing is applicable to this, as in the former experiment.

*Remark.* Great caution should be taken in making this experiment; for, if more than a bubble or two come in contact with the oxygen at once, a considerable explosion may follow. It may not be improper to add, that it is in consequence of the rapid decomposition of the gases, when brought into contact, that flame ensues; for the caloric of the phosphuretted hydrogen gas, as well as of the oxygen gas, is immediately set at liberty.

*Experiment 7.* To fresh prepared *phosphuretted hydrogen gas*, add oxymuriatic acid gas over mercury; a detonation will take place accompanied with flame and vapour.

*Rationale.* The oxygen of the oxymuriatic acid unites with the phosphorus and the hydrogen, and forms phosphoric acid and water; the oxymuriatic acid being changed into common muriatic acid gas.

*Experiment 8.* If *phosphuret of lime* be dropped into water, and half its weight of *oxygenized muriate of potash* added; and if the vessel be now filled with water, and three or four parts of concentrate *dsulphuric acid* poured through a tube to the bottom, flashes of flame will be produced.

*Rationale.* In this experiment the phosphuret of lime as well as the oxymuriate of potash, are decomposed, together with the water. The phosphuret combines with the oxygen, whilst the hydrogen, the other constituent part of the water, dissolves a portion of the phosphorus, and forms phosphuretted hydrogen gas, which is inflamed under the water by the action of oxymuriatic acid gas disengaged from the oxymuriate of potash by the sulphuric acid. Phosphuretted hydrogen gas, therefore, burns in nascent oxygenized muriatic acid gas under the surface of water.

*Experiment 9.* If *sulphurous acid* and *phosphuretted hydrogen gases*, be mingled together, they mutually decompose each other.

*Rationale.* In this process the hydrogen unites with the oxygen of the sulphurous acid gas, and the sulphur and phosphorus are deposited in flakes of a yellow colour.

*Experiment 10.* If *phosphuretted hydrogen gas* be exposed to the light of the sun in a white glass jar it will be decomposed; but if kept in the dark, or the jar painted black, it will undergo no decomposition.

*Rationale.* In this case the light has the tendency of separating the hydrogen from the phosphorus; the latter will be deposited on the glass; but when the light is shut out no effect of this kind follows.

*Experiment 11.* Make a solution of *muriate of gold*, consisting of one part of the muriate and eighteen parts of water, and wet a silk ribbon with the solution; then expose it over mercury to an atmosphere of phosphuretted hydrogen gas for a few days, and the ribbon will become coloured with gold.

*Rationale.* The hydrogen as well as the phosphorus unites with the oxygen of the oxyd of gold, forming water and phosphoric acid. The oxyd of gold, therefore, which was dissolved in the muriatic acid, being thus deprived of its oxygen, becomes reduced to the metallic state, and attaches itself to the ribbon.

*Remark.* A number of amusing experiments of this nature may be made by using other metallic solutions.

The gas, to which Fourcroy and Vauquelin have given the name of *phosphorized hydrogen*, they obtain-

ed by letting bits of phosphorus remain in contact with hydrogen gas for some hours; but it appears that hydrogen will combine with different proportions of phosphorus. The compound procured by melting phosphorus in hydrogen gas, by means of a burning glass, was discovered in 1783, by Mr. Gengembre, to which the name of *phosphuretted hydrogen* was given. Mr. Kirwan appears to have discovered it in 1784 without the knowledge of Mr. Gengembre's experiments. But various experiments have been made since that period. It may not be improper to remark, that in the preparation of phosphorus itself, as we shall see hereafter, in which phosphoric acid and charcoal are employed, phosphuretted hydrogen gas is extricated; this takes place by the union of hydrogen, probably from the water which the materials might contain, with a portion of the phosphorus.

## SECTION X.

### OF AMMONIACAL GAS.

*Experiment 1.* If a mouse be introduced into a jar of *ammoniacal gas* standing over mercury, it will be instantly destroyed.

*Remark.* This gas is therefore fatal to animal life.

*Experiment 2.* If a lighted candle be let down into a jar of this *gas* it goes out three or four times successively; but at each time the flame is considerably enlarged by the addition of another flame of a pale yellow colour, and at last this flame descends from the top of the vessel to the bottom.\*

*Remark.* This gas is, therefore, a non-supporter of combustion.

*Experiment 3.* If a jar filled with this *gas* be placed with its mouth upwards, it is soon found to exchange its contents for *common air*.

\* Priestley, iii. 391.

*Remark.* It is lighter than atmospheric air. But its specific gravity has been stated differently by different chemists. Mr. Kirwan found it 0.600 that of air being 1.00.

*Experiment 4.* If *hydrogen gas* be introduced into a long tube, and half its quantity of *ammoniacal gas* be added, and to this a like quantity of *muriatic acid gas*; the cloud which is formed will not rise beyond the confines of the *hydrogen gas*.

*Rationale.* After adding the ammoniacal to the hydrogen gas, it is evident that the latter displaces the former; for on adding the muriatic acid gas it falls, and unites with the ammonia (which now is at the bottom) and forms the white fumes, or muriate of ammonia. The cloud thus generated will not rise within the space occupied by the hydrogen gas; consequently, the latter had kept its place below the other without mixing with it.

*Experiment 5.* If a jar of the gas standing over mercury, be transferred to a tub of water, or if a little water be introduced into it; or if ardent spirit be used instead of water, applied in this way, or in a sponge, paper, &c. the gas will be immediately absorbed. If the gas be pure, the whole will combine with the water, or spirit.

*Rationale.* This absorption of ammoniacal gas by water takes place so rapidly, that a mercurial trough is absolutely necessary in collecting it; the water and gas unite and form a fluid, called *liquid ammonia*.

*Remark.* From Mr. Davy's experiments, it appears that 100 grains of water absorb 34 grains of ammoniacal gas, or 190 cubic inches. Therefore a cubic inch takes up 475 cubic inches of the gas. When a piece of ice is brought into contact with this gas, it melts and absorbs the ammonia, while at the same time its temperature is diminished. Cold water absorbs this gas almost instantaneously, and at the same time heat is evolved, and the specific gravity of the water is diminished. If a temperature of  $130^{\circ}$  be applied, the gas quits the water. The combination of ammoniacal gas with water, in the formation of liquid ammonia, is effected in

the large way by distilling a mixture of muriate of ammonia and quicklime with water. Here the ammoniacal gas is given out by the muriate, which is decomposed by the lime, which then unites with the water in distillation, and forms liquid ammonia. If sub-carbonate of potash is employed in the place of the lime, we have a product of ammonia, partly combined with carbonic acid. But this subject will be considered under the head of alkalies.

*Experiment 6.* If a piece of *paper* coloured yellow with *turmeric*, or blue with *cabbage juice*, be exposed to ammoniacal gas, the former will become brown, and the latter of a green colour.

*Remark.* Ammoniacal gas, like its solution in water, will change some vegetable colours of a brown, some of a green, and reproduce the blue colour of reddened litmus paper. This is a characteristic property of the alkalies.

*Experiment 7.* If *ammoniacal gas* and *muriatic acid gas* be mixed together, they will quit their gaseous form, and produce a concrete substance.

*Rationale.* As soon as these gases meet, they unite, that is, the muriatic acid combines with the ammonia, and forms muriate of ammonia, whilst the caloric is set at liberty.

*Experiment 8.* If *carbonic acid* be mingled in the same manner with this gas, a mutual decomposition will ensue, and a solid be produced.

*Rationale.* Here the gases quit their aeriform state, and heat is liberated; carbonate of ammonia being formed.

*Experiment 9.* If two parts of *oxymuriatic acid gas* be added to one part by measure, of *ammoniacal gas*, a brisk detonation is produced, accompanied with yellowish light.

*Rationale.* Ammoniacal gas consists of azote, hydrogen, and caloric; and oxymuriatic acid gas of oxygen, muriatic acid, and caloric. A reciprocal decomposition ensues. The hydrogen of the ammonia unites with the oxygen of the oxymuriatic acid gas and forms water, while

the azote, the other component part of the ammonia, becomes disengaged. The oxymuriatic acid, being thus deprived of its oxygen, is converted into the common muriatic acid gas, which, by uniting with the undecomposed ammonia, forms muriate of ammonia; but if a smaller proportion of ammonia be mixed, no muriate of ammonia will be generated, for the decomposition of all the ammonia will then be complete.

*Remark.* If the solution of ammoniacal gas in water, be brought in contact with oxymuriatic acid gas, a decomposition will also ensue analogous to the last experiment.

*Experiment 10.* If a mixture of *ammoniacal gas* and oxygen gas be passed through a *red hot* porcelain tube, a detonation takes place, *water* is formed, and *azotic gas* emitted.

*Rationale.* Here it is evident that the oxygen abstracts the hydrogen from the azote, and forms water, which, together with azotic gas, is given out.

*Remark.* If the proportion of oxygen gas be considerable, nitric acid is also formed, in consequence of the combination of azote with the superabundant oxygen.

*Experiment 11.* If *oxyd of manganese* be ignited in an earthen tube, and *ammoniacal gas* be made to pass over it, the latter will be decomposed.

*Rationale.* When a red heat is applied to oxyd of manganese, oxygen gas is given out in abundance. Therefore, on presenting ammoniacal gas to it in this state, the hydrogen of the ammonia will unite with a part of the oxygen given out, and form water; whilst the azote combines with another portion of oxygen and produces nitric acid; and, as a portion of ammonia passes undecomposition, the ammonia unites with the nitric acid, and forms nitrate of ammonia.

*Experiment 12.* If about 200 electric shocks be passed through *ammoniacal gas* in a detonating tube, it will increase three times its original bulk, and be decomposed.

*Remark.* If a small quantity of water be admitted, the gas will not, as heretofore, be completely absorbed by this fluid, but a part will remain. On examining the gas, it will be found that the original compound is destroyed, and that the hydrogen and azote are only in mechanical mixture.

*Experiment 13.* The decomposition of *ammonia* may also be easily shown by the galvanic apparatus; for a solution of the gas in water, exposed to the action of the galvanic fluid, will have its component parts separated in the same manner as in the former experiment.

*Experiment 14.* If *ammoniacal gas* be made to pass through a red hot iron tube containing *phosphorus*, it will be decomposed.

*Rationale.* The products in this experiment, according to Fourcroy, are phosphuretted hydrogen gas, and phosphuretted azotic gas. The ammonia is, therefore, decomposed; its hydrogen unites with a part of the phosphorus, forming the phosphuretted hydrogen gas, whilst its azote combines with another portion of the phosphorus, and produces phosphuretted azotic gas.

*Experiment 15.* Pass *ammoniacal gas* through ignited charcoal in a gun barrel heated to redness, and a new product, called *prussic acid*, will come over.

*Rationale.* In this experiment part of the charcoal unites with the ammonia, and produces a compound containing hydrogen, carbon, azote, &c.

*Experiment 16.* If *tin* is moistened with *nitric acid*, and after a minute or two, a little *potash* or *lime* added, *ammoniacal gas* will be evolved.

*Rationale.* The nitric acid and the water which it contains are decomposed in this experiment; the oxygen of each unites with the tin, and reduces it to the state of an oxyd; while at the same time the hydrogen of the water combines with the azote of the acid, and forms ammonia, which is driven off by the stronger affinity of the potash or lime.

*Remark.* Ammonia as a gas, or in a state of purity, called also alkaline gas, has been known but a few years: in combination it has been long known by the name of

*volatile alkali, spirit of sal ammoniac, spirit of urine, spirit of hartshorn, &c.*

One hundred parts of ammoniacal gas are said to contain about 80 parts of azote and 20 of hydrogen. From some late experiments of Mr. Davy, he concluded that ammonia contained a small portion of oxygen in its composition. Since Mr. D. has announced the fact, no less than four new analyses of ammoniacal gas have been made, and these by chemists of the first eminence. Mr. Davy and Dr. Henry both agree in the result of their experiments: they make the composition of ammonia to be 74 measures, by bulk, of hydrogen gas, and 26 of azotic gas, but they do not point out the oxygen. For an account of the experiments on ammoniacal gas with potassium, see a modern publication of Mr. Davy.

## SECTION IX.

### OF SULPHUROUS ACID GAS.

*Experiment 1.* If a jar of *sulphurous acid gas* be exposed with its mouth upwards to the atmosphere, and a lighted taper let down, the taper will be extinguished. If the jar is inverted, it will exchange its contents for common air.

*Remark.* In this case we are furnished with two facts: first, that sulphurous acid gas is heavier than common air; secondly, that it extinguishes flame, and, of course, is a non-supporter of combustion.

*Experiment 2.* Into a jar of *gas*, introduce a mouse; it will die in a few minutes.

*Remark.* This gas is, therefore, fatal to animal life.

*Experiment 3.* Introduce some of the *gas* into a jar, or tube, over mercury, and throw up a portion of water. The gas will be diminished, and the mercury will rise in the vessel; or,

*Experiment 4.* If the *gas*, as it arises from the retort, be allowed to come in contact with cold water, by immersing the beak of the retort in that fluid, a rapid absorption will ensue.

*Remark.* In either case the gas combines rapidly with water. If even ice be present it melts instantaneously. Water saturated, acquires the odour of the gas. When it is exposed to a temperature of about 65 or 70°, the sulphurous acid is evolved in bubbles of air.

*Experiment 5.* To water impregnated with *sulphurous acid gas* put into a retort, apply a gentle heat, and immerse the beak into mercury, in a mercurial trough; *sulphurous acid gas* will come over.

*Rationale.* In this experiment the application of heat decomposes the compound of sulphurous acid and water, and disengages the former in the state of sulphurous acid gas.

*Remark.* Water saturated with this gas carried to the maximum is 1.0513 sp. gr. and forms *liquid sulphurous acid*.

*Experiment 6.* If into water impregnated with *sulphurous acid gas*, infusion of *litmus* be added, the colour will not be reddened, as acids in general do, but, on the contrary, it totally destroys its colour.

*Rationale.* The character of the acids, generally, is to redden litmus, but this acid is an exception to this property: the destruction of the colour, however, is owing to a change of affinities in the rays of light, agreeably to the observations on colours given under the head of light.

*Experiment 7.* If a red rose be confined in a jar of this *gas*, or if it be exposed to the fumes of burning sulphur, its colour will be destroyed, and at length the flower will become quite white.

*Remark.* It is on this account that sulphurous acid gas has been employed in the *bleaching* of a number of substances, as *straw*, for the purpose of bonnets, &c. It is usually obtained for this purpose by burning the common roll sulphur in confined situations, to the air

of which the articles are exposed in a wet state. By the combustion of sulphur, however, we obtain not only sulphurous acid, but also a portion of sulphuric acid; the latter is inconsiderable to the former.

*Experiment 8.* If *sulphurous acid gas* be made to pass into sulphuric acid, cooled by a frigorific mixture, the gas will be absorbed, and the sulphuric acid assume a solid form. If a part of the concrete acid be laid upon a glass plate, it exhibits an effervescence.

*Remark.* This concrete acid (a kind of *glacial sulphuric acid*) is produced by the combination of sulphurous acid gas with sulphuric acid.

*Experiment 9.* To a portion of water saturated with this gas, add a little *oxyd of manganese*; the pungent smell of the water and other characteristics of sulphurous acid will soon disappear.

*Rationale.* In this experiment part of the oxygen of the oxyd unites with the sulphurous acid, and converts it into sulphuric acid.

*Experiment 10.* If to two parts of *sulphurous acid gas*, standing over mercury, one part of *oxygen gas* be added, no union will ensue, if even the mixture be suffered to stand for some months; but if a small quantity of water be added to the mixture, an absorption gradually takes place, the volume of the gases become diminished, and sulphuric acid is formed.

*Remark.* The water here promotes the union; the sulphurous acid gas first unites with it, for which it has a strong affinity, and the oxygen then converts the sulphurous into the sulphuric acid.

*Experiment 11.* Convey *oxygen gas* and *sulphurous acid gas* into an earthen tube heated to redness; they will form *sulphuric acid*.

*Rationale.* In this experiment the oxygen at a high temperature combines with the sulphurous acid, and sulphuric acid is produced.

*Experiment 12.* Add to *sulphurous acid gas* some *hydrogen gas*, and no change will take place; but,

*Experiment 13.* If we transmit a mixture of three parts of *hydrogen gas* and one of *sulphurous acid gas*

through an earthen tube, *sulphuretted hydrogen gas* will be evolved, and *sulphur* deposited at the other extremity of the tube.

*Rationale.* A part of the hydrogen unites with the oxygen of the sulphurous acid and forms water, and sulphur is separated; another part of the hydrogen, by combining with a portion of the sulphur, forms sulphuretted hydrogen, whilst the remaining sulphur is left undisturbed.

*Remark.* In a former experiment, the oxygen converts the whole of the sulphur into sulphuric acid, whereas in the latter hydrogen gas decomposes the sulphurous acid, and forms water, &c.

*Experiment 14.* When *sulphurous acid gas* and *ammoniacal gas* are mingled together, a mutual decomposition will ensue.

*Rationale.* In this experiment a sulphate of ammonia is generated, which is owing to the conversion of the sulphurous into the sulphuric acid by a further union with oxygen, given out somewhere, which combines with the ammonia, and forms sulphate of ammonia.

*Experiment 15.* Ignite a quantity of *charcoal* in a tube, and pass through it *sulphurous acid gas*; a decomposition of the gas will ensue.

*Rationale.* The products in this experiment are carbonic acid, sulphuretted hydrogen, and sulphur. At the temperature of ignition, the charcoal unites with the oxygen of the sulphurous acid, and forms carbonic acid, whilst the sulphur is disengaged. A portion of water in the coal being also decomposed, affords hydrogen, which dissolves a part of the sulphur, and constitutes sulphuretted hydrogen.

*Experiment 16.* If fresh prepared *muriate of tin* be exposed to *sulphurous acid gas*, it will be decomposed.

*Rationale.* The oxygen of the acid unites with the *muriate* forming *oxymuriate of tin*, for which it has a superior affinity, whilst the sulphur is deposited.

*Experiment 17.* If *sulphurous acid gas* be surrounded with a mixture of *snow* and *muriate of lime*, it is changed into a liquid state.

*Remark.* This takes place in consequence of a reduction of temperature; for by using the snow and muriate of lime, caloric is absorbed from the gas, which, therefore, takes the liquid state. The reduction of temperature should always be— $18^{\circ}$ .

*Experiment 18.* Expose unbleached wool, or linen, wet with water, to the action of sulphurous acid gas, it will gradually become white.

*Remark.* Hence also we learn the utility of this gas, (which is usually prepared for the purpose, by the slow combustion of sulphur) in its application to the bleaching of a number of substances, conformably to Experiment 7.

*Experiment 19.* If a piece of linen stained by means of fruits, be wetted and exposed to this gas, the colour will be discharged.

*Remark.* Hence its application to the purpose of removing fruit stains.

Sulphurous acid gas, formerly called *phlogisticated sulphuric acid*, was examined by Stahl, and afterwards by Scheel, Priestley and other philosophers. It is composed, according to Thomson, of 53 sulphur and 47 oxygen in the hundred, or 100 sulphur and 88.6 oxygen.

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## SECTION XII.

### OF NITRIC OXYD GAS.

*Experiment 1.* If an animal be confined in a jar of nitric oxyd, or nitrous gas it will be immediately suffocated.

*Remark.* Hence this gas is deleterious to animal life.

*Experiment 2.* If water be boiled, and after it has become cold, exposed to nitrous gas, a portion of the gas will be absorbed.

*Remark.* It appears, from the experiment of Mr. Davy, that 100 cubic inches of water at the common temperature, and previously freed from air, absorb 11.8 cubic inches of nitrous gas, or nearly one-tenth, as Dr. Priestley had ascertained. Dr. Henry says, that water will absorb only five *per cent.* The solution has no particular taste, and does not redden blue vegetable colours. The gas is expelled again by boiling the water; it separates also when the water is frozen. The solution of nitrous gas in water according to La Grange, is converted by long keeping, into nitrate of ammonia, in consequence of the decomposition of the water.

*Experiment 3.* Nitrous gas, if washed, does not redden litmus paper, when introduced into it through water.

*Remark.* Nitrous gas, as we shall see hereafter, when it comes in contact with the least portion of oxygen gas, or atmospheric air, is partially converted into nitrous acid. If the gas be washed, in order to free it from any portion of acid, the effect on litmus will not ensue.

*Experiment 4.* If 16 measures of *atmospheric air* be passed up into a tube containing  $7\frac{3}{4}$  measures of *nitrous gas*, or about two measures of atmospheric air and one of nitrous gas, the two fluids will unite, red fumes will appear, and the volume of the gases will be diminished, at the same time heat will be evolved.

*Rationale.* The oxygen of the atmospheric air unites with the nitrous gas, and forms nitrous acid, whilst the azote, the constituent of atmospheric air, remains untouched.

*Experiment 5.* If one ounce measure of *oxygen gas* be mingled with two ounce measures of *nitrous gas*, the volume of the gases will almost entirely disappear.

*Rationale.* The same thing happens in this experiment as in the former.

*Remark.* Mr. Dalton\* informs us, that nitrous gas will combine with two different proportions of oxygen gas. Twenty-one measures of oxygen gas uniting with 36 measures of nitrous gas, or with 72 measures.

When 85 measures of nitrous gas, containing 13 per cent. of azotic gas, are added to a mixture of one hundred measures of oxygen and azotic gases, they will be reduced to 39; consequently, if 11 measures of azotic gas contained in 85 measures of nitrous gas, be deducted, we find that the air, under examination, contained 28 per cent. of oxygen gas. Upon this property which nitrous gas possesses of absorbing the oxygen of the atmosphere, Priestley and Fontana founded their *eudiometers*. There are several sources of error, to which the nitrous test is liable, notwithstanding the improvement lately made in its application by M. Humboldt.\* Mr. Dalton has given some useful observations on the use of this test, which may be seen in Henry's Chemistry, 8vo. p. 153. And Mr. Davy has applied the gas, for the same purpose, in solution, as we shall presently describe.

*Experiment 6.* If a piece of *litmus* paper be passed up into a jar containing a mixture of *oxygen* gas and *nitrous* gas, it will be reddened; or,

*Experiment 7.* If a piece of *litmus* paper be pasted in a jar near the bottom, and washed *nitrous* gas thrown up, the colour will not be changed; but if *oxygen* gas be now added, the colour will immediately be converted to a red.

*Remark.* This, as well as the preceding experiment, is designed to shew, that nitrous acid is formed in the admixture of oxygen and nitrous gas, for the original colour of the litmus is changed to red.

*Experiment 8.* Into a jar, over mercury, introduce proper measures of *nitrous* gas and *oxygen* gas, having previously thrown up a solution of *caustic* potash. After standing for some time, remove the solution, and expose it to the atmosphere; afterwards evaporate; crystals of *nitrate* of potash will be formed, or a salt which contains *nitric* acid.

*Experiment 9.* To a portion of the salt of the last experiment, add *sulphuric* acid and apply heat; *nitric* acid will be disengaged.

\* Ann. de Chim. xxviii. p. 123.

*Rationale.* The union of nitrous gas with oxygen takes place in Experiment 8, which is absorbed by the alkali, forming nitrate of potash; this is decomposed in Experiment 9, in which the sulphuric acid unites with the alkali, and the nitric acid is disengaged.

*Experiment 10.* Let *nitrous gas* pass as it is liberated from the materials which afford it, into a bottle containing colourless *nitric acid*. The acid will undergo successive changes of colour, first yellow, then green, next orange coloured, and at last dark olive-coloured and fuming.

*Rationale.* In this experiment the nitrous gas is absorbed, and converts the nitric into nitrous acid. The successive changes in colour depends on the absorption of different quantities of nitrous gas. Dr. Priestley found, that 100 parts of nitric acid of the specific gravity 1.400 absorbed, in two days, 90 parts of nitrous gas. When seven parts of gas have been absorbed, the acid acquires an orange colour; when 18 have been absorbed, it becomes green; and the whole quantity which it is capable of condensing, changes it into a liquor, which emits an immense quantity of red fumes.

*Experiment 11.* If to *nitric acid*, thus impregnated with *nitrous gas*, heat be applied; the colour of the acid will be resumed.

*Rationale.* In this case the heat disengages nitrous gas, and the fuming acid is changed into the colourless.

*Experiment 12.* Inflamm a mixture of one part of *nitrous gas* and four of *hydrogen gas*, the flame will appear of a green colour.

*Remark.* Nitrous gas, therefore, imparts a green colour to the flame of hydrogen gas.

*Experiment 13.* If a jar of *nitrous gas* be prepared, and a burning taper immersed into it; the taper will be extinguished.

*Remark.* Nitrous gas, though considered a supporter of combustion, only however, under certain circumstances, in this instance extinguishes flame. The same thing will happen to ardent spirit, oils, &c. But if it were possible that these substances should have the power of decomposing nitrous gas, conse-

quently the disengagement of its oxygen, combustion would of course take place. This occurs however in certain cases, as in the following :

*Experiment 14.* Introduce some fresh prepared *pyrophorus*, placed in a copper spoon, into a jar of the gas; the *pyrophorus* will instantly take fire, and the volume of the gas be diminished.

*Rationale.* In this experiment the *pyrophorus* takes the oxygen from the nitrous gas, consequently a diminution ensues, and the azote, the other constituent of nitrous gas, is left behind; it will be found at the same time, that the union of a portion of the carbon of the *pyrophorus*, with some of the oxygen forms carbonic acid, for on throwing up lime water a turbidness takes place.

*Experiment 15.* *Phosphorus*, if inflamed, and conveyed into a jar of *nitrous gas*, will burn with considerable splendour; but if it be introduced into the gas and even melted, no combustion will follow.

*Rationale.* The phosphorus in this experiment destroys the former affinities existing between the oxygen, azote and caloric, but in order to effect this decomposition the temperature must be considerably raised. Hence the phosphorus unites with the oxygen and forms phosphoric acid, heat and light are evolved, and the azote remains in the form of gas.

*Experiment 16.* Ignite a piece of *charcoal*, and in that state introduce it into a jar of the *gas*, and vivid inflammation will ensue.

*Rationale.* In this case, as in the one with phosphorus, the charcoal at a high temperature changes the equilibrium of affinities, consequently decomposes the nitrous gas, carbonic acid being formed, whilst the azote remains.

*Experiment 17.* Pass the electric spark through a mixture of *hydrogen* and *nitrous gas*; no decomposition will take place.

*Experiment 18.* But if these gases be made to pass through a red hot porcelain tube, a detonation will ensue, water will be formed, and azotic gas evolved.\*

\* Fourcroy, ii. 91.

*Rationale.* In this experiment, the hydrogen unites to the oxygen of the nitrous gas, and forms water, and azotic gas is disengaged.

*Experiment 19.* Pass electric sparks through nitrous gas, and decomposition will ensue.

*Rationale.* In this experiment, according to Dr. Priestley *nitric acid* and *azotic gas* are produced, which can only take place by the abstraction of a part of the azote, whilst the remaining azote unites with the oxygen forming nitric acid.

*Experiment 20.* Expose a solution of the green *muriate, sulphate* or *nitrate of iron* to *nitrous gas*, an absorption will immediately take place, the solution will assume a brown colour, and any uncombined azotic gas will remain unabsorbed.

*Remark.* This is an experiment to prove that nitrous gas is absorbed by the *muriate, sulphate, and nitrate of iron*.

*Rationale.* In this experiment the nitric oxyd is absorbed by the solution of iron; which takes place, according to Davy, in the following manner:

1. That it depends merely on an equilibrium of affinities produced by simple attractions.

2. The affinity of the green oxyd of iron for the oxygen of nitrous gas and water.

3. The affinity of the hydrogen of the water for the azote of the nitrous gas; and,

4. The affinity of the principles of sulphuric acid for nitrogen and hydrogen.

It would appear, however, that this explanation is not altogether consistent with the laws of chemical affinity; for instead of the gas being decomposed, which we consider to be nothing more than a mere solution, it is combined with the water, in consequence only of their respective affinities for each other.

The solution, thus combined with the gas, has the property of absorbing oxygen from the atmosphere, as we shall presently see.

If the green oxyd of iron decomposes nitrous gas and water according to Mr. Davy, the solution will certainly not have the property of absorbing oxygen,

because the green oxyd of iron, according to him, would take the oxygen from the nitrous gas, and of course would decompose it, producing either nitrous oxyd or azote, neither of which can unite with oxygen from the air.

If the hydrogen were to unite with the azote according to his second position, ammonia would be produced; and as to the principles of the sulphuric acid, viz. sulphur and oxygen having an affinity for azote and hydrogen, the supposition would not appear chemical.

*Remark.* Seventy-five cubic inches of a concentrated solution of the muriate of iron absorb about 18 of nitrous gas; sulphate of iron absorbs only one half this quantity. The gas absorbed may be expelled again by heat.

Mr. Davy has proved that all salts containing the black oxyd of iron, possess the same property, and that they all absorb nitrous gas unaltered. This gas is also absorbed by the white prussiate of iron, in contact with water, according to the experiments of Mr. Davy, and also by several other metallic salts, if the metals which form them are at the minimum of oxydization; the solution of nitrous gas in the green sulphate of iron has been extensively used in eudiometry to determine the quantity of oxygen gas in the atmosphere. The most commodious method of applying this solution is by means of Dr. Hope's eudiometer. This solution, in which nitrous gas has the same property as in an unmixed state, removes every objection to the gas as a test for oxygen.

*Experiment 21.* Nitrous gas left in contact with iron, is gradually decomposed, and changed into nitrous oxyd. See Experiment 23.

*Rationale.* Here the iron unites with a part of the oxygen, and consequently reduces it to a state of nitrous oxyd, or gaseous oxyd of azote.

*Remark.* Dr. Priestley announced this fact, and in this manner he discovered nitrous oxyd.

*Experiment 22.* If alkaline sulphites, hydroguretted sulphurets, muriate of tin, sulphuretted hydrogen gas, or

iron or zinc filings be put into a jar of nitrous gas, and suffered to remain for a week or more the gas will be decomposed.

*Rationale.* In this experiment a portion of oxygen is abstracted by these substances, which are converted into oxyds or salts, and the gas is consequently changed, forming nitrous oxyd. In some cases water, ammonia, as well as nitrous oxyd, are generated. The water is formed by the union of oxygen and hydrogen; and the ammonia by the combination of azote and hydrogen.

*Experiment 23.* When *nitrous gas* is exposed to *wetted* iron filings, a diminution of its volume takes place; the iron becomes oxydized, and *ammonia* is formed, together with *nitrous oxyd*.

*Rationale.* This is an experiment, in which nitrous gas is decomposed by nascent hydrogen gas. The water is decomposed; its oxygen unites with the metal, while its hydrogen combines with a part of the azote of the nitrous gas, and forms ammonia, the nitric oxyd being reduced to the nitrous oxyd. Another portion of the hydrogen unites with the excess of oxygen of the nitrous gas, and forms water.

*Experiment 24.* When powdered *tin* is moistened with strong *nitric acid*, and, when the red fumes have ceased to arise, if some *quicklime* or solution of pure potash be added, *nitric acid* is decomposed, and *ammonia* is generated.

*Rationale.* In this experiment the tin unites with the oxygen of the nitric acid as well as of the water, and the hydrogen and azote are set at liberty. Before they have assumed the gaseous state, these two bases combine and form ammonia. The ammonia thus generated unites with a portion of undecomposed nitric acid, and is disengaged from this combination by lime or potash. See Ammoniacal Gas.

*Experiment 25.* If *oxyd of manganese* be heated to redness in an earthen tube, and ammoniacal gas passed through it, nitrous gas will be formed.

*Rationale.* The hydrogen of the ammonia unites with a part of the oxygen given out from the oxyd,

and forms water, whilst the azote from the same source combines with another portion of oxygen, and constitutes nitrous gas. See Ammoniacal Gas.

*Remark.* Nitrous gas, called also nitric oxyd, was obtained accidentally by Hales, but its properties were investigated by Dr. Priestley, at an early period of his philosophical researches. Mr. Lavoisier, the father of antiphlogistic chemistry, and afterwards professor Davy, the learned chemist of the Royal Institution, have made a number of experiments on this gas, in order to determine the proportion of its constituent parts. According to Davy's experiments nitrous gas is composed of 100 parts of azote and 136 parts of oxygen ; or,

Azote	Oxygen	Nitrous oxyd.		Oxygen	Nitrous gas.*
1.00	+ 0.58	= 1.58		1.58	+ 0.78 = 2.36

or, it is composed of 57 oxygen, and 43 azote.

Gay-Lussac has instituted some experiments on nitrous gas, in which it appears that it is composed of equal bulks of oxygen and azotic gas united together, and its specific gravity is exactly the mean.

## SECTION XIII.

### OF AZOTIC GAS.

*Experiment 1.* If into a long narrow tube, divided into cubic inches, and these again in to hundredth parts, we throw up, over water, one cubic inch of *azotic gas*, no absorption will ensue.

*Remark.* Although water absorbs no sensible quantity of azotic gas, as is proved by this experiment, yet if it be first boiled, in order to free it of all the air which it might contain, and then employed, it will

\* Thomson.

be found that 100 inches of it are capable of absorbing, according to Dr. Henry, only 1.47 inches of the gas at the temperature of  $60^{\circ}$ .

*Experiment 2.* Pass a slip of *litmus paper* into a jar of the gas, it will come out unaltered.

*Remark.* Hence this gas shows no signs of acidity.

*Experiment 3.* A mouse put into a vessel of the gas, is instantly killed.

*Remark.* Hence it is fatal to animal life; hence also the origin of its name, *azote*, which signifies, "destructive to life."

*Experiment 4.* If a lighted taper be plunged into the gas, the flame will be extinguished.

*Remark.* It is on account of this gas that a candle is extinguished in atmospherical air, as soon as the oxygen is consumed. But,

*Experiment 5.* If a mixture of four parts of *azotic gas* and one part of *oxygen gas* be made, and a taper immersed in, it will burn as in atmospheric air.

*Remark.* This mixture resembles atmospheric air, which is composed of the same gases about in this proportion.

Though we are not capable of imitating exactly the air of the atmosphere, yet we may approach very near it, from our knowledge of the nature and quantity of the gases which compose it, in our imitation, we have only *mechanical mixture*.

*Experiment 6.* Into a jar of *azotic gas* introduce phosphorus in the state of inflammation; it will immediately be extinguished.

*Remark.* This also proves, that azote is a non-supporter of combustion.

*Experiment 7.* If 13 parts of *azotic gas* and 87 of *oxygen gas*, be passed up into a tube over mercury, and electric sparks transmitted through them by means of conductors, the volume gradually diminishes, and *nitric acid* is generated.

*Experiment 8.* Proceed in the same manner as in Experiment 7, but throw up some *tincture of litmus*; the litmus will be changed to red.

*Rationale.* Azote, therefore, is capable of combus-

tion with oxygen at high temperatures; the bases of these gases unite and form nitric acid.

*Remark.* Dr. Priestley originally made this experiment; from which Mr. Cavendish made the important conclusion, that nitric acid was composed of oxygen and azote. This discovery was announced to the Royal Society on the 2d of June, 1785. It is supposed, that at certain periods, the electric fluid of the atmosphere combines azote with oxygen, forming nitric acid, which has been detected in rain water, and also in snow.

Azote, called also *nitrogen*, from its being a component of nitric acid, and *septon* by professor Mitchell of New York, was discovered in 1772, by Rutherford of Edinburgh; and Scheele procured it from the atmosphere as early as 1776.

Azote is a simple substance. Dr. Priestley supposed it to be composed of *dephlogisticated air* (oxygen gas) and *phlogiston*; hence he gave it the name of *phlogisticated air*. The specific gravity of azote is to common air as .985 to 1.000. It has been found in the mineral waters of Bath and Buxton, Great Britain.

Dr. Austin succeeded in combining azote with hydrogen, and formed ammonia; for an account of the experiment, see Thomson, i. 111.

According to Troussset, the gas emitted by the skin is pure azote.

The following are the primary compounds of azote.

#### A. Binary.

##### a. a. With oxygen.

1. Atmospheric air.
2. Nitrous oxyd.
3. Nitric oxyd.
4. Nitric acid.

##### b. b. With hydrogen.

1. Ammonia (nitroguet of hydrogen.)

##### c. c. With sulphur.

1. Sulphuretted azotic gas.

##### d. d. With phosphorus.

1. Phosphuretted azotic gas.

B. Quaternary, with hydrogen, carbon, and oxygen.

*a. a.* Oxyds. Animal substances.

*b. b.* Acids. Animal acids.

## SECTION XIV.

### OF NITROUS OXYD GAS.

*Experiment 1.* If a glass cylinder or tube be filled with *nitrous oxyd* inverted in a basin of water, that has been previously boiled; on agitating it a considerable diminution of volume will ensue.

*Remark.* This diminution, of course, is an absorption of the gas. Water absorbs 0.86 parts of its bulk of this gas, or according to Dalton nearly its own bulk. It acquires a sweetish taste; but its other properties do not differ perceptibly from common water. According to Mr. Davy\* when this gas combines with water, it expels the common air which was dissolved in the water. Hence when this gaseous oxyd is exposed to a sufficient quantity of water, a residuum always appears; this is atmospheric air. The quantity of common air thus produced, generally amounts to  $\frac{1}{16}$ th part of the volume of water.†

The absorption of nitrous oxyd and the evolution of common air by water, is in consequence of the superior affinity of water for nitrous oxyd.

*Experiment 2.* If water impregnated with the *gas* be introduced into a retort, and exposed to the temperature of  $212^{\circ}$ , the whole of the *gas* will be liberated.

*Rationale.* In this case it is apparent, that caloric destroys the affinity subsisting between water and nitrous oxyd; the latter is therefore expelled.

\* Davy's Researches, p. 89.      † Accum.

*Experiment 3.* Introduce a lighted taper into a jar of *nitrous oxyd*; the flame will become larger, and throw out sparks. The lustre, however, as the combustion goes on, will diminish, the flame gradually lengthen, and become surrounded with a pale blue cone of light until the process ceases.

*Rationale.* In this experiment the gas is gradually decomposed; its oxygen goes to maintain the combustion, and heat and light are set at liberty. In order that bodies should burn in *nitrous oxyd*, it is necessary that they should be in the state of inflammation, as appears from the following experiment:

*Experiment 4.* Fill a jar over mercury with the gas and keep it over that fluid; introduce into it a small piece of *sulphur*, *camphor*, or *phosphorus*, and touch these substances with a bent wire heated to a *dull redness*. The sulphur, camphor, or phosphorus, will melt, and by continuing the heat it may even be made to sublime in the gas, but no accension will take place.

*Experiment 5.* When *phosphorus* is exposed in a jar of the gas, and in this situation touched with a wire heated to *whiteness*, it will detonate with prodigious violence.

*Rationale.* In order to overcome the affinity of oxygen for azote, to effect the combustion of a substance, it is necessary that a high temperature should be applied; hence in this experiment the decomposition takes place with considerable violence when a *white heat* is used. The products of the combustion are azotic gas, phosphoric acid, and nitric acid; a part of the oxyd remains undecomposed.

*Experiment 6.* Introduce into a jar of the gas some *phosphorus* in the state of inflammation; combustion will go on as rapidly as in oxygen gas; or,

*Experiment 7.* Let the jar containing the gas be placed over mercury; introduce the phosphorus in a small tube containing oxygen gas, so ballanced as to swim on the surface of the mercury without communicating with the oxyd. Then fire the phosphorus in the *oxygen gas* by an ignited iron wire; by which, at the moment of combustion, the tube containing it

must be raised in the *gaseous oxyd*, and thus the combustion continues.\*

*Rationale.* In this experiment, as well as in Experiment 6, the phosphorus decomposes the nitrous oxyd; a part of its oxygen uniting with it forms phosphoric acid.

*Experiment 8.* Sulphur put into a copper ladle and inflamed, and then introduced into the *gas*, will be extinguished; but,

*Experiment 9.* If it be introduced in the state of actual combustion, and not when the flame is of a feeble blue colour, it will continue burning with a beautiful flame very much enlarged and of a rose colour. Or, this experiment may be made in the same manner as Experiment 7.

*Rationale.* When sulphur is introduced into nitrous oxyd, when its flame exhibits a *blue* colour, the temperature is not sufficient to destroy the union of oxygen and azote; consequently the flame is extinguished; but if it be introduced when in an actual state of combustion, or when it exhibits a *white* flame, it continues to burn for some time in the manner stated in the experiment. When half the quantity of the gas is decomposed, the sulphur is extinguished. The products are sulphuric acid and azote, arising from the decomposition of the gas, and the union of phosphorus with oxygen.

*Experiment 10.* If *red hot charcoal* be introduced into the gas it burns with more brilliancy than in the atmosphere.

*Rationale.* In this experiment charcoal decomposes the gas; it unites with its oxygen and forms carbonic acid, while its azote is set at liberty. The same result happens in the following experiment.

*Experiment 11.* Introduce a piece of *charcoal* into the gas, and set it on fire by means of a burning lens posed to the sun's rays; combustion will ensue, as in Experiment 10.

\* Accum.

*Experiment 12.* Introduce *iron wire* into the gas in the same manner as in *oxygen gas*, (which see) it will burn with the same brilliancy as in oxygen gas.

*Rationale.* Part of the nitrous oxyd is decomposed; its oxygen oxydises the iron, which is converted into the black oxyd, while its azote is disengaged.

*Experiment 13.* Make a ball of *zinc shavings*, put into it a piece of *phosphorus*, and attach it to a copper wire; set fire to the phosphorus, and immediately introduce it into a jar of the gas, and the zinc will burn with a white flame surrounded by a green one.

*Rationale.* During the combustion, which is a decomposition of the gas, the zinc is converted into an oxyd, and appears in the form of dense white vapours. The zinc thus unites with the oxygen, and azote is set free.

*Experiment 14.* If *pyrophorus* be introduced into the gas, accension will immediately follow, provided the temperature be raised to about  $500^{\circ}$ , which may be effected by touching it with a wire sufficiently heated.

*Remark.* During this combustion, the oxygen is separated and azote disengaged; only a part of the gas, however, is decomposed.

*Experiment 15.* When *nitrous oxyd* is made to pass through a red-hot porcelain tube, it is decomposed, and, according to Priestley, is converted into *nitric acid* and *common air*; or,

*Experiment 16.* If electric sparks are made to traverse this gas, the same result ensues.

*Remark.* The proportions of azote and oxygen are, therefore, differently arranged; for the original gas, though composed of the same principles, is changed.

*Experiment 17.* If 35 parts of *nitrous oxyd* and 15 of *carburetted hydrogen* be passed up into a detonating tube, and elective shocks transmitted, an explosion will ensue, and the space occupied by the gases will be about 60.

*Rationale.* The gases are mutually decomposed; carbonic acid, some water, &c. are formed. The products differ according to the proportions of the gases mixed.

*Experiment 18.* If ten grain measures of *phosphuretted hydrogen gas*, and 52 of *nitrous oxyd* are detonated by the electric spark, the volume of the gas left behind will fill a space nearly equal to 60. On agitating this fluid with water, no absorption will take place. On admitting nitrous gas a diminution ensues.\*

*Rationale.* In using a small quantity of phosphuretted hydrogen, both the phosphorus and hydrogen are consumed; whilst the superabundant gaseous oxyd is converted into nitrous acid and atmospheric air by the ignition; or a certain quantity is partially converted into atmospheric air by the combination of a portion of its oxygen with the combustible gas. The following experiment given by Accum, in relation to the preceding, will further illucidate the point.

*Experiment 19.* Twenty-five parts of *nitrous oxyd* mingled with 10 of *phosphuretted hydrogen*, after inflammation by the electric spark, occupy a space equal to 25.

*Rationale.* We conclude, therefore, that when phosphuretted hydrogen and gaseous oxyd are to each other as 25 to 10, they both disappear: in this case the phosphorus unites with a part of the oxygen and forms phosphoric acid; the hydrogen with the other part, forming water, whilst the azote is set at liberty.

*Experiment 20.* Make a mixture of about equal parts of *nitrous oxyd* and *hydrogen gas*, and detonate the mixture in a tube by the electric spark; water and azote will be formed; or,

*Experiment 21.* Make a similar mixture and apply a lighted taper; an explosion will ensue, and the same products be formed.

*Rationale.* In this experiment the hydrogen unites with all of the oxygen of the nitrous oxyd, and forms water, whilst the azote is disengaged.

*Experiment 22.* Prepare another mixture of *hydrogen gas* and *nitrous oxyd*, in which the proportion of hydrogen is smaller, and detonate them by the electric spark. The product contains also *nitric acid*.

*Remark.* The formation of nitric acid is the consequence of a smaller quantity of hydrogen being present; therefore, oxygen and azote unite in proper proportions, and constitute it. If a larger quantity of hydrogen is used, the products would be in that case only water and azote.

*Experiment 23.* Introduce *nitrous oxyd* properly prepared, into an oiled silk bag or bladder, furnished with a stop cock, and receive it into the lungs; a singular sensation will be produced in the system.

*Remark.* The *apparent* action of this gas on the body, is one of its most extraordinary properties. Animals when wholly confined in this gas die speedily; but when it is received into the lungs it does not prove fatal, because, when received into the lungs, it is mixed and diluted with atmospherical air present in that organ. The gas may be breathed repeatedly from the bag and back again, as long as it will last. "The sensations that are produced, vary greatly in persons of different constitutions; but, in general, they are highly pleasurable, and resemble those attendant on the pleasant period of intoxication. Great exhilaration, an irresistible propensity to laughter, a rapid flow of vivid ideas, and an unusual fitness for muscular exertion, are the ordinary feelings it produces. These pleasant sensations it must be added, are not succeeded, like those accompanying the grosser elevation from fermented liquors, by any subsequent depression of nervous energy." For the effect of this gas on Mr. Davy, see his *Researches*.\* Nitrous oxyd, formerly dephlogisticated nitrous air, was discovered by Dr. Priestley in 1776. In 1793, the associated Dutch chemists examined it and demonstrated it to be a compound of azote and oxygen. It has also been examined by Davy, who published an excellent dissertation on it in the year 1800. Nitrous oxyd is susceptible of combination with alkalies, in certain processes, and forms a class of salts, called *azotites*, which will be considered hereafter.

\* See also Woodhouse's edition of Chaptal's Chemistry, and Dr. Barton's Inaugural Dissertation.

Nitrous oxyd, or gaseous oxyd of azote, is composed of seven parts by weight of oxygen, and 12 of azote, or nearly 63 of azote, and 37 of oxygen in the hundred. Its specific gravity, according to Davy, is 1.603, that of air being 1.000. It is to common air nearly as 5 to 3. Dr. Thomson classes this gas among the oxyd supporters.

## SECTION XV.

### OF MURIATIC ACID GAS.

*Experiment 1.* If a jar, filled with *muriatic acid gas* over mercury, be raised from the mercurial trough, it will discharge its contents for common air.

*Remark.* The specific gravity of this gas, according to the experiments of Mr. Kirwan, is 1.929, that of air being 1.000, at the temperature of 60° barometer 30 inches: 100 cubic inches of it weighs 59.8 grains.

*Experiment 2.* If a mouse be immersed in a jar of the *gas*, convulsions will ensue, and immediate death will be the consequence.

*Experiment 3.* If a lighted taper be plunged into the *gas*, the flame will be extinguished.

*Remark.* Dr. Priestley, however, observes, that *muriatic acid gas*, has a considerable effect upon the flame of burning bodies; for a burning taper before it goes out, assumes a green colour, and the same tinge appears the next time the taper is lighted. A white vapour surrounds the extinguished wick, which is attributed to the combination of water, produced by the combustion of the candle.

*Experiment 4.* Pass up into the jar of the *gas*, the *infusion of litmus*, or *infusion of red cabbage*; on its coming in contact, the colour will be changed to red.

*Rationale.* *Muriatic acid gas* when in contact with water, of which the infusion is made, is absorbed. It

acts therefore, as an acid, and changes the colour of the infusion to red.

*Experiment 5.* Into a jar of the gas introduce a small quantity of water; an absorption will immediately ensue, and, if the saturation be complete, it will exhibit all the properties of muriatic acid; or,

*Experiment 6.* Let the beak of the retort, from which the gas is obtained, pass into water, no bubbles of air will arise, but on the contrary, the gas will be absorbed, and the water will probably go over into the retort; or,

*Experiment 7.* Let the gas pass into a receiver moistened with water; an absorption will ensue, which will be known by the properties of the water being altered.

*Rationale.* The union of muriatic acid gas with water takes place in consequence of a strong affinity; the result of this combination is muriatic acid. The preparation of muriatic acid is effected by the decomposition of muriate of soda by sulphuric acid, in contact with water. In this case at the moment the gas is disengaged, it unites with the water. According to Mr. Kirwan an ounce measure troy of water absorbs 800 cubical inches (or 420 times its bulk) of muriatic acid gas; and the water by this absorption, is increased about one third its original volume. Dr. Thomson says, that a cubic inch of water at the temperature of 60 degrees, absorbs 515 inches of the gas, which is equivalent to 308 grains nearly. See Muriatic Acid.

*Experiment 8.* If a tube coming from the retort pass into a three necked bottle, of a Woulfe's Apparatus, in which water and a thermometer had been put, and the gas be disengaged from the materials, a considerable increase of temperature will ensue, which will be shown by the rise of the mercury.

*Rationale.* This is owing to a condensation of the gas, in consequence of its absorption; for a portion of caloric necessary in the formation of the gas, is given out in a free state, which is appreciable by the thermometer.

*Experiment 9.* If water thus impregnated be exposed to heat, the gas will be expelled.

*Rationale.* In this experiment, the application of heat overcomes the affinity subsisting between the constituent parts of the liquid acid; consequently, muriatic acid gas is expelled, and if the heat be not too powerful, the water will remain behind.

*Experiment 10.* If a current of the gas be passed into a vessel filled with ice, broken into small pieces, an immediate liquefaction will take place.

*Rationale.* This phenomena is attributable to the rapid absorption of the gas, in its reduction to the liquid state, and the consequent disengagement of caloric, which of course liquefies the ice.

*Experiment 11.* Into a wide mouthed bottle introduce half its capacity of the gas; remove it from the mercury, so that atmospheric air may be admitted; dense white vapours, accompanied with a considerable degree of heat, will be produced.

*Rationale.* The muriatic acid gas unites with the moisture in the air, and is more or less changed into muriatic acid; hence the evolution of uncombined caloric. According as the atmosphere is more moist, or saturated with water, the phenomena is more striking.

*Experiment 12.* Into a jar standing over mercury and containing half its bulk of muriatic acid gas, put an equal quantity of ammoniacal gas; an absorption will ensue, heat be evolved, and white fumes will be formed, which in the course of a short time, will condense on the sides of the vessel; or,

*Experiment 13.* Into a cup put a mixture of muriate of ammonia and quicklime, and add a sufficient quantity of water to slack the lime; now introduce the cup with its contents under a jar containing ammoniacal gas, and the same appearance will ensue; or,

*Experiment 14.* Into one of two cups put muriate of soda with half its weight of sulphuric acid; in the other muriate of ammonia and quicklime as in the last experiment; heat the former, and introduce it under a large glass vessel; and when the quicklime has slacked put it also under the jar, and a considerable cloud will be formed.

*Rationale.* In all these experiments the two gases quit their aeriform state, heat is evolved, and muriate of ammonia produced, which at first appears in the form of clouds. If the experiment be made over mercury, and the gases pure and in proper proportions, the mercury will rise and fill the vessel. In the last experiment, muriatic acid gas is disengaged from the muriate of soda by the sulphuric acid, and ammoniacal gas from the muriate of ammonia by quicklime; consequently, when the gases, thus disengaged, come in contact, the same result takes place.

*Experiment 15.* If *electric sparks* be made to pass through this *gas*, its bulk is diminished, and *hydrogen gas* is evolved.

*Remark.* This effect is attributed to the water contained in the gas. It ceases when it is partly deprived of moisture, as has been proved by Mr. Henry.

Muriatic acid gas, formerly called *marine acid air*, was first examined by Dr. Priestley. It is supposed that the base of this gas is hydrogen and oxygen, as the constitute parts of muriatic acid; but this conclusion is unfounded. Besides its absorption by water, which constitutes the liquid *muriatic acid*, it is absorbable by ardent spirit, ether, fat, and essential oils, melted wax, phosphorus, and many other bodies. According to some recent experiments, it appears that water is an essential constituent of muriatic acid gas; that the gas cannot be formed unless water be present; and that it cannot be deprived of its water without losing its gaseous form. According to Berthollet, 100 parts of muriatic acid gas, after being exposed to the cold produced by a mixture of snow and salt, still retain 56.7 parts by weight of water. From Mr. Davy's experiments we infer, that the water contained in muriatic acid gas amounts to  $\frac{1}{3}$ rd of the weight, while Thenard and Gay Lussac make it only  $\frac{1}{4}$ th of the weight. The attempts made to prepare muriatic acid gas free from water, have hitherto failed notwithstanding the sagacity of Davy and the French chemists.

## SECTION XVI.

## OF OXYGENIZED MURIATIC ACID GAS.

*Experiment 1.* A mouse or other animal, if confined in a jar of *oxymuriatic acid gas*, is affected with convulsions, and death finally ensues.

*Remark.* It is obvious, therefore, that *oxymuriatic acid gas* cannot be breathed without proving fatal. The death of Pelletier, a chemist of considerable eminence in France, was occasioned by his attempting to respire it. A consumption was the consequence of this attempt, which in a short time proved fatal. A mixture of this ~~gas~~ with atmospheric air, when breathed, occasions a violent and almost consumptive cough, attended with much pain in the chest. In preparing it, therefore, care should be taken to avoid its escape into the atmosphere.

*Experiment 2.* If a vial filled with the *gas* be brought into contact with water, especially if it be shaken, a rapid absorption takes place, and the water will ascend in the vial.

*Rationale.* When water is brought into contact with *oxymuriatic acid gas*, it loses its former properties, and unites with the *gas*; and, if the impregnation be complete, it forms the *oxymuriatic acid*.

*Remark.* Scheele found, that after standing 12 hours over water,  $\frac{4}{5}$ ths of the *gas* was absorbed. The specific gravity of water, fully saturated, according to Berthollet, is 1.003 at the temperature of  $43^{\circ}$ ; a cubic inch of water is capable of absorbing about 1.6 grains (French) of this *gas*. The best method of effecting the impregnation of water, is by means of a Woulfe's apparatus, the bottles of which should be surrounded by ice-cold water. Water thus saturated has a pale greenish yellow colour, and a suffocating odour like the *gas*; its taste, however, if perfectly free from *muriatic acid*, is not acid, but astringent. Its purity from the *muriatic acid* may be known by the following experiment.

*Experiment 3.* To the watery solution of *oxymuriatic acid gas*, add *nitrate of mercury*; if a white precipitate is formed, the common muriatic acid is detected.

*Rationale.* The common and not the oxygenized muriatic acid, occasions a precipitation with nitrate of mercury, which is owing to the acid combining with the oxyd of mercury, and forming sub-muriate of mercury. If the water used for the purpose contains common salt in solution, which is generally the case, a precipitation will also arise from this cause.

*Experiment 4.* Into water saturated with the *gas* immerse patterns of unbleached calico; the colour of which will be discharged.

*Rationale.* This gas, even in combination with water, as we shall hereafter see, has the property of discharging vegetable colours, or of bleaching certain stuffs.

In this experiment the acid is decomposed, its oxygen goes to discharge the colour, and is reduced to the state of common muriatic acid, as is evident from the following experiment.

*Experiment 5.* To a portion of the remaining liquor in Experiment 4, add *nitrate of mercury*, and a copious precipitation will ensue.

*Experiment 6.* Expose water saturated with the *gas*, to a temperature little above that of freezing water; the gas will separate in the form of a liquid heavier than water.

*Remark.* According to the experiments of Berthollet, it appears that water saturated with the gas, if put into bottles, and surrounded with ice, is decomposed; that is, the gas separates, and takes the concrete form, which immediately descends to the bottom of the vessel. The smallest heat makes it rise in bubbles, and endeavour to escape in the form of gas. Westrumb remarks, that it becomes solid when exposed in large vessels to the temperature of  $40^{\circ}$ ; and that then it exhibits a kind of crystallization.

*Experiment 7.* Expose the solution of the *gas* in water to the direct rays of the sun, a decomposition will ensue, and *oxygen gas* will be evolved.

*Rationale.* In this experiment the rays of light decomposes the *gas*; its oxygen is disengaged in the form of gas, while its base remains in union with the water in the form of muriatic acid.

*Remark.* The oxygen gas may be collected, by exposing the solution in a gas bottle furnished with a bent tube, which terminates in the pneumato-chemical apparatus.

*Experiment 8.* Introduce into a jar of the *gas*, a sprig of mint, a rose, &c. their colour will soon be destroyed, and the *gas* diminished; or,

*Experiment 9.* Put flowers, of variegated colours, or green leaves, into the *gas*; keep them in it for some time, and their colours will be discharged; or,

*Experiment 10.* Suspend a piece of yellow wax in the *gas*; its colour will gradually disappear, and white wax will be formed; or,

*Experiment 11.* Introduce into a jar of the *gas* some unbleached linen, or calico, previously moistened with water, their colour will soon disappear, except those which are yellow.

*Rationale.* The action of oxymuriatic acid gas in the operation of bleaching, depends upon the facility with which it parts with its oxygen; the vegetable substances seize it with avidity; and by this absorption lose their colour; the oxymuriatic being reduced to the state of common muriatic acid.

*Remark.* Oxymuriatic acid, therefore, renders vegetable colours *white* and not red (as it discharges the colour of litmus) as other acids do; and the colour thus destroyed, can neither be restored by alkalies nor acids. If the vegetable substances are sufficient, the whole of the oxymuriatic acid is decomposed.

*Experiment 12.* Introduce a burning taper, affixed to a wire, into a tall jar of the *gas*, it will burn of a red colour, and more vividly than in atmospheric air; a great quantity of smoke will be formed.

*Rationale.* Oxymuriatic acid gas is, therefore, a supporter of combustion. In this experiment it is decomposed; its oxygen unites with the carbon and hydrogen of the (wax) taper, and forms carbonic acid and water; the oxymuriatic returning to the state of common muriatic acid.

*Experiment 13.* If a piece of *phosphorus*, dried on blotting-paper, and put into a copper ladle, be introduced into a jar of the gas, it will instantly take fire, and burn with a greenish white light.

*Rationale.* The phosphorus, at the common temperature of the atmosphere, decomposes oxymuriatic acid; its oxygen unites with the phosphorus, forming phosphoric acid; and the oxymuriatic is changed into the muriatic acid.

*Experiment 14.* When sulphur is presented to *oxymuriatic acid gas*, no action ensues; but if it be melted, and then introduced into the gas, it will take fire and burn rapidly.

*Rationale.* Sulphur at the common temperature does not inflame spontaneously in this gas, because it is obvious that it cannot separate the oxygen from the acid gas, but when its temperature is raised, by melting it, it will then decompose the acid; hence sulphuric acid is generated, and the oxymuriatic is reduced to the state of muriatic acid.

*Remark.* Sulphur, however, when fastened to the end of a glass rod, and confined in the gas, is slowly oxygenized, and drops down in a liquid form. It was by passing streams of this gas through flowers of sulphur, that Dr. Thomson obtained a new combination of oxyd of sulphur with muriatic acid, which he termed *sulphuretted muriatic acid*.

*Experiment 15.* If charcoal of beech wood be finely pulverized, made perfectly dry, and heated to about  $90^{\circ}$ , and then introduced into a jar of the gas, it will immediately inflame.

*Rationale.* In this experiment the carbon unites with the oxygen, in combustion, forming carbonic acid;

heat and light are set at liberty, and the oxymuriatic acid is changed into the common muriatic.

*Remark.* According to professor Lampadius, the diamond also, when heated to redness, and plunged into oxymuriatic acid gas, burns in it with great splendour; but this experiment has failed in the hands of other chemists.

*Experiment 16.* Let fall into a tall jar containing *oxymuriatic acid gas*, a few leaves of copper, usually called Dutch metal, before it reaches the bottom of the jar it will take fire and burn with a pale green light; or,

*Experiment 17.* Let fall in a similar manner gold leaf, it will take fire as in Experiment 16; or,

*Experiment 18.* Introduce *silver* leaf into the gas, and the same effect will ensue; or,

*Experiment 19.* Heat a piece of fine *copper* wire to redness, and immerse it in the gas, combustion will also take place; or,

*Experiment 20.* Pulverise metallic *antimony*, and throw it into a tall jar of the gas, a brilliant white light, accompanied with sparks, will be produced; or,

*Experiment 21.* Introduce *arsenic* in the same manner; a fine green or blue flame, attended with sparks, and a dense white smoke will be the result; or,

*Experiment 22.* Pulverise *bismuth*, and throw the powder into the gas, a bluish flame will be formed; or,

*Experiment 23.* *Nickel* used in the same manner, affords a yellowish white flame; or,

*Experiment 24.* *Cobalt* thrown into the gas, produces a bluish white flame; or,

*Experiment 25.* If *zinc*, in powder, be introduced into the gas, it will burn with a white flame, and emit an abundance of sparks; or,

*Experiment 26.* If *tin* is used, a bluish white light will be formed; or,

*Experiment 27.* If the filings of *lead* be substituted, a clear white flame will be produced; or,

*Experiment 28.* If iron filings be thrown in, a bright red flame will be the result.

*Remark.* In all these experiments, in order to insure success, the gas should be pure, and heated to the temperature not short of  $70^{\circ}$ . It is necessary that the metal should be reduced to a fine powder, and employed in the proportion of one grain to two or three cubic inches of the gas. Iron, lead, and zinc, are more difficult to inflame than any of the former. The very malleable metals, such as gold, silver, &c. which can be reduced to extremely thin leaves, are best applied to the gas in this state. The most readily oxydized metals, as we shall presently see from the rationale, burn with the greatest brilliancy. Into the bottom of the jar a little sand may be poured to prevent it from being broken.

*Rationale.* Oxymuriatic acid gas is a compound of oxygen, muriatic acid, and caloric. On presenting to it any of the before mentioned metals, it is decomposed, and so rapidly as to occasion spontaneous accension. The oxygen is abstracted by the metal, which is converted into an oxyd, whilst the light and heat of the gas are set at liberty in the form of fire. The oxymuriatic acid is, therefore, reduced to the common muriatic acid. The metal, being of course oxydized, and in this state susceptible of union with muriatic acid, combines with the remaining acid into a muriate. Gold leaf, for instance, though insoluble in this state in muriatic acid, when thus oxydized, is readily soluble in this acid, with which it forms muriate of gold. Copper leaf also, by combining first with oxygen and then with muriatic acid, constitutes muriate of copper, similar to the native muriate brought from Peru. The different colours the metals assume in oxymuriatic acid gas, is owing to the different refrangibility of the rays of light, which is set at liberty in the act of combustion; and which, from certain habits or affinities, is decomposed, by which certain rays are absorbed, and others reflected.

*Experiment 29.* Into a jar of the *gas* introduce *sulphuret of antimony*, reduced to a fine powder, in the same manner as before, and combustion will ensue.

*Rationale.* In this experiment the acid gas is decomposed. The sulphur as well as the antimony unites with oxygen, and converts the oxymuriatic into the common muriatic acid.

*Experiment 30.* Introduce in the same manner into the *gas* either *cinnabar* (sulphuret of mercury) *iron pyrites* (sulphuret of iron) or *realgar* (sulphuret of arsenic) they will take fire as in Experiment 28.

*Remark.* Other metallic sulphurets will exhibit the same phenomena, the theory of which is analogous to the former.

*Experiment 31.* Into a wine glass put one part of *hyperoxymuriate of potash*, and pour on it two or three of *sulphuric acid*; now add one part of *sulphuric ether*, *alcohol*, or *oil of turpentine*, an accension will take place, accompanied with a crackling noise.

*Rationale.* In this experiment the hyperoxymuriate is decomposed by the sulphuric acid, sulphate of potash is formed, and oxymuriatic acid gas is evolved. This gas, therefore, acts on the ether, alcohol, or oil of turpentine, which ever is used, and inflames it; the oxygen in that case changes the hydrogen and carbon of which it is composed into carbonic acid and water.

*Remark.* The same phenomena occurs with other substances besides inflammable fluids, as camphor, resin, tallow, pitch, &c.

*Experiment 32.* Into a cylinder put one part of *hyperoxymuriate of potash*, and three or four of water, with half a part of *oil of olives*, or of *linseed oil*: now add four parts of *sulphuric acid*, a violent action will take place, much charcoal will be deposited, and ignited sparks will pass through the black fluid. On adding more of the hyperoxymuriate and sulphuric acid the whole mass takes fire, and burns with a dense yellow flame.

*Rationale.* In this case the hyperoxymuriate is decomposed, a part of the sulphuric acid unites with the potash, forming sulphate of potash, and disengages the

oxymuriatic acid; the other portion of the acid partially decomposes the oil by which its carbon is partly set at liberty, which inflames. A still further addition of the salt and acid, sets the whole on fire, the result of which is the formation of carbonic acid and water, from the union of carbon and hydrogen of the oil, with oxygen.

*Experiment 33.* Into a wine glass, two thirds filled with water, put one part of *phosphorus*, and two of *oxymuriate of potash*. Pour through a tube or funnel, to the bottom, three or four parts of concentrated sulphuric acid; the phosphorus takes fire, and burns vividly under the surface of the fluid.

*Rationale.* In this case the oxymuriate is decomposed as in the last experiment, and the oxymuriatic acid, thus disengaged, is acted upon by the phosphorus; combustion therefore ensues, phosphoric acid is formed, and the oxymuriate is reduced to the common muriatic acid.

*Experiment 34.* Into a vessel or jar of *oxymuriatic acid gas* introduce some *nitrous gas*; the mixture becomes warm, reddish fumes appear, and nitro-muriatic acid is produced.

*Rationale.* The nitrous gas takes part of the oxygen from the oxymuriatic acid gas, and is converted into nitrous acid, which by uniting with the remaining acid, constitutes nitro-muriatic acid.

*Experiment 35.* Introduce into a jar of the *oxymuriatic gas* either *sulphurous* or *phosphorous acids*, a decomposition will ensue.

*Rationale.* The sulphurous or phosphorous acids are converted into sulphuric, or phosphoric acids, by the union of oxygen from the oxymuriatic acid, which is therefore changed into the muriatic.

*Experiment 36.* Introduce into a well ground stoppered bottle a mixture of three parts of *hydrogen gas* and four of *oxymuriatic acid gas*. Put the stopper in its place, and keep the bottle 24 hours inverted with its mouth under water. On withdrawing the stopper near-

ly the whole of the gas will have disappeared; and the remainder will be absorbed by the contact of water.

*Rationale.* In this case the oxygen unites with the hydrogen and forms water, and the oxymuriatic acid is changed into muriatic; hence on presenting the mixed gases to water, the muriatic acid gas is absorbed.

*Experiment 37.* Pass a mixture of *oxymuriatic acid gas* and *hydrogen gas* through a red hot porcelain tube, a violent detonation will take place.

*Rationale.* In this experiment, the hydrogen unites with the oxygen and forms water, and muriatic acid gas is disengaged.

*Experiment 38.* Put in a detonating tube three measures of *hydrogen gas* with four of *oxygenized muriatic gas*, and pass an electric spark through them. A detonation will ensue, and nearly the whole will be absorbed.

*Rationale.* The theory of this is analogous to the last experiment.

*Remark.* According to Mr. Cruikshank, the proportion of hydrogen and pure oxymuriatic acid gases, necessary for mutual saturation, is three of the former to three and a half of the latter.

*Experiment 39.* Introduce into the detonating tube one measure of *carburetted hydrogen gas* from moistened charcoal, from distilled coal, or from stagnant water, with three or four measures of *oxymuriatic acid gas*, and pass the electric spark through the mixture, a detonation will ensue.

*Rationale.* A part of the oxygen of the oxymuriatic acid unites with the carbon, held in solution in the gas, and forms carbonic acid, whilst another part combines with the hydrogen and forms water. Muriatic acid gas will remain.

*Experiment 40.* Make a mixture similar to the preceding, but with about half the quantity mentioned, of *oxymuriatic acid gas*; pass the electric spark as before, and an abundant precipitation of *charcoal* will take place.

*Rationale.* In this case the oxygen, not being sufficient to saturate both the carbon and hydrogen, unites with the hydrogen and forms water, whilst the carbon held in solution in the gas, is precipitated in the state of charcoal.

*Experiment 41.* To two measures of *carbonic oxyd gas*, add two thirds of the *oxygenised gas*, and allow them to stand, for 24 hours, in a bottle which is entirely filled by the mixture. On withdrawing the stopper at this period under water, the water will rush in, and will fill two thirds of the bottle.

*Rationale.* The carbonic oxyd is converted into carbonic acid by the addition of oxygen from the oxymuriatic acid gas, by which means the oxymuriatic gas is changed into the muriatic. On presenting the mixed gases to water, after they have stood for 24 hours, two thirds of the gas will be absorbed, which is muriatic acid gas, and the remaining one third will be absorbable by lime water; hence it is carbonic acid.

*Experiment 42.* To  $2\frac{1}{2}$  measures of *supercarburetted hydrogen gas* (olefiant gas) add 3 of the *oxygenized gas*; a diminution of bulk will ensue and a thin film of *oil* will form on the surface of the water.

*Rationale.* Although this phenomenon is not perfectly understood, yet from circumstances we may conclude, that the hydrogen and carbon of the gas unites with a portion of oxygen so as to constitute an oleaginous fluid.

*Remark.* One measure of carburetted hydrogen, from ether or camphor, mixed with two measures of oxymuriatic gas, and allowed to remain 24 hours in a vial closed with a ground stopper, mutually decompose each other; water, muriatic acid, carbonic acid, and carbonic oxyd are formed, accordingly, when water is admitted, the whole is absorbed except about 0.43 of a measure: 0.09 of this residue is absorbed by lime water; the rest is carbonic oxyd. When there is an excess of oxymuriatic acid, the resulting substances are water, muriatic acid, and carbonic oxyd.\*

*Experiment 42.* Introduce *sulphuretted hydrogen gas* into a jar partly filled with the gas; a condensation, and a precipitation of sulphur will ensue.

*Rationale.* The oxygen of the oxygenized gas unites with the hydrogen, whilst the sulphur is precipitated, being of course separated from the hydrogen.

*Experiment 43.* Mix *oxymuriatic acid gas* with *ammoniacal gas*, a rapid combustion, attended with a white flame, instantly takes place.\*

*Rationale.* Both the gases are decomposed; the hydrogen of the ammonia unites with the oxygen and forms water, whilst the azote, the other constituent of the ammonia is disengaged, and muriatic acid is reproduced.

*Remark.* Accum observes, that this experiment succeeds remarkably well, if about eight cubic inches of ammonia are sent up in a jar holding at least fifty cubic inches of oxygenized muriatic acid gas.

Oxymuriatic acid gas, formerly *dephlogisticated marine acid air*, is composed, according to Chevenix, of 77.5 muriatic acid, and 22.5 of oxygen in the hundred.

Oxymuriatic acid was discovered by Scheele in 1774, during his experiments on manganese; since that period its nature and properties were investigated by the first chemists of Europe. The oxymuriatic acid gas is not *invisible*, but has a *yellow-greenish* colour.

Oxymuriatic acid gas, as appears from the experiments both of Davy and the French chemists, contains water as an essential constituent. For the experiments and observations upon this subject, see the Appendix to Thomson's Chemistry. Thenard and Gay Lussac have shewn that hydrogen gas, olefiant gas, and other similar gases decompose oxymuriatic acid gas, simply in consequence of the hydrogen which they contain. They have shewn that gases which contain no hydrogen, as nitrous gas, produce no change upon oxymuriatic acid gas, unless water be present. As carbonic oxyd is not decomposed by it, this is additional proof

\* Fourcroy, Ann. de Chim. iv. 255.

that hydrogen is not one of the constituents of that gas. Thus it appears that oxymuriatic acid is one of the most intimate combinations known, and that the presence of water, or the formation of it, is almost always necessary for its decomposition.\*

## SECTION XII.

### OF FLUORIC ACID GAS.

*Experiment 1.* Into a jar of *fluoric acid gas* standing over mercury, immerse a lighted taper; it will become green and be immediately extinguished.

*Remark.* Hence this gas does not support combustion. In order to prevent the action of the gas on the glass, it should be coated inside with wax.

*Experiment 2.* An animal plunged into the *gas*, is affected with convulsions, and instantly dies.

*Remark.* It is, therefore, unfit for respiration.

*Experiment 3.* On immersing a piece of flesh into the *gas* it is soon corroded.

*Remark.* Besides muscular flesh, it corrodes skin as instantaneously.

*Experiment 4.* Into a jar of the *gas*, standing over mercury, introduce a little water, and agitate it; the *gas* will be absorbed, accompanied with an evolution of heat.

*Rationale.* On presenting water to *fluoric acid gas*, a partial condensation of the latter ensues; hence the extrication of heat; and the solution takes the name of *fluoric acid*.

*Remark.* Water, thus impregnated, will be found to possess all the properties of the *gas*, some of which we have already stated; it will corrode glass, flint, quartz, and other siliceous substances. *Fluoric acid* is specifically heavier than water, has an acid taste, red-

\* See the Appendix to Thomson's Chemistry.

dens vegetable blues, and does not freeze until cooled down to  $23^{\circ}$ .

*Experiment 5.* Expose water saturated with the gas to the action of heat, the gas will be disengaged.

*Rationale.* Caloric tends to separate not only the particles of bodies, but substances from each other; hence the acid takes the gaseous form, forming fluoric acid gas. The last portions of the gas which remains with the water, is disengaged with more obstinacy than the first, owing probably to the strong affinity subsisting between determinate proportions of water and gas, which can only be overcome by the application of a greater heat.

*Remark.* Gas obtained by this means is purer than that procured in glass vessels; for, if they were used, a quantity of silex is dissolved, which is deposited the moment the gas is absorbed. In obtaining it, however, leaden vessels should be employed.

*Experiment 6.* If the gas, as it issues from a leaden or tin retort, be received in a dry glass vessel, it will corrode it, and render it opaque.

*Remark.* Hence it is that this gas dissolves silex, which it takes from the glass, as glass is a compound of silex and alkali. On this property, the idea was conceived of etching on glass, either by means of the gas or the liquid acid.

*Experiment 7.* Powder some *fluat* of lime, and strew it on the surface of a pane of glass, and pour some sulphuric acid upon it; the glass will be acted upon; or,

*Experiment 8.* If a pane be coated with a thin covering of wax, and any figure drew upon it; when powdered fluor spar is put on, and *sulphuric acid* added, the glass will be corroded only where the wax has been removed; or,

*Experiment 9.* Take a pane of glass, cleanse it and cover it over either with a thin coat of bees wax, isinglass dissolved in water, or engraver's varnish. When it is dry trace upon it by means of a graver, or any sharp pointed instrument, any subject whatever. Then introduce into a leaden basin or cup a sufficient quantity of *fluat* of lime, with half its weight of sulphuric

acid; place it in a sand bath and apply heat; then hold the pane of glass close over it, in order that the gas which is disengaged may act upon the glass, which will soon become corroded, and appear like engraven when the varnish or coating is removed.

*Rationale.* In this as well as in the two preceding experiments, the fluat of lime is decomposed; sulphate of lime is formed, and the fluoric acid is disengaged in the form of gas. As this acid does not act on wax, and some other substances of this kind, it attacks the glass in every place where the coating is removed. It destroys the glass by dissolving its silex, and consequently produces a corrosion.

*Remark.* This gas may be employed advantageously for engraving labels on glass bottles, intended for containing acids, for graduating glass tubes, as eudiometers and thermometers; for ornamenting glass vessels; for removing injured enamels, &c. The art of etching on glass is not of very modern date. Beckman in his History of Inventions, observes, that it was employed for that purpose by Henry Swankard as early as 1670. He seems to have kept his art for some time secret; but the receipt was made public by Pauli, in 1725.

*Experiment 10.* Let the gas, as it comes from a glass retort, be received in a vessel filled with water and resting upon mercury; the bubbles as they come over, will become enveloped in silex, and leave, as they ascend to the surface of the water, traces in the form of tubes.

*Rationale.* The fluoric acid gas first corrodes the retort, and dissolves the silex; this solution when it comes in contact with water is decomposed. A condensation, with an extrication of heat ensues; consequently it takes a liquid form, and the silex is deposited.

*Experiment 11.* Introduce the gas into a receiver lined with wax, as before mentioned, previously placing it over any substance capable of retaining moisture, such as lizards, frogs, moist fruits, bits of sponge, &c. either of these substances so exposed will be encrust-

ed with a coat of silex, and may thus be preserved for years.

*Rationale.* It is evident that the moisture absorbs the gas, which deposits the silex it acquired from the retort, in the act of its condensation.

*Experiment 12.* Let the gas as it issues from the materials in a leaden retort, come in contact with lime water, an immediate precipitation will ensue.

*Rationale.* The fluoric acid quits its aeriform state, and unites with the lime, forming a precipitate of fluuate of lime. Hence the use of the acid as a test for the detection of lime.

*Remark.* Margraff so early as 1768 wrote on the subject of fluor or Derbyshire spar, in which he proved that it contained no sulphuric acid, but that he disengaged a peculiar acid which corroded and pierced holes through the retort. Scheele afterwards examined the nature of this acid, which he found consisted of a peculiar acid, to which the name of fluoric has been applied, and the gas has been called fluoric acid gas.

The properties of this gas have been investigated by Dr. Priestley. Mr. Davy has lately decomposed its base, by means of potassium, and the decomposition is attended with combustion.\* A proof that oxygen is one of its constituents.

The base of the acid is analogous to sulphur.† From some experiments he concludes that this acid is truly an acid product. But this subject, as well as its combinations, will be noticed under the head of fluoric acid. Thenard and Gay Lussac have obtained a peculiar gas by exposing a mixture of fluuate of lime and vitreous boracic acid to the action of a strong heat, as in the following manner :

*Experiment 13.* Expose in an iron tube to a strong heat, a mixture of *fluuate of lime* and *vitreous boracic acid*, and a gas will come over, to which Thenard and Gay Lussac have given the name of *fluo-boric gas*.

\* Phil. Mag. xxxiii. 89.

† Nicholson's Journal, xxii. 238.

*Rationale.* In this experiment the boracic acid combines with the fluoric and forms a compound gas which is disengaged.

*Remark.* When this gas is mixed with air or any other gas, except the oxymuriatic acid, it produces dense white fumes, unless the gases have been previously artificially dried. Water absorbs this gas in great quantities, and when saturated with it is limpid, smoking, and very caustic. By heat about one fifth part of the gas is expelled. The liquid then assumes the appearance of sulphuric acid; it is equally caustic, does not boil till heated considerably above the boiling point of water, and when distilled over, condenses like that acid. It acts like sulphuric acid on vegetable substances, in charring them, and forming a quantity of water. With alcohol it forms a peculiar ether.\*

It may not be improper to add, that according to Thomson (vol. v. p. 811.) when fluat of lime and sulphuric acid are heated in leaden vessels, no gas is obtained, but only an acid liquid, consisting of water and fluoric acid combined together.

When exposed to the air it emits vapours. When mixed with water it heats, and even enters into ebullition. When brought in contact with glass, it acts upon it, becomes hot, and is converted into siliciferous fluoric acid gas. When allowed to touch the skin a white spot is formed, with the pain of a burn, which terminates in a blister. The best remedy is to touch the place with a weak solution of potash. When brought in contact with potassium, a violent combustion takes place, hydrogen is evolved, and fluat of potash and water disengaged.

Fluoric acid gas may likewise be obtained from the animal kingdom; its base has been discovered in the enamel of the petrified teeth of an elephant; also in the enamel of the human teeth, and in ivory. Besides occurring in the fluor spar, it has been detected in other stones.

\* See Thomson's Appendix to vol. v. Also Murray's Supplement.

## PART VI.

### ATMOSPHERIC AIR.

That fluid which surrounds the globe to a certain height, in which the processes of respiration, combustion, vegetation, &c. are carried on, is called the atmosphere. It possesses mechanical as well as chemical properties; those of the latter will only be described. Atmospheric air is a compound of about 22 per cent. of oxygen and 77 of nitrogen.

*Experiment 1.* Take a bladder partly filled with *air*, and hold it to the fire; the air within will gradually dilate, and if the heat be continued, will burst the bladder; or,

*Experiment 2.* To the bottom of a hollow glass-ball let an open bended tube be affixed. Fill the lower part of the bended tube with mercury; the external surface will be pressed by the weight of the atmosphere, and the air inclosed in the ball of the tube by means of the mercury will be equally pressed by the spring of the air within the vessel. Immerse the ball in boiling water, and the mercury will rise.

*Rationale.* The expansion or dilatibility of the atmosphere is daily exemplified to our senses in the production of wind, as this effect presupposes a previous expansion. Heat has a tendency to overcome the attraction of cohesion, so far as to place the particles of bodies beyond a certain sphere of action; hence they *dilate* or *expand*. This effect is counteracted by cold, by pressure, &c. as is evident from the following experiment.

*Experiment 3.* Immerse the bladder, or hollow glass ball into a vessel of cold water; the air will condense or contract into its former state.

*Remark.* The theory of Mongolfier balloon depends on the rarefaction of the air, thereby lessening its specific gravity, and causing the balloon to ascend in a medium more dense, until an equilibrium is attained. It appears, that the air which is disengaged in firing of gun powder, is rarefied by the heat, so as to occupy a thousand times the space of the whole of the gun powder employed.

*Experiment 4.* If a *lighted* taper be placed under a jar of *air* over water, it will burn for a certain length of time; and on observing it, it will be found that the pressure of the air becomes proportionably less on the water immediately under the jar, while part of the water in the dish, in which the jar was placed, will rise or be forced up.

*Remark.* We therefore see that atmospheric air is necessary for combustion, that in that process a part of it is consumed, and that an external pressure forces the water up into the jar. The pressure of the air may be demonstrated by a variety of experiments; the *barometer*, an instrument calculated to shew the difference in atmospheric pressure, which is about 15lbs. upon a square inch; the construction of pumps and various other hydraulic machinery; the variety of effects in the economy of nature, all tend to prove this fact.

The specific gravity of common air is usually reckoned 1.000: it is 8.16 lighter than water. One hundred cubic inches of it weigh 31 grains troy. As it respects the density of the air, we may remark, that as it is an elastic fluid, and compressed at the surface of the earth by the whole weight of the incumbent atmosphere, its density diminishes according to its height above the surface of the earth, about in the ratio of the compression; or the density decreases in a geometrical progression, while the heights increase in an arithmetical progression. That it is this pressure of the air that preserves many of the operations of nature in order, is evident; thus it is, that water will boil in *vacuo* much sooner than in the open air, and also on the tops of high mountains; that evaporation is consequently retarded, &c.

*Experiment 5.* Take an instrument called a *fulcrum glass*, which consists of two bulbs exhausted of its air, one of which is filled with coloured alcohol, connected together by means of a glass tube, and hold one of the bulbs in the hand in a sloping position; the heat of the hand will cause the fluid to boil.

*Remark.* This instrument shews, that a very small degree of heat would be sufficient to evaporate most of our fluids if we had no atmosphere.

*Experiment 6.* Fill a long necked bottle with boiling water, and cork it close so as to exclude the air. Put it now in a vessel of cold water, and the water will sink in the neck of the bottle as it cools, and recommence its boiling with great violence; or,

*Experiment 7.* Fill a flask two-thirds with hot water, and place it over a lamp that boiling may be produced; when this has taken place remove the flask from the heat, cork it tight, and wet the upper surface; and, notwithstanding the boiling has ceased, it will be renewed.

*Rationale.* In both cases, as liquids boil with a less heat in vacuo, an imperfect vacuum is formed: in the latter case a condensation of the vapour ensues, consequently a vacuum is produced, the pressure of the air is removed, and ebullition commences.

*Experiment 8.* Fit a cork to a bottle sufficiently large, and adapt to it a small taper; light it and introduce it into the bottle, holding of course atmospheric air, and it will burn for a short time; when it has ceased remove it, placing the thumb on the aperture of the bottle, and introduce it, lighted a second time; it will be immediately extinguished. Invert the bottle in a basin of water, withdraw the cork, and the water will ascend.

*Remark.* This experiment proves, besides, that air is necessary to combustion, and that a diminution ensues in that process.

*Experiment 9.* If *phosphorus* be burnt in a given volume of atmospheric air, in the manner described in that of oxygen gas, a diminution of bulk will ensue.

*Remark.* This effect, as we shall hereafter see, depends on the formation of phosphoric acid by the union of phosphorus with the oxygen of the atmosphere.

*Experiment 10.* Procure two circular pieces of lead, three inches diameter, and half an inch thick, from the centre of each of which proceeds a perpendicular iron wire, six or eight inches high; to the end of both wires fasten a piece of wax taper. Provide also two jars, each two inches diameter, and twelve long, and having a neck at the top, with a compressed bladder tied upon it. Fill one of the jars, leaving the bladder empty, with oxygen gas; and, at the same instant, with the aid of an assistant, invert both jars over the burning candles, keeping the oxygen gas in its place till the jar is inverted, by a piece of pasteboard.

*Rationale.* As in every combustion, according to the Lavoisierian theory, a diminution, consequently an absorption of oxygen ensues, it follows in this instance, as will be found on experiment, that in oxygen gas the candle will burn for a longer time, and with more brilliancy than in the atmospheric air. On the first impression of the flame, a quantity of expanded gas will rise into each bladder, which is to be pressed out at the close of the experiment, in order that the absorption may be compared in both cases. The diminution will be found to be greater in the jar of oxygen gas. The products of combustion always depend upon the substances submitted to that process. In the present instance, as carbon and hydrogen are the principal constituents of tallow, or wax, the products are carbonic acid and water, resulting from the union of oxygen with the carbon and hydrogen, during which the heat and light of the oxygen gas are disengaged in a free state. After combustion what remains is therefore carbonic acid, aqueous vapour, and azotic gas.

*Experiment 11.* If two tubes each containing oxygen gas and atmospheric air be inverted in two separate cups filled with a solution of sulphuret of potash, and exposed in that situation for some time, it will be found, that in the tube containing atmospheric air, about  $\frac{4}{5}$ ths of its

original volume will remain, but in that containing oxygen, it will ascend much higher, and if the gas be pure, will even absorb the whole.

*Rationale.* In this case the sulphuret absorbs oxygen, and is changed into a sulphate, from the formation of sulphuric acid. As atmospheric air contains 77 per cent. of azote, the greater diminution in the oxygen gas is not surprising when we consider, that the sulphuret absorbs oxygen only. Hence the use of graduated tubes, certain solutions, &c. in ascertaining the purity of the atmosphere, or for determining the proportion of its constituent parts. Hence also the construction of *eudiometers*.

*Remark.* Air was for many years considered a simple substance. The celebrated Dr. Priestley made many experiments on atmospheric air, which he began in 1774, in which he showed, that common air was composed of *air deprived of phlogiston* or *dephlogisticated air* (oxygen gas) and *air saturated with phlogiston*, or azotic gas. After him Scheele proceeded to the analysis of air by using liquid sulphurets, phosphorus, &c. which when confined along with air, have the property of diminishing its bulk. After subjecting air to these and other substances, the residue he named *foul air*. The composition of the atmosphere being known, philosophers took it for granted that the proportion of its oxygen varies at different times and in different places; and that upon this variation depended the purity or noxious qualities of air. Various methods were accordingly invented, to determine the proportions of its constituent parts. Eudiometers, or more properly *oxyometers*, were constructed for this purpose. It may not be improper to notice them.

#### 1. *Priestley's and Fontana's Eudiometer.*

The first eudiometer was made in consequence of Dr. Priestley's discovery, that when nitrous gas is mixed with air over water, a diminution of bulk ensues, owing to the combination of the gas with the oxygen of the air, and the absorption of the nitric acid thus form-

ed by the water. The nitric oxyd unites with the oxygen, leaving the azote of the air behind, and by making the experiment in graduated tubes, the precise quantity of oxygen absorbed, and azote which remains, may be readily determined.

Dr. Priestley's method was to mix together equal bulks of air and nitrous gas in a low jar, and to transfer the mixture into a narrow graduated glass tube about three feet long, in order to measure the diminution of bulk. Dr. Falconer invented a more convenient instrument. Fontana, however, improved upon this plan of determining the purity of the air. Mr. Cavendish deserves the credit for determining with precision, by this mode, the constituents of the air. It is unnecessary to enter into a detail on his improvement, or the observations of chemists, as the nitrous test has been employed by Mr. Davy with more accuracy in a different manner.

## 2. *Davy's Eudiometer.*

In order to get rid of anamolies, Mr. Davy proposed the following method for using nitrous gas. Take a small glass tube graduated into 100 equal parts; fill this tube with the air to be examined, and plunge it into a bottle or any other convenient vessel, containing a concentrated solution of green muriate or sulphate of iron, strongly impregnated with nitrous gas. If the tube be agitated an absorption will ensue, the degree of which indicates the quantity of oxygen absorbed.

*Rationale.* Nitrous gas held in solution in this manner, has the same avidity for combining with oxygen as it has in the state of gas; hence it is, that when oxygen is presented to it, as it is in atmospheric air, it absorbs it, and is changed into nitric or nitrous acid. The degree of absorption is shewn by the graduated scale.

*Remark.* One cubic inch of moderately impregnated solution is capable of absorbing five or six inches of oxygen in common processes, which takes place in a few minutes.

By means of this, Mr. Davy examined the air brought from Bristol, England, and found it always to contain about 21 of oxygen, which is about the same that the honourable Adam Seybert made it in the city of Philadelphia.\*

### 3. *Scheele's Eudiometer.*

This is a graduated glass vessel containing a given quantity of air exposed to newly prepared liquid alkaline or earthy sulphurets, or to a mixture of iron filings and sulphur, formed into a paste with water. As these substances have the property of absorbing oxygen, its *modus operandi* is readily perceived.

It requires some time to make an experiment, and at best inaccuracies will arise, owing to the evolution of sulphuretted hydrogen gas, and occasionally the absorption of azote, notwithstanding they embrace the improvements of Dr. Marti.

### 4. *Volta's Eudiometer.*

This consists in detonating a mixture of hydrogen gas and atmospheric air, in a graduated glass tube, and measuring the diminution after combustion. Gay Lussac and Humboldt have highly recommended this plan. When .100 measures of hydrogen are mixed with 200, or any greater bulk of oxygen, up to 900 measures, the diminution of bulk after detonation is always 146 measures. The same diminution is retained, if the hydrogen be increased up to a certain quantity. It is, therefore, ascertained, that 100 measures of oxygen gas require 200 of hydrogen for complete combustion. Hence, if equal bulks of the air, to be examined, and of hydrogen gas, be exploded, and the diminution of bulk be ascertained and divided by three, the quotient represents the number of measures of oxygen in the air.

\* See his Experiments in the Transactions of the American Philosophical Society.

5. *Berthollet's Eudiometer.*

This method of ascertaining the proportion of oxygen is by the use of phosphorus; it has been used, in the state of rapid, as well as spontaneous combustion. The latter has been recommended by Berthollet, which absorbs the oxygen of the air completely. It consists of a narrow graduated glass tube, containing the air to be examined, into which is introduced a cylinder of phosphorus supported upon a glass rod, while the tube stands inverted in water. The phosphorus should be nearly as long as the tube. Immediately white vapours rise from the phosphorus, and fill the tube. These continue until the whole of the oxygen combines with phosphorus, when they cease, the process is at an end.

*Rationale.* The phosphorus unites with the oxygen, and leaves the azote untouched.

*Remark.* Berthollet has remarked, that the volume of azotic gas is increased to  $\frac{1}{6}$ th part; consequently, the bulk of the residuum, diminished by  $\frac{1}{6}$ th, gives us the bulk of the azotic gas of the air examined; which bulk subtracted from the original mass of air, affords the proportion of oxygen gas contained in it. There are several circumstances to be attended to in experiments on air, as the density, or barometrical pressure, temperature, &c. which may be found in Thomson, iv. 21.

6. *Hope's Eudiometer.*

In Nicholson's Journal, iv. 210, we have a description of an eudiometer invented by professor Hope of Edinburgh. It consists of a small bottle, of the capacity of 20 or 24 drachms, destined to contain the eudiometric fluid, having a small stopper at the side. Into the neck of the bottle a tube is accurately fitted, by grinding, which holds precisely a cubic inch, and is divided into 100 equal parts. To use the apparatus, the bottle is first filled with the liquid employed, which is best prepared by boiling a mixture of quicklime and sul-

phur with water, filtering the solution, and agitating it for some time in a bottle half filled with common air. The tube, filled with the air under examination, is next put into its place; and on inverting the instrument, the gas ascends into the bottle, where it is brought extensively into contact with the liquid, by brisk agitation. An absorption ensues; and, to supply its place, the stopper in the side is opened under water, a quantity of which rushes into the bottle. The stopper is replaced under water; the agitation renewed; and these operations performed alternately, till no further diminution takes place. The tube is then withdrawn, the neck of the bottle being under water, and is held inverted in water for a few minutes; at the close of which the diminution will be apparent. Its amount may be measured by the graduated scale engraved on the tube.

It was a matter of some moment to discover means by which the quantity of oxygen in the atmosphere might be ascertained, as atmospheric air ministers to the support of animal life, only in consequence of the oxygen gas which it contains. Air, after having been received into the lungs, and again expired, is found to have lost considerably of its oxygenous part, viz. 10 or 12 *per cent*.

*Experiment 12.* Take caustic potash, and expose it to the atmosphere; it will deliquesce, and after it has remained some short time, will effervesce on the addition of acids.

*Remark.* Atmospheric air contains also carbonic acid, in the proportion of about one or two per cent. hence the caustic alkali absorbs it, which is evident by the effervescence, on the addition of acids; that it likewise contains water is shewn by the same experiment, as the alkali deliquesces.

*Experiment 13.* Confine a mouse in a small glass jar, and tie the jar over, quickly and firmly, with moistened bladder. When the life of the animal is extinct, the bladder exhibits a hollow surface.

*Remark.* This method was contrived by Mayow, to shew that atmospheric air is diminished in volume by animal respiration. The heat of the animal will first

expand the air, and consequently make the bladder convex; but after the animal is dead, the air within will be considerably diminished. The exact amount of the diminution may be shewn, by confining a mouse, over water, in a graduated jar, furnished with a stop cock, and containing common air. We have seen that air is not a simple element, as was maintained by the ancient philosophers, but that it is composed of oxygen and azotic gases, as its principal constituent part; that it possesses fluidity, elasticity, expansibility and gravity; that it is necessary for respiration, combustion, and various other processes.

Mr. Parke, in his Chemical Catechism, has made a just remark on the use of the atmosphere. Were it not for atmospheric air, says he, we should be unable to converse with each other; we should know nothing of sound, or of smell, or of the pleasures which arise from the variegated prospects which now surround us. A French writer, of considerable note, adds, that in the use of atmospheric air, *man* is the only being who gives to it all the modulations of which it is susceptible. With his voice alone, he imitates the hissing, the cries, and the melody of all animals; while he enjoys the gift of speech denied to every other. To the air he also sometimes communicates sensibility; he makes it sigh in the pipe, lament in the flute, threaten in the trumpet, and animate to the tone of his passions even the solid brass, the box tree and the reed. Sometimes he makes it his slave: he forces it to grind, to bruise, and to move for his advantage an endless variety of machines. In a word, he harnesses it to his car, and obliges it to waft him over the stormy billows of the ocean.

If there were no atmosphere surrounding the earth, only that part of the sky would appear light in which the sun was placed; and if a person should turn his back to the sun, he would directly perceive it as dark as night; for in that case there would be no substance to reflect the rays of the sun to his eyes. It is owing

to refraction, that the sun enlightens the earth sometime before it rises, and sometime after it sets.\*

The atmosphere, says Fourcroy, is a vast laboratory, in which nature operates immense analysis, solutions, precipitations, and combinations: it is a grand receiver, in which all the attenuated and volatilized productions of terrestrial bodies are received, mingled, agitated, combined, and separated. Notwithstanding this mixture, of which it seems impossible for us to ascertain the nature, atmospheric air is sensibly the same, with regard to its intimate qualities, wherever we examine it.

The constituent parts of the atmosphere more properly speaking, are considered under four heads, viz. 1. Air. 2. Water. 3. Carbonic acid gas. 4. Unknown bodies. We have before observed, that common air is composed of oxygen and azotic gases, that the atmosphere contains water, which varies at different seasons as is shewn by an instrument called the *hygrometer*, which gives rise to clouds, fogs, rain and dews; and that it also contains carbonic acid. Besides these there are other bodies found, or contained in it, such as hydrogen gas, carburetted hydrogen gas, contagious matter, electricity, &c. to which we may add the stones which sometimes fall from the atmosphere, during the appearance of *luminous bodies or meteors*, commonly called *fire balls*. When these meteors burst, an explosion is the consequence, and a shower of stones fall to the earth. A table of these remarkable phenomena may be seen in Thomson's Chemistry, iv. 122. These stones have been carefully analysed, an account of which may be seen in the same work. Professor Silliman of Yale College, Connecticut, examined a meteoric stone which fell in that neighbourhood, and found the result nearly the same as those found in Europe.

\* Gregory's Astronomical Lessons, page 78—82.

## PART VII.

### OF WATER.

*Experiment 1.* If *water*, contained in a small glass tube be exposed to a freezing mixture (see the table of freezing mixtures) it will lose its fluidity, and be converted into *ice*.

*Rationale.* Water when cooled down to  $32^{\circ}$  assumes the form called ice. This process is, therefore, nothing more than the *abstraction* of caloric from the water, which is effected by the freezing mixture.

*Remark.* If this process goes on very slowly, the ice assumes the form of crystalline needles, crossing each other at angles either of  $60^{\circ}$  or  $120^{\circ}$ , as Mr. De Mairan has remarked. Ice, while kept at a temperature below  $32^{\circ}$ , is very hard, and may be pounded into the finest dust. It is elastic. Its specific gravity is less than that of water; the latter is always supposed to be 1.000, which is made the measure of the specific gravity of every other body.

It is by this abstraction of heat, or reduction of temperature, that the atmosphere, being the agent by which this change is effected, deprives the water of a certain portion of its caloric. As water holds atmospheric air in solution, it is owing, it is said, to this circumstance, that ice contains vacuities filled with air, and that it expands in the act of freezing. Rocks and trees are often split during intense frosts. A spherule of water, according to the calculations of the French Academicians, only one inch in diameter expands in freezing with a force superior to the resistance of thirteen and an half tons weight. It may be remarked, that though

fresh water freezes when reduced to the temperature of  $32^{\circ}$ , sea water does not freeze till cooled down to  $28.5^{\circ}$ .

Underneath the poles the water is always solid, to which the coldness at the poles is attributed. At the whimsical marriage of Prince Gallitzin, in 1739, the Russians applied ice to the same purpose as stone. Blocks of ice were employed in building a house; cannon were also made of it, which performed their office several times, in honour of the day, without bursting.

In cements and mortar, in which water is employed, it is said to become still more hard than in ice.

*Experiment 2.* Put some water into a pot or kettle, introduce a thermometer, and cause the water to boil; it will be found, that the mercury indicates  $212^{\circ}$ , which is the boiling point.

*Rationale.* The conversion of water into steam or vapour, takes place when the temperature is at  $212^{\circ}$ , with a phenomena called boiling. It is therefore by the accession of temperature, that water is changed into vapour.

*Remark.* Steam is an invisible fluid like air, but of a less specific gravity. It occupies about 1800 times the space that water does. Its elasticity is so great, that it produces the most violent explosions when confined. It is said, that water, in being converted into vapour, combines with more than five times the quantity of caloric that is required to bring ice cold water to a boiling point, and occupies a space 800 times greater than it does when in the form of water. Steam has therefore been employed as a useful and powerful agent, in the construction of the steam engine, the discovery of which is a great acquisition to the arts.\*

The phenomena of boiling are owing to the rapid formation of steam at the bottom of the vessel. The boiling point of water varies according to the pressure

\* See Evans's Treatise on Steam Engines, 8vo.

of the atmosphere, as is shewn by the following experiment.

*Experiment 3.* Heat water to  $70^{\circ}$ , and introduce it in a cup under the receiver of an air pump; exhaust the air, and ebullition will ensue. Again, by confining water in a proper apparatus, as in a Papin's digester, it may be almost heated red hot without boiling. The mixture of various salts with water affect its boiling point considerably.

*Experiment 4.* Let a thermometer bulb, and part of its tube, having a wide bore, be filled with *water*, tinged with a little litmus, which may be introduced by the same means as those used for filling with quicksilver. Immerse the thermometer in water at the temperature of  $40^{\circ}$ ; and when the included water may be supposed to have attained the same degree of heat, remove the instrument successively into water of the temperature of  $36^{\circ}$  and  $32^{\circ}$ . At each immersion the water will rise in the tube. Bring its temperature again to  $40^{\circ}$ , and it will descend to the same point as before. Place it in water of  $50^{\circ}$ , and it will again be expanded.

*Remark.* This experiment is designed to shew, that the *enlargement* of the bulk of water begins long before its temperature has descended to the freezing point, viz. at about  $40^{\circ}$  Fahrenheit. We find that precisely similar effects appear to result from two opposite causes, for the bulk of water is alike increased by reducing or raising its temperature.

Mr. Dalton, however, is of opinion, that in the apparent expansion by a lower temperature, there is a deception, arising from the contraction of the glass, which must lessen the capacity of the bulb, and force the water up the stem. This opinion is contrary to that of count Rumford and of Dr. Hope.

*Experiment 5.* Place water under the receiver of an air pump, and exhaust it; bubbles of *air* will arise from the water; or,

*Experiment 6.* Put *water* into a retort, heat it, and collect the air which rises; it will be found to be *atmospheric air*. Or,

*Experiment 7.* Fill a barometer tube, about 32 inches long, sealed at one end with quicksilver, except about four inches, and the remainder with water. On inverting the open end of the tube in quicksilver, bubbles of *air* will be seen, in a short time, to rise from the water.

*Remark.* These experiments prove, that water contains air in solution, and that it is separated when subjected to certain processes. The greatest part of this air is driven off by boiling; but, from the experiments of Dr. Priestley, it appears that the whole of it is not separated. Water owes its agreeable taste to the air which it contains; hence the insipidity of boiled water. It absorbs oxygen gas in preference to common air, and nearly in the same proportion, as was first ascertained by Scheele. Mr. Driessen has shown, that in order to free water from air, it must be boiled at least for two hours, and kept in a flask with its mouth inverted over mercury. In order to ascertain whether water be perfectly free from air, Mr. D. has instituted the following method.

*Experiment 8.* Tinge water blue with *litmus*, fill a flask with it, invert the flask under water, and introduce into it pure *nitrous gas* till about  $\frac{1}{20}$ th of the vessel is filled: if the water contains air, a portion of the nitrous gas will combine with its oxygen, and be converted into nitric acid, and the litmus become *red*.

Remark the proportion of air may be estimated by the quantity of ammonia necessary to restore the blue colour to the litmus.

*Experiment 9.* Put *carbonate of potash*, or salt of tartar of the shops, into a dish, and expose it to the atmosphere; in a few days it will have become *moist* or *deliquated*.

*Rationale.* The alkali absorbs moisture, for which it has a strong affinity, and becomes of a fluid consistence.

*Remark.* Water is contained in the air of the atmosphere, even during the dryest weather. See Atmospheric Air.

*Experiment 10.* Expose solid *alkali* in the same manner as in the last experiment to an atmosphere of *oxygen*, *hydrogen*, or any of the gases; it will gradually become fluid.

*Remark.* Gases, in their usual state, contain combined with them a quantity of water, which often amounts to a considerable proportion of their weight; hence the cause of the alkali becoming fluid.

*Experiment 11.* Pass the vapour of water through a gun barrel containing *charcoal*, previously heated to redness; the water will be decomposed by the *coal*.

*Rationale.* This effect takes place agreeably to the rationale given under hydrogen and carburetted hydrogen gas, which see.

*Remark.* The simple combustibles have no action on water while cold. Hydrogen does not act upon it even at a red heat. Charcoal forms with it, when ignited, carbonic acid and carburetted hydrogen gas. Phosphorus at a red heat has not been tried. Sulphur, as far as is known at present does not decompose it. Of the metals, iron, zinc, antimony, and tin, decompose it when assisted by heat; silver, gold, copper, and platinum, have no effect upon it. See subsequent experiments.

*Experiment 12.* Pour water on pure *barytes*, *lime* or *strontia*; it will be found that it will dissolve any of these earths, until it is saturated.

*Remark.* The alkaline earths are soluble in water, but the earths proper are insoluble in it.

*Experiment 13.* *Glauber salt*, *nitre*, and a variety of salts are soluble in *water*, which may be seen by pouring that fluid upon them.

*Remark.* The substances on which water has this effect, are said to be soluble, and there are various degrees of solubility. Water unites also with acids.

In most cases an absorption of caloric, in other words a production of cold, is attendant on solution. See Freezing mixtures. In other cases caloric is evolved, or heat is produced. The common salt of tartar, during solution in water, raises the temperature of the solvent; and caustic potash in a state of dryness, does

the same still more remarkably. As the difference, in the crystallized and uncrystallized state, depends chiefly on their containing in the former, but not in the latter, water chemically combined, we may infer, that the cold produced during the solution of salts, is occasioned by the conversion of the water, which exists in these bodies, from a solid to a liquid form. See Caloric.

*Experiment 14.* Put an ounce of *sulphate of soda* into a vial, and fill the bottle with water, and air will be evolved.

*Remark.* During the solution of salts in water, a quantity of air is disengaged. The air contained in the pores of the salt will be thus disengaged, but a very small portion of salt will be dissolved. On shaking the vial more salt will be dissolved, and a fresh portion of air will be liberated. The air, that now appears, is extricated from the water in consequence of the affinity between the water and salt being greater than that between the water and the air.

*Experiment 15.* Into a flask, having a long neck, introduce an ounce or two of *sulphate of soda*. Then, add as much water as will fill the globe, and about three fourths of the neck. This should be done with as little agitation as possible, in order that the salt may not dissolve till required. Mark, by tying a thread, the line where the water stands; and then agitate the flask or matrass, and a considerable diminution will result.

*Remark.* The salt will dissolve; the air will be set at liberty; and during the solution, the water will sink considerably below its level. That during the solution of salts, the bulk of water changes is therefore evident. This contraction of bulk is owing to the diminution of temperature; and, when the water has regained its former temperature, it will also be found, that its bulk is increased by the addition of salt.

*Experiment 16.* Introduce into a flask half a pound of *sulphate of soda*; pour on it barely a pint of water, and apply the heat so as to boil the water. The whole of the salt will be dissolved. Boil the solution for a few minutes, so as to drive out the air; and cork the

bottle tightly, immediately on its removal from the fire. To prevent more completely the admission of air, tie the cork over with a bladder. As the vessel cools an imperfect vacuum will be formed over the solution; for the steam, which arises during the ebullition, expels the air, and takes its place. The steam is condensed again when the vessel cools. The solution, when perfectly cold, may be shaken without any effect ensuing, so long as the vessel is kept closely stopped; but, on removing the cork and shaking the vessel, the solution will immediately congeal, and heat be produced.

*Remark.* This experiment shews, that water has its solvent power increased by diminishing the pressure of the atmosphere. It also shews, that caloric is evolved during the transition of bodies from a fluid to a solid state. It is the reverse of that, in which cold is produced, or caloric absorbed, during the solution of salts.

*Experiment 16.* If *water* be thrown on *quicklime*, it will lose its former state, and becomes *slacked lime*.

*Rationale.* This combination of lime and water, during which an evolution of heat takes place, in the language of Proust, is a *hydrate* of lime.

*Remark.* Water, therefore, combines in two forms; in the first it acts as a solvent, by which a *solution* is effected; in the second it loses its fluid form and assumes that of the substance to which it has united, as in hydrates and crystallized bodies. In the latter way it unites to lime, alumina, to many saline bodies, and to metallic oxyds. The crystals of barytes and strontia, are hydrates of these alkaline earths, and crystallized potash and soda and hydrates of the fixed alkalies. The hydrates of potash and soda contain about 30 *per cent.* of water. Hydrate of alumina, is the *spongy alumina* of Saussure.

*Experiment 17.* If to a solution of *nitrate of copper*, a sufficient quantity of *potash* be added, a *blue precipitate* will be formed, which when washed and dried, forms *hydrate of copper*.

*Rationale.* The potash unites with the nitric acid, forming nitrate of potash, and the copper is precipitated

in union with oxygen and water in the state of hydrate of copper.

*Remark.* This precipitate is composed of 25 parts water, and 75 of black oxyd of copper.

*Experiment 18.* If to a solution of *sulphate of iron*, *potash* be added in the same manner, a *hydrate of iron* will be obtained.

*Rationale.* Analogous to the preceding.

*Remark.* This hydrate is of a green colour, and readily parts with its water.

*Experiment 19.* If to a solution of *tin* in *muriatic acid*, the same *alkali* be added, a *hydrate of tin* will be precipitated.

*Rationale.* Analogous to the preceding.

*Remark.* This preparation is of a white colour, and loses, when distilled about 5 *per cent.* of water, and is converted into prot-oxyd of tin, or tin oxydized to the *minimum*. There is reason to believe, that most all the metals will form peculiar compounds with water.

*Experiment 20.* Put *gypsum* or *sulphate of lime* into a crucible, and apply a sufficient heat to drive off the water, which it contains; take the calcined gypsum, powder it, and add to it a portion water; it will again become solid almost immediately.

*Rationale.* On exposure to heat, the gypsum loses its water, but the component parts of the plaster (provided the heat be not too considerable) remains unaltered; on adding water, the affinity of the plaster is so great for it, that the whole of the pulverent matter will be converted to a solid.

*Experiment 21.* Procure a gun barrel, the breech of which has been removed, so as to form a tube at each end. Fill this with iron-wire coiled up in a spiral form. To one end of the barrel adapt a small glass retort, partly filled with water, and to the other a bent glass tube, the open end of which terminates under the shelf of the pneumatic cistern. Let the barrel be placed horizontally (or rather with that end, to which the retort is fixed, a little elevated) in a furnace having two openings in its body opposite to each other. Light a fire in the furnace; and when the gun barrel

has become red hot, apply a lamp under the retort. The steam of the water will pass over the red hot iron, and will be decomposed, and hydrogen gas will be disengaged.

*Rationale.* In this experiment the water is decomposed, its oxygen unites with the iron, forming the oxyd of iron, and its hydrogen is disengaged in the form of gas.

*Remark.* From experiments of this kind, conducted with the utmost accuracy, as well as from synthetic investigations, water is found to be composed of 85 parts of oxygen and 15 of hydrogen by weight, very nearly. Hydrogen gas being about eleven times lighter than common air, the proportion of gases, by volume required to form water, is about two of hydrogen to one of oxygen. It is not necessary to remark, that water was one of the four supposed elements. Mr. Cavendish must be considered as the discoverer of the composition of water. The experiments of Mr. Cavendish were repeated in England and France. Mr. Lavoisier, assisted by several of the French Academicians, instituted a series of experiments on water, about the same time, and proved that water is composed of hydrogen and oxygen; it has, therefore, been called an oxyd of hydrogen.

*Experiment 22.* Introduce *iron wire* into an earthen tube, and ignite it in a furnace; pass the vapour of water through it, and *hydrogen gas* will be obtained.

*Rationale.* The effect is the same as in the preceding experiment: if the iron wire be first weighed, it will be found, after the experiment, to have increased in weight in proportion to the quantity of oxygen absorbed. If the additional weight be added to that of the hydrogen gas, it will make up exactly the weight of the water that has disappeared.

*Experiment 23.* Pass the vapour of *water* through an ignited gun barrel containing charcoal, the water will be decomposed.

*Rationale.* The oxygen of the water unites with the charcoal forming carbonic acid, and the hydrogen is disengaged partly in a free state, and partly united

with the carbon in the state of carburetted hydrogen gas. See Hydrogen and Carburetted Hydrogen Gas.

*Experiment 24.* When two wires from the opposite extremity of a *galvanic battery* are placed in a tube containing water, so that they are distant from each other one quarter or half an inch, a stream of gas issues from each wire—from the positive wire *oxygen*, from the negative, *hydrogen gas*; and these are in the proportions which when exploded, either by galvanism or electricity, re-forms water.

*Remark.* This experiment is designed to shew, that water is susceptible of decomposition by the galvanic influence. The decomposition may also be effected in the following manner:

*Experiment 25.* Take a narrow glass tube, three or four inches long; fit each end with a cork, penetrated by a piece of slender *iron wire*, and fill the tube with water. Let the ends of the two wires be distant from each other about three fourths of an inch; and let the one be made to communicate with the bottom of the galvanic pile, the other with the top. On making this communication, bubbles of air will form, and will ascend to the top of the tube.

*Rationale.* The wire is oxydized by the decomposition of the water; its oxygen unites with the iron, while its hydrogen appears in the state of gas.

*Experiment 26.* By using a similar apparatus, but with the substitution of *gold wire*, or some metal that is not oxydized by water, we obtain a mixture of *hydrogen* and *oxygen gases*.

*Rationale.* It is apparent that in the case with iron, which readily unites with oxygen, the oxygen is absorbed, and the hydrogen is set at liberty; but in the experiment with gold wire, the water is also decomposed, but, as the metal is not readily oxydized, the oxygen as well as the hydrogen is set free.

*Remark.* This experiment is similar to that performed by the society of Dutch chemists. Dr. Wollaston has adopted the following method for effecting the decomposition of water.

*Experiment 27.* Let two fine gold wires be fixed in separate small glass tubes by fusion; and let the end of these tubes be ground till the very section or extremity of each is laid bare, let the other end of each tube be furnished with a larger wire connected with a metallic ball, which wire communicates with the gold wire within. These two tubes are then fixed by fusion in a larger glass tube, provided with a conical drawn aperture, through which it can be filled with water, all but a small vacuity or bubble, and then sealed. If a small stream of *electricity*, or *galvanism* be passed through it, the water is decomposed.

*Remark.* The decomposition of water by galvanism was announced by Messrs. Nicholson and Carlisle, in the year 1801. A very evident difference may be observed in the quantity of gas extricated from the two wires of the galvanic machine. That connected with the zinc end is much less in quantity than what issues from the copper end. By placing the two wires in separate legs of a syphon, as represented in Nicholson's Journal, 4to. vol. iv. plate 21, the two gases may be separated.

The phenomena which occurs in the decomposition of water by galvanism, Davy has explained in conformity to the general law which he established as regulating the chemical changes produced by that agent. The law is, that different substances have such a relation to galvanism, that some are attracted forcibly to the *positive* others to the *negative* side of the galvanic arrangement; oxygen and those compounds in which it predominates being attracted to the positive side; hydrogen, inflammable and metallic substances, to the negative. Hence he concludes that when water is submitted to the action of galvanism, the oxygen of a portion of it is attracted to the positive side, and its hydrogen repelled; the opposite process takes place at the negative side, the hydrogen being attracted, and the oxygen repelled; and at the wires connected with the two sides, these gases appear in their insulated form. In the separation of the gases, by the agency of galvanism, in the decomposition of water, it is asserted that the water at one wire receives positive elec-

tricity and appears as oxygen, and at the other receives negative electricity, so as to assume the form of hydrogen. This hypothesis appeared extravagant, and little or no attention paid to it, until sir Humphrey Davy brought it forward, as connected with the general theory of the dependence of the chemical forms of matter on electrical powers. Water positively electrified would be hydrogen; water negatively electrified, oxygen; and, says Mr. Davy, as in the physical experiments of temperature, ice, added, to a certain quantity of steam by an equilibrium of heat, produces water; so in the chemical experiments of the generation of water, the positive and negative electricity of oxygen and hydrogen in certain proportions would annihilate each other, and water alone be the result. No certain conclusions, however, can be drawn, from our imperfect knowledge of this subject.

Having had the pleasure of witnessing the decomposition of water by galvanism, conducted in a very simple and ingenious manner by Mr. Franklin Bache, by which the oxygen and hydrogen were separated in distinct vessels, it appeared from the phenomena, as well as from the products of the experiment, that hydrogen, as we have already stated, is given out at the negative wire, but oxygen was not given out at the positive wire, but from the positive end of the connecting wire, i. e. the end which is under the same glass with the positive wire. His apparatus was the following. Two bell glasses were inverted over water in separate vessels, under each of which was carried a wire, one from the positive, the other from the negative end of the battery. These bell glasses were now connected by a wire. It was perceived the moment the connection was made, that hydrogen gas was extricated from the negative wire, as heretofore stated; but, on the contrary, the oxygen was not given out at the positive wire, but from the positive end of the connected wire as before noticed. This experiment, therefore, contradicts some conclusions heretofore made. Mr. B. supposes, that the water is decomposed at the negative end, at which the hydrogen is given out, and that the

oxygen, from its attraction to the positive pole, is *carried along* the connecting wire, and a *part* at least is given out at the positive end of this wire. This rationale, from the phenomena of the experiment, appears to be correct, or at least extremely probable.

We are told that the portion evolved by the wire from the *zinc end* will be found to be oxygen, and that from the other end hydrogen, in the proportion by measure of one of the former to two of the latter. The following method of effecting the decomposition of water, was employed by Messrs. Dieman and Van Troostwyk.

*Experiment 28.* Take a glass tube, about one-eighth of an inch diameter, and twelve inches long, one of the ends of which is sealed hermetically, and insert a *gold wire*, projecting about an inch and a half within the tube, at this end. Fix another wire about the distance of five-eighths of an inch from the extremity of this, which may extend to the open end of the tube. The tube is next to be filled with *distilled water*; and to be placed inverted in a vessel of the same. When thus disposed, electrical shocks are to be passed between the two ends of the wire through the water; and, if these shocks be sufficiently strong, bubbles of air will be formed at each explosion, and will ascend till the upper part of the wire is uncovered by the water. As soon as this is effected, the next shock that is passed will set fire to the air, and the water will rise again in the tube, a very small quantity of gas remaining.

*Rationale.* The decomposition of the water is effected, as in the former experiments; the hydrogen and oxygen of which are *first* liberated, and *then* inflamed by a subsequent shock, and water is reproduced.

*Remark.* Mr. Cuthbertson has invented an apparatus, of a similar kind, which exhibits the same experiments with less trouble to the operator. It may be seen described and figured in Dr. Pearson's paper in the Philosophical Transactions for 1797, or in Nicholson's Journal, vol. i. and ii. 4to. See Oxygen Gas.

*Experiment 29.* Fill, with *hydrogen gas*, a bladder furnished with a stop cock and bent pipe. Then pour

into a shallow earthen dish as much mercury as will half fill it, and invert over this a glass bell, full of *common air* and perfectly dry. Expel the hydrogen gas through the pipe; light the stream, and bring it under the glass bell, by raising this, and depressing it into the mercury; as soon as the inflamed gas is introduced, a portion of air will escape, at first, in consequence of the rarefaction. As the combustion continues, *water* will form, and will condense on the sides of the glass.

*Rationale.* The hydrogen unites with the oxygen of the air, heat and light are disengaged, and water is formed; or,

*Experiment 30.* Procure a large glass globe, capable of holding three or four quarts, and having two openings opposite to each other, which may be drawn out for a short distance, like the neck of a retort. Inflamm the stream of *hydrogen gas*, and introduce it into the centre of the globe. The rarefied and vitiated air will ascend through the aperture of the globe, and a constant supply of fresh air will be furnished from beneath. A quantity of *water* will be generated, which will be condensed on the inner surface of the vessel; or,

*Experiment 31.* If *hydrogen gas* be burnt in the same manner in a vessel of *oxygen gas*, *water* will be formed, and if the hydrogen be sufficient, and the oxygen pure, the whole of the oxygen will disappear; or,

*Experiment 32.* By employing the hydro-pneumatic blow pipe, by which *oxygen* and *hydrogen* are united, the formation of water may be shewn; or,

*Experiment 33.* If a proper mixture of *oxygen* and *hydrogen gas*, according to Mr. Biot, be *suddenly* compressed, by an instrument similar to that of the condensing syringe, combustion will ensue, and *water* be formed.

*Rationale.* By compression, the particles of gas are brought into intimate union, a sufficient heat is therefore disengaged to inflame the hydrogen, and combustion ensues.

*Remark.* Besides the analytical experiments before enumerated to prove the composition of water, we are furnished with other proofs drawn from synthetical in-

vestigations, so that both analysis and syntheses confirm the fact, that water is composed of the base of two gases united, viz. oxygen and hydrogen. Water is formed in the combustion of different substances, which contain hydrogen, as in the following experiment.

*Experiment 34.* Put a little *alcohol* in a tea-cup, set it on fire, and invert a large bell glass over it. In a short time an aqueous vapour will be seen to condense upon the inside of the bell, which by means of a dry sponge may be collected, and will be found to be pure water.

*Rationale.* Alcohol is a compound of hydrogen and carbon; during combustion, its hydrogen unites with the oxygen of the air, and produces water.

*Remark.* Nature also decomposes water in many of her operations, particularly by means of any living vegetable. See Oxygen Gas. From the decomposition of water is attributed the formation of oil, wax, gum, rosin, sugar, &c. Fish, and all cold-blooded amphibious animals, are, it is said, endowed with the power of decomposing water: a fish, we are told, was kept three years in a vessel, and fed only with water; and at last it became too large to live any longer in the vessel.\*

Mr. Davy, according to some recent speculations, suspects that water is not a compound body, but is the ponderable base both of oxygen and hydrogen gases, assuming these forms according to their electrical states. An hypothesis of this nature has been suggested by Ritter, and adopted by some of the German and British chemists. Water they regarded as simple: when united to negative electricity, it constitutes oxygen gas; when united to positive electricity, it forms hydrogen gas, and in both is the sole gravitating matter.

\* Rondelet de Piscibus, lib.i. cap. 12.

## PART VIII.

### OF SIMPLE COMBUSTIBLES.

By *combustibles* we understand those substances which are capable of combustion. They are either simple or compound. By simple combustibles we mean those bodies which have not hitherto been decomposed. The metals, however, may be classed under this head; but the greater number of their properties are so different from those which we include in this class, that it is proper to consider them by themselves as a distinct set of bodies.

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### SECTION I.

#### OF CARBON.

*Experiment 1.* If pieces of *oak, willow, hazle*, or other woods deprived of their bark, be buried in sand in a crucible, and exposed, covered, to the strongest heat of a wind furnace, the *charcoal* of wood will be formed.

*Rationale.* The conversion of vegetable matter, or ligneous fibre, into charcoal, by exposing wood, or other vegetable substance, to the action of heat in a close vessel, or in a crucible covered with sand, to prevent the admission of air, takes place in consequence of the disengagement of its volatile parts, and the conversion of the fibre, by its decomposition, into a black substance, which from the process is called charcoal, and is considered an oxyd of carbon.

*Remark.* Charcoal is, therefore, the coaly residuum of any vegetable that has been burnt in close vessels. For common purposes, charcoal is made by disposing the wood in heaps regularly arranged, and covered with earth, so as to prevent the access of any more air than is absolutely necessary to support the fire, which is kept up till all the water and oil are driven off; after which the fire is extinguished by shutting up all the air holes. Charcoal is generally black, sonorous, brittle, very light, and destitute of taste or smell. It is so porous that it may be seen through with a microscope.

*Experiment 2.* Pulverise charcoal, and wash it with diluted *muriatic acid*, and afterwards with a considerable quantity of distilled water; it will then be purified.

*Rationale.* As charcoal may contain foreign matter, principally earth, the addition of *muriatic acid* will carry it off, in combination, and thus leave the coal, as it is not acted upon by the acid in a pure state.

*Remark.* It is of considerable importance in some delicate experiments, to have the charcoal of the utmost purity. By this method we are furnished with a means of accomplishing it. As charcoal enters into the composition of gun powder, it is also of importance to have it for this purpose in as fine a state as possible. This is effected by *charring* the wood in iron cylinders: light woods are preferred, such as willow, alder, poplar, and linden. When iron cylinders are employed, it is the custom in England to collect the *pyroligneous acid* from the wood, by dry distillation.

*Experiment 3.* Put *bone* into a crucible, in the same manner as in Experiment 1, or introduce it into an iron cylinder; on exposing it to a red heat, it will be converted into *coal*.

*Rationale.* In this case, the volatile matter of the bone is dissipated, and the solid or fixed parts are changed, by the action of heat, into a carbonaceous substance, known by the name of *ivory* or *bone black*.

*Experiment 4.* Pour *water* upon charcoal, and let it remain for some time; it will be found that the *water* has no action upon it: but,

*Experiment 5.* Make a little *charcoal* perfectly dry, pulverise it very fine, and put it into a warm tea cup. If some strong *nitric acid* be now poured in, so as to trickle down the inner side of the vessel and mix with the charcoal, it will burn rapidly, giving out a beautiful *flame*, and throwing up the powder so as to resemble a beautiful fire work.

*Rationale.* The acid is decomposed, combustion ensues, and the oxygen of the acid unites with the coal, forming carbonic acid, at the same time nitrous gas is disengaged.

*Experiment 6.* Take *charcoal*, pulverise it, and mix it with a weak solution of *gum arabic*; it will form the *writing ink* of the ancients.

*Remark.* The ancients wrote with levigated charcoal. The writings found in Herculaneum, which were formed with this ink, are still a perfect black. Hence its indestructible nature. The incorruptibility of charcoal was known in ancient times. The temple of Ephesus was built upon wooden piles, which had been charred on the outside to preserve them. Bishop Watson in his Chemical Essays, vol. iii. 48, says, that the beams of the theatre at Herculaneum were converted into charcoal by the lava which overflowed that city; and during the lapse of seventeen hundred years the charcoal has remained entire as if it had been formed but yesterday.

It is said that there still exists charcoal made of corn in the days of Cæsar, which is in so complete a state, that the wheat may be distinguished from the rye. We are told also, that about forty years ago a quantity of oak stakes were found in the bed of the Thames, in the very spot where Tacitus says that the Britons fixed a vast number of such stakes, to prevent the passage of Julius Cæsar and his army. They were *charred* to a considerable depth, retained their form completely, and were firm at the heart. It was a custom among the ancients to *char* the outside of those stakes which were to be driven into the ground or placed in water, in order to preserve the wood from decay.

*Experiment 7.* Mix together  $2\frac{1}{2}$  or 3 grains of *lamp-black*, or finely pulverised *charcoal*, with a solution of 25 grains of *gum copal* in 200 grains of *oil of lavender*, so that they may be intimately combined, and the *writing ink* of Mr. Close will be formed.

*Remark.* As all writing inks, into the composition of which iron enters, are liable to decay by time, and to be destroyed by various agents, the above composition was recommended to obviate these objections.

*Experiment 8.* If new-made *charcoal* be rolled up in clothes which have contracted a disagreeable odour, it will effectually destroy it.

*Remark.* Hence it is, that charcoal has been used to destroy the fetid or disagreeable odour, which clothes contract when kept in close situations.

*Experiment 9.* If a piece of *flesh-meat*, which has begun to be tainted, be rubbed daily with powdered charcoal; its sweetness will be restored: or, if meat be buried in charcoal, which is to be renewed daily, it may be preserved sweet for some time; or,

*Experiment 10.* If charcoal be added to *putrid water*; the putrid quality will be discharged, and the water return to its original state. Hence the use of charring the inner surface of the casks, which are used to contain water at sea.

*Rationale.* The antiseptic power of charcoal is accounted for either by its preventing the action of air, or a change in the body itself, by which putrefaction is retarded; or, if the change has already commenced, by decomposing the products of putrefaction.

*Remark.* Besides the application of charcoal to the purposes before stated, it may be used for correcting the empyreumatic flavour of spiritous liquors, which it effects by absorbing the empyreumatic oil; and may also be used as a dentifrice. Mr. Lowitz of Petersburg has shewn that it may be used with advantage to purify a great variety of substances.\*

Dr. Black remarks, that casks charred in the inside to hold water in sea voyages, preserves the water uncor-

\* See Crell's Annals, ii. 156.

rupted. Charcoal has a remarkable effect in destroying the taste, odour, and colour of many vegetable and animal substances. Common vinegar, by being boiled in it, is rendered perfectly limpid. The colour of litmus, indigo, and other pigments, dissolved or suspended in water, is destroyed.

*Experiment 11.* If a piece of new made charcoal, of a known weight, be exposed to the atmosphere for a day, it will be found to have increased about  $12\frac{1}{2}$  per cent. in weight.

*Remark.* This effect, being owing principally to the absorption of moisture, accounts for the rapid increase of weight, which coal undergoes on exposure to the air. According to Allen and Pepys, when coal thus charged with moisture, is exposed under mercury to the heat of  $214^{\circ}$  its water is dissipated.

*Experiment 12.* If a piece of charcoal be heated, and then plunged into a jar of atmospheric air; it will be found that the bulk of the latter is diminished.

*Remark.* A piece of charcoal previously ignited, and then plunged into mercury, in order to extinguish it, and afterwards introduced into a glass vessel filled with common air, M. La Metherie found absorbed four times its bulk of air. One fifth of the air was disengaged on plunging the charcoal into water. This air, on being examined, was found to contain a smaller quantity of oxygen than atmospherical air does.

*Experiment 13.* Plunge a piece of charcoal, in the same manner, into a jar of oxygen gas, and the bulk of the latter will be diminished.

*Remark.* The quantity of oxygen gas absorbed amounts to about eight times the bulk of the charcoal. This property of charcoal, of absorbing air, was noticed by Fontana, Priestley, Scheele and Morveau. Morozzo, however, published the first set of accurate experiments on this subject. According to Mr. Rouppe and Dr. Van Noorden of Rotterdam, seventeen cubic inches of charcoal will absorb, in five hours, 48 cubic inches of air, or 2.8 times its bulk.

*Experiment 14.* If *charcoal* be exposed in the same manner to an atmosphere of *hydrogen gas*, an absorption will take place.

*Remark.* The absorption of hydrogen gas amounts to about 0.17. It is said that charcoal, which has imbibed oxygen gas, if it be brought into contact with hydrogen gas, produces water from the union of the bases of the two gases.

Count Morozzo has given the following table of the quantities of different gases absorbed by charcoal. In each experiment he employed a piece of that substance 1 inch long, and  $\frac{3}{4}$ ths of an inch diameter. The receiver containing gas was 12 inches long, and one inch diameter.

<i>Gas absorbed.</i>	<i>inches.</i>	<i>Gas absorbed.</i>	<i>inches.</i>
Atmospheric	$3\frac{1}{2}$	Nitrous	$6\frac{5}{6}$
Carbonic acid	11	Hydrogen	$2\frac{1}{12}$
Ammonia	11	Oxygen	$2\frac{1}{6}$
Muriatic acid	11	Sulphurous acid	$5\frac{1}{2}$
Sulphuretted hydrogen	11		

*Experiment 15.* If pulverised *charcoal* be thrown into a crucible containing melted *nitre*, in the state of ignition, a violent deflagration will ensue.

*Rationale.* As charcoal has a great affinity for oxygen, it acts in this case by decomposing the nitric acid of the nitrate of potash: it is, therefore, in the act of combustion, converted into carbonic acid, part of which is disengaged, and another portion unites with the potash of the decomposed nitre, whilst the azote of the nitric acid is set at liberty, still however in union with a part of the oxygen forming nitrous gas.

*Experiment 16.* If three grains of pulverised *charcoal* be mixed with ten of *nitre*, and the mixture thrown on a red hot fire shovel, a very brilliant combustion, accompanied with a loud detonation, will be the consequence.

*Rationale.* Analogous to the preceding.

*Remark.* If fossil or pit coal be used by subjecting a given quantity into a crucible containing a certain

proportion of melted nitre, the latter will be decomposed, in the ratio to the quantity of the carbonaceous principle. Every 100 grains of nitre that are decomposed in this way, denote ten grains of carbon.

*Experiment 17.* If one part of powdered *charcoal*, one of *sulphur*, and five of *nitre*, be mixed together, and intimately combined, *gun powder* will be produced. See Nitrate of Potash.

*Remark.* The combustion of gun powder depends upon the decomposition of the nitric acid of the nitre, by the charcoal; some other changes also take place: to the production and expansion of carbonic acid and other gases, which will be hereafter noticed, the force of gun powder is attributed.

*Experiment 18.* If a mixture of *charcoal* and *nitrate of strontian* be thrown on a red hot shovel, a beautiful crimson flame will be produced.

*Rationale.* The nitric acid of the nitrate is decomposed; and, during the combustion, the flame of the charcoal is tinged by the strontian.

*Experiment 19.* If a mixture of *hyper-oxy muriate of potash* and *charcoal* be placed on a shovel heated to redness, a deflagration will ensue.

*Rationale.* The charcoal unites with the oxygen of the oxy muriatic acid of the oxy muriate, and forms carbonic acid.

*Experiment 20.* Wet a piece of *charcoal* with a solution of *muriate of gold*, or place a thin slip of it in the solution, and heat the whole by means of a sand bath, and the gold will be revived forming a singular and beautiful appearance; or,

*Experiment 21.* Proceed as in the last experiment, and place the vessel with its contents to the direct rays of the sun, and the same effect will take place.

*Rationale.* As metals become insoluble the moment they part with their oxygen, in this case the oxygen of the oxyd of gold, which is held in solution, is separated by the coal; hence the gold is precipitated. For particulars, see Gold.

*Experiment 22.* If red oxyd of lead be put into a crucible, and exposed to a violent heat, it will remain unaltered; but,

*Experiment 23.* If a mixture of charcoal and red oxyd of lead be exposed to heat, the latter will be decomposed, and the lead revived.

*Rationale.* The charcoal, therefore, acts as a flux; for it unites with the oxygen of the oxyd, and flies off in the state of carbonic acid, leaving the lead in its metallic state.

*Experiment 24.* If charcoal be put into sulphuric acid, and subjected to distillation, the acid will be decomposed.

*Rationale.* As carbon has a stronger affinity for oxygen than sulphur, in this experiment the sulphuric acid, which is a compound of sulphur and oxygen, is decomposed; sulphurous acid and carbonic acid gas passes over, and, if the quantity be sufficient, sulphur will be separated.

*Experiment 25.* If sulphate of potash and charcoal be mixed, and thrown into a crucible and heat applied, sulphuret of potash will be formed.

*Rationale.* The carbon unites with the oxygen of the sulphuric acid of the sulphate, and forms carbonic acid; the sulphur then combines with the alkali, and produces sulphuret of potash.

*Remark.* Besides the properties and uses of charcoal already enumerated, it may be proper to add, that it is a very slow conductor of caloric. It is said to be conveyed through charcoal more slowly than through sand, in the proportion of three to two. Hence powdered charcoal may be advantageously employed to surround substances which are to be kept cool in a warm atmosphere; and also to confine the caloric of heated bodies. Mr. Lavoisier concluded, from an experiment which he made, that charcoal was a compound of at least two bodies, both of which during the combustion of charcoal, unite to oxygen, and form, the one water, and the other carbonic acid. Charcoal then according to Lavoisier, is a compound of hydrogen and

carbon. Priestley, Cruikshank, and Berhollet, junior, have confirmed this deduction. Charcoal, therefore, is not pure carbon: it has been considered an oxyd of carbon. Messrs. Allen and Pepys have lately determined, that charcoal, when properly prepared, contains no sensible quantity of hydrogen. Many bituminous substances, pit-coal, petroleum, &c. contain more or less carbon. The solid bases of all vegetables, from the most delicate flower to the huge oak of the forest, is principally composed of carbon. It is a component part of wax, oils, gums, rosins, &c. Carbon combined with different proportions of iron, forms *cast iron*, *steel*, and *filumbago*. Charcoal is sometimes used by mathematical instrument makers and engravers to polish their brass and copper-plates. Plates of horn, and lanthorn leaves are polished with it.

In the combustion of oil, turpentine, &c. a soot is obtained, called *lamp black*, which is nothing more than a finer kind of charcoal. As charcoal is an oxyd of carbon, carbon properly speaking is only known to us in the state of *diamond*. The DIAMOND is a precious stone, which has been known from the earliest ages. It is transparent like crystals. Its figure is commonly in the form of a six sided prism, terminated by a six sided pyramid. It is so hard, that the best tempered steel makes no impression on it. The powder of the diamond can only be obtained by grinding one diamond against another. It is a nonconductor of electricity. Its specific gravity is about 3.5. For many ages the diamond was considered as incombustible. Sir Isaac Newton suspected that as combustibles refract light more powerfully than other bodies, and as the diamond possesses this property in great perfection, that the diamond was capable of combustion. The Florentine Academicians in the presence of Cosmo III, grand duke of Tuscany, in 1694 verified this conjecture. Several diamonds were consumed by means of a burning glass. Several more were consumed, or destroyed, in the heat of a furnace, in the presence of Francis I, emperor of Germany. Many chemists in

Europe, among whom we may include Darcet, Rouëlle, Macquer, Cadet, and Lavoisier, repeated these experiments. They proved, that the diamond was actually burnt. The diamond is not soluble in water, nor is it acted upon by any chemical agent, except oxygen at very high temperatures. When exposed in oxygen gas to the rays of the sun, concentrated by a very powerful lens, it becomes sensibly blackened; it is ignited, and at last consumed, carbonic acid gas being produced. Morveau, in 1800, found, by accurate experiments, that one part of diamond, during its combustion, combines with 4.55 parts of oxygen, and the carbonic acid gas formed amounts to 5.55. Carbonic acid gas, therefore, contains one part of diamond or 4.55 of oxygen; or 100 parts of carbonic acid gas are composed of 17.88 of diamond, and 82.12 of oxygen. Charcoal requires 2.57 times its weight of oxygen to convert it into carbonic acid, whilst the diamond requires 4.55 times its weight to undergo the same change. This can only be explained by supposing that charcoal already contains a considerable proportion of oxygen, which is wanting in diamond. This conclusion, however, has been doubted by Messrs. Allen and Pepys, from some experiments which they made on the subject. See Phil. Trans. 1807. For the gaseous compounds of carbon, see *Carbonic Acid*, *Carbonic Oxyd Gas*, and *Carburetted Hydrogen Gas*.

Mr. Davy has submitted a variety of carbonaceous substances to the agency of galvanism, and from the results he has given some new views with regard to their mutual relations. The nonconducting nature of the diamond, and its infusibility, rendered it impossible to act on it by the galvanic discharge. When heated with potassium, no elastic fluid was given out, but the diamond blackened, and scales seemed to detach themselves from it, gray externally, and internally of the colour of plumbago. For the conclusions on this subject by professor Davy, consult his paper in the *Philosophical Transactions*, 1809. They appear, however, to be generally speculative.

Mr. Pepys deflagrated charcoal with the galvanic power, after passing through 16 persons with wetted hands joined. Mr. Berthollet has lately exposed charcoal to a violent heat in porcelain and glass retorts, and shown that the gas which comes over, contains a mixture of azote. He inferred therefore, that azote is one of the constituents of charcoal.

We shall conclude this subject, by giving the following table of the

*Primary compounds of carbon.*

<b>A. Binary.</b>		<i>l.</i> Jelly.
<i>a. a.</i> With oxygen.		<i>n.</i> Tannin.
1. Incombustible coal.	} oxyds.	2. Acids.
2. Charcoal (carbonous oxyd.)		<i>a.</i> Acetic.
3. Carbonic oxyd gas.		<i>b.</i> Oxalic.
4. Carbonic acid.		<i>c.</i> Tartaric.
<i>b. b.</i> With metals; carburets.		<i>d.</i> Citric.
<b>B. Ternary.</b>		<i>e.</i> Malic.
<i>a. a.</i> With oxygen and hydrogen.		<i>f.</i> Lactic.
1. Oxyds.		<i>g.</i> Gallic.
<i>a.</i> Alcohol.	} Fluid or fusible without decomposition.	<i>h.</i> Mucous.
<i>b.</i> Ether.		<i>k.</i> Benzoic.
<i>c.</i> Fixed oils and fats.		<i>l.</i> Succinic.
<i>d.</i> Wax.		<i>m.</i> Camphoric.
<i>e.</i> Adipocire.		<i>n.</i> Suberic.
<i>f.</i> Volatile oils.		<i>o.</i> Laccic.
<i>g.</i> Resins.		<i>p.</i> Sebacic.
<i>h.</i> Camphor.		<i>q.</i> Kinic.
<i>i.</i> Starch.		<i>r.</i> Sacclactic.
<i>k.</i> Sugar.		<i>s.</i> Sebacic.
		<b>C. Quaternary.</b>
		With azote, hydrogen, and oxygen.
		1. Oxyds.
		<i>a.</i> Gum.
		<i>b.</i> Gum resin.
		<i>c.</i> Extracts.
		<i>d.</i> Lignin.
		<i>e.</i> Suber.

f. Caoutchouc.  
g. Gelatin.  
h. Albumen.  
i. Fibrin.  
k. Urea.

2. Acids.  
a. Prussic.  
b. Zoonic.  
c. Uric.  
d. Amnic.

## SECTION II.

### OF PHOSPHORUS.

*Experiment 1.* Let a quantity of *bones* be burnt to whiteness, and reduced to powder. Put 100 parts of this powder into a basin of porcelain or stone ware, dilute it with four times its weight of water, and then add gradually (stirring the mixture after every addition) 40 parts of *sulphuric acid*. The mixtures become hot, and a vast number of air bubbles are extricated. Leave the mixture in this state for 24 hours; taking care to stir it well every now and then with a glass or porcelain rod to enable the acid to act upon the powder. Pour the whole now on a filter of cloth; the liquid which runs through the filter is to be received in a porcelain basin; and the white powder which remains on the filter, after pure water has been poured on it repeatedly, and allowed to strain into the porcelain basin below, being of no use, may be thrown away. Evaporate the strained liquor in earthen vessels, placed in a sand heat, and, when reduced to about half its bulk, let it cool. A white sediment will form in considerable quantity, which must be allowed to subside; the clear solution must be decanted, and boiled to dryness in a glass or porcelain vessel. A white mass will remain which is the dry *phosphoric acid*. Pulverise this and mix it with its weight of charcoal; or to the evaporated liquor, which when acquiring a thick consistence powdered charcoal may be added, in sufficient quantity, to give it solidity. In the latter mode, however, the materials are apt to swell, and boil over. The mix-

ture is then to be put into a stone ware retort, which may be coated in the usual manner, and the neck of which is lengthened out by a tin pipe. The open end of the pipe is to be immersed in a vessel of water. The heat is to be slowly raised, and at length made very intense. An enormous quantity of gas escapes, which takes fire on coming into contact with the atmosphere, and phosphorus will distil over in drops, which congeal in the water.

*Rationale.* When bone, and indeed most of the solid parts of animals, are burnt in the open air, their volatile parts, gelatine, &c. are dissipated or consumed, and there remains a white ash, called bone ash. This is principally composed of lime and phosphoric acid. On adding sulphuric acid, the phosphoric acid is disengaged, and a compound of lime and sulphuric acid is formed. The phosphoric acid, therefore, remains in solution. When the whole is subjected to the filter, the sulphate of lime is separated, and the liquor which runs through is phosphoric acid in solution, but containing, however, an admixture of some sulphate of lime. Hence, on evaporation, this is deposited. When the fluid is now evaporated to dryness, and the dry mass, which is solid phosphoric acid, is mixed with charcoal and distilled, the product of distillation is phosphorus; for as the carbon unites with the oxygen of the phosphoric acid, forming carbonic acid, it follows, that the phosphorus is deprived of its oxygen, and is obtained in a free state. The gas which takes fire is phosphuretted hydrogen, arising either from the decomposition of moisture in the coal, or the combination of hydrogen, which coal generally contains, with a portion of phosphorus.

*Remark.* As the phosphorus is apt to condense in, or stop up the neck of the retort and tin pipe, it must be occasionally melted out of these, by a shovel full of hot cinders, held under them. Three pounds of bones yield an ounce and a half and 30 grains of phosphorus, if the process be well conducted.

*Experiment 2.* Proceed as in the last experiment, except the evaporation, and mixing of charcoal, and

add to the liquid a solution of *nitrate of lead*, by degrees a white powder will fall to the bottom. The addition of the *nitrate* is to be continued until no more precipitate is formed. Collect this precipitate, by pouring the whole upon a filter, wash it, dry it, and mix it with about  $\frac{1}{6}$ th of its weight of *charcoal* powder. Expose the mixture in a retort to the action of heat, as in the last experiment, and phosphorus will be obtained.

*Rationale.* In this experiment the phosphoric acid unites with the lead of nitrate, and forms phosphate of lead, which is precipitated. When this is mixed with charcoal, and distilled, the charcoal carries off the oxygen of the phosphoric acid, forming carbonic acid, whilst the phosphorus is set at liberty, which is then volatilized as before; at the same time the lead is revived.

*Experiment 3.* If *nitrate of lead* be added to *urine*, a white powder will fall, which, when collected and treated with charcoal as before, affords *phosphorus*.

*Rationale.* As urine contains phosphoric acid in combination with soda and ammonia, in the form of a triple phosphate or microcosmic salt, the addition of nitrate of lead separates the phosphoric acid by compound affinity. The nitric acid of the nitrate unites with the soda and ammonia, whilst the phosphoric acid combines with lead, and precipitates a phosphate of lead. This is then decomposed by charcoal, in the same manner as before stated.

*Experiment 4.* If *acetate of lead* be added to *urine*, a powder is also obtained, which when treated in the same manner with charcoal, produces *phosphorus*.

*Rationale.* The same as the preceding, except acetate of soda and ammonia are formed by the double decomposition.

*Experiment 5.* If the *phosphate of lead*, produced as in the last experiment, be washed, and decomposed by means of *muriatic acid*, the *phosphoric acid* is disengaged in a liquid state, which, when evaporated to dryness, and mixed with *charcoal*, and treated as in the former experiments, yields phosphorus.

*Rationale.* In this case the phosphate of lead is produced from the urine, by the agency of acetate of lead, and is decomposed by muriatic acid; an insoluble muriate of lead being produced. The phosphoric acid, thus disengaged, being evaporated to dryness, and disoxygenized by means of charcoal, affords phosphorus.

*Experiment 6.* According to Margraaf, if ten pounds of *urine* be evaporated to the consistence of honey, and mixed with *muriate of lead* (remaining after the distillation 4lbs. of *minium* and two of *muriate of ammonia*) and half a pound of *charcoal*, and this mixture dried in an iron pot until reduced to a black powder, and distilled in an earthen retort *phosphorus* will be obtained.

*Rationale.* The muriate of lead here decomposes the phosphoric salt, and produces a phosphate of lead, which is decomposed by the charcoal in the manner before stated.

*Experiment 7.* Take a solution of *phosphate of soda*, and mix it with one of *acetate of lead*, in the proportion of one part of the former salt, to one and a quarter of the latter; a precipitate will be obtained, which when collected, washed, dried, mixed with *charcoal*, and distilled, yields *phosphorus*.

*Rationale.* In this experiment a double affinity takes place: the phosphoric acid unites with the lead forming a phosphate of lead, which is precipitated, whilst the acetic acid of the acetate of lead, unites with the soda, producing an acetate of soda, which remains in solution. The phosphate of lead is then collected, and treated with charcoal as in the preceding experiments; the theory of which has already been stated.

*Remark.* Brandt, a German chemist, discovered phosphorus in the year 1669, when prosecuting some experiments on urine. Kunckel saw it, and communicated the fact to one Kraft, a friend of his at Dresden. Kraft purchased the secret from Brandt for 200 dollars. Soon after he exhibited it in France. Kunkel, however, prepared it himself without any knowledge of the process, although he saw the phosphorus which Brandt prepared. Kraft it is said taught Boyle, who commu-

nicated the process to Godfrey Hankwitz, a London apothecary, who continued to supply all Europe with phosphorus. Hence it was known to chemists by the name of *English phosphorus*. It was afterwards made in France. But it was not until a subsequent period, that it was found that bones would afford phosphorus. This fact was discovered in 1769 by Gahn. Scheele, a Swedish chemist, very soon after, invented a process for obtaining it from bones. Since this period, the process was improved, principally by Fourcroy and Vauquelin. Several dissertations have appeared on the properties of phosphorus.

Phosphorus, when pure, is semi-transparent, and of a yellowish colour; but when kept some time in water, it contracts the appearance of white wax. It may be cut with a knife. It is insoluble in water. Its mean specific gravity 1.770. Phosphorus, when used internally, is poisonous. It has been employed, however, as a medicine. It is related in the *Annales de Chimie*, that a great number of domestic fowls were poisoned merely by drinking the water in which phosphorus had been put. Mr. Davy suspects, that phosphorus, though considered a simple, is a compound body, and that it contains hydrogen as one of its component parts.

*Experiment 8.* If figures be marked on a wall, with *phosphorus*, and the room darkened, they will appear luminous.

*Rationale.* The emission of light is owing to the gradual absorption of oxygen, by the decomposition of oxygen gas; heat and light are set at liberty from the gas, and the phosphorus is converted into *phosphorous acid*. The phosphorus emits a white smoke.

*Experiment 9.* If water be heated to about 100°, according to Pelletier, and phosphorus introduced into it, it will melt.

*Remark.* Phosphorus when exposed to the open air and heat applied, will inflame; but if the same heat be used through the medium of water, it will only melt. As phosphorus when first prepared is mixed with im-

purities, it may be freed from them by melting it in hot water, and straining it through a piece of clean shamois leather. It may be formed into sticks, by putting it in a glass funnel with a long tube, stopped at the bottom with a cork, and plunging the whole under warm water.

*Experiment 10.* If a retort be filled with *hydrogen*, or *azotic gas*, and phosphorus introduced; it will evaporate when a temperature of  $554^{\circ}$  is applied.

*Remark.* The retort should be supplied with the gas, to prevent an absorption, which may be effected by filling a bladder with the gas; through the stop cock into the retort, it may be forced by compressing the bladder. The use of azotic or hydrogen gas is obvious, as they are non-supporters of combustion.

*Experiment 11.* If *phosphorus* be immersed in a jar of *oxygen gas*, heated to  $60^{\circ}$ , according to Fourcroy and Vauquelin, a part of it is dissolved; but, if the temperature of the gas be raised to  $80^{\circ}$ , the *phosphorus* becomes luminous.

*Remark.* We learn, therefore, that phosphorus burns at a lower temperature in common air than in oxygen gas.

*Experiment 12.* If a piece of *phosphorus* be rubbed between two pieces of brown paper, it will inflame.

*Rationale.* The heat produced by friction inflames the phosphorus, which of course, decomposes the oxygen gas of the atmosphere.

*Experiment 13.* If a piece of *phosphorus*, according to Dr. Higgins, be exposed to a temperature of  $60^{\circ}$ , it will inflame.

*Remark.* It is said, however, on the authority of Dr. Thomson, that at a temperature of  $148^{\circ}$ , phosphorus takes fire, and gives out a great quantity of white smoke, which when collected will be found to possess acid properties. This acid is the phosphoric, and is composed of phosphorus and oxygen. From Mr. Lavoisier's experiments it follows, that 100 parts of phosphorus during this combustion, unite with 154 parts oxygen. One grain of phosphorus condenses no less than  $4\frac{1}{2}$  cu-

bic inches of oxygen gas, and five grains are capable of depriving  $102\frac{1}{4}$  cubic inches of air of all its oxygen gas. It is conjectured, that the reason why phosphorus sometimes inflames at a low temperature, is because it contains a portion of oxygen. It is also said that phosphorus in this state is an oxyd, which has been called an oxyd of phosphorus. Phosphorus in this state is distinguished by its appearance—that of white flakes. It is this kind which usually forms the phosphoric matches, and phosphoric bottles. The phosphorus, for this purpose, is generally mixed with sulphur. Phosphorus, long acted upon by water, is changed into an oxyd, which may be separated by plunging it into water heated to about  $100^{\circ}$ . The phosphorus melts, while the oxyd remains unchanged.

*Experiment 14.* If any light substance capable of conducting heat be placed upon the surface of boiling water, and a bit of *phosphorus* be laid upon it, the *phosphorus* will immediately inflame.

*Remark.* The heat of the water is here sufficient to set the phosphorus on fire.

*Experiment 15.* If *nitric acid* be poured on a mixture of *phosphorus* and *oxygenized muriate of potash*, flashes of fire will be emitted at intervals for some time.

*Rationale.* The oxymuriate is decomposed by the acid; the oxymuriatic acid gas thus disengaged, inflames the phosphorus, phosphoric acid and common muriatic acid gas being the result.

*Experiment 16.* Introduce into a flask 30 grains of *phosphorus*, and three or four ounces of *water*. Apply the heat of a lamp; so that ebullition may take place. Balls of fire will issue from the water, after the manner of artificial fire works, attended with most beautiful coruscations.

*Rationale.* The ebullition of the water causes the melted particles of the phosphorus to be thrown up, which are then inflamed by the oxygen gas of the atmosphere.

*Experiment 17.* Put *phosphorus* into a tumbler of boiling water, and from a bladder furnished with a stop

cock, force a stream of *oxygen gas* directly upon it, and combustion under water will take place.

*Rationale.* The oxygen combines with the phosphorus and forms phosphoric acid, as in a former experiment, heat and light being set at liberty.

*Experiment 18.* If *phosphorus*, surrounded by cotton rubbed in powdered rosin, be placed under the receiver of an air pump, it will take fire when a part of the pressure of the atmosphere is removed, and on the gradual admission of air, will exhibit a beautiful phenomena.

*Remark.* This experiment is rather singular. On removing the pressure of external air, it appears that when a part of the air is exhausted, consequently a dilatation of the remaining air ensues, the phosphorus inflames, though a less portion of oxygen gas is presented to it. On admitting fresh air, the combustion which has thus begun, is continued.

*Experiment 19.* Put a small thin bottle into sand contained in a ladle, heat it, and introduce into it a few grains of *phosphorus*. Stop the mouth of the bottle loosely, then add by degrees more phosphorus. The phosphorus will thus be melted, and form the *phosphoric fire-bottle*.

*Remark.* The phosphorus is partly oxydized. On immersing a sulphur match, it will inflame when it comes to the air; or,

*Experiment 20.* Proceed as in the last experiment, and add to the *phosphorus* one sixteenth part of *sulphur*, melt them together, and a *phosphoric fire-bottle* will also be formed; or,

*Experiment 21.* If *phosphorus* and *sulphur*, in the same proportions, be added to boiling water, a compound will be formed having the same properties as the last. It must be taken out, and put into a bottle.

*Experiment 22.* Take a glass tube, about four inches long, and one line wide, closed at one end. A small quantity of *phosphorus* is to be introduced into the tube, and pushed to its extremity by an iron wire, after which a taper covered at one end with wax is put into it; the open end of the tube is to be hermetically seal-

ed, and the other plunged into hot water. The *phosphorus* melts, and fixes as it cools upon the taper. A line is then drawn by means of a diamond or file, at one third of the tube. To use these *phosphoric tapers*, the tube is broken at the marked line; and when it is quickly drawn out, it takes fire, and burns rapidly.\*

*Experiment 23.* If *phosphorus* be dissolved in *sulphuric ether*, forming the *phosphorized ether*, and poured into a decanter containing a little water, a brilliant light will appear, which passes with a serpentine motion along the surface of the fluid. The air also becomes luminous.

*Experiment 24.* If air be now blown into the decanter, the luminous vapour disappears; if the mixture be again agitated, several luminous points appear at the surface of the water.

*Experiment 25.* Dip a feather wetted with water into *phosphorized ether*; when the fluids come in contact flashes of light appear (in a dark place) to issue out of the mouth of the vial.

*Experiment 26.* Wet a lump of sugar with *phosphorized ether*, and drop it into a glass of water a little warm. The surface of the water will soon become luminous; and if it be moved by blowing gently with the mouth, beautiful and brilliant undulations of its surface will be produced, exhibiting the appearance of liquid combustion.

*Experiment 27.* If *phosphorized ether* be rubbed on the face or hands, and the room be darkened, the face or hands will appear as though they were on fire without producing any dangerous effect, or sensation of heat.

*Rationale.* Water, in some of these experiments, has the property of separating phosphorus from its solvent, so that it emits, when exposed to the air, a luminous appearance, which is nothing more than a slow combustion of the phosphorus.

\* Accun, i. 198.

*Experiment 28.* Put into a vial one part of *phosphorus* and six of *olive oil*; place it in warm ashes, and a solution will be formed, which is the *phosphoric oil*, or *liquid phosphorus* of some authors; or,

*Experiment 29.* Add to one part of *phosphorus* in a mortar one sixteenth part of *sulphur*, and a small quantity of *olive oil*; triturate them together, and *phosphoric oil* will be obtained.

*Remark.* Phosphorus dissolved in oil has the property of becoming luminous in the dark, as soon as the vial containing it is unstopped, and opaque again when the vial is corked. Liquid phosphorus, as it is called, may serve for showing the hour of the night, by holding a watch against the bottle when unstopped. Luminous writings or drawings, by means of a brush, may be formed with it. It may be rubbed on the face or hands without injury.

*Experiment 30.* Put a table spoonful of water into a cup, put it over the fire and add a small quantity of *phosphorus*: when the water boils pour into it about one dram of *sulphuric acid*, and a considerable ebullition will take place, accompanied with combustion, which will be followed by a loud explosion.

*Rationale.* The accension of phosphorus by sulphuric acid, is owing to the evolution of heat by the mixture of the acid and water.

*Experiment 31.* With a needle pass a thread through a small piece of *phosphorus*, previously freed from moisture by immersing it in alcohol. If this be suspended in an aqueous solution of *muriate of gold*, in a few minutes the phosphorus will become covered with pure gold.

*Rationale.* The phosphorus has a stronger affinity for oxygen than gold has; hence the solution of the latter is decomposed, and the oxygen taken from the gold.

*Remark.* Not only the solution of gold, but also the solutions of silver, mercury, tin, lead, and manganese are all de-oxygenized by phosphorus, and in some instan-

ces the phosphorus unites with a portion of the metal forming a phosphuret.

*Experiment 32.* When *phosphorus* is exposed to the air, it is changed first into *oxyd of phosphorus*, and then into *phosphorous acid*, which appears in a liquid state.

*Remark.* According to the quantity of oxygen absorbed, or the degree of oxygenizement of the phosphorus, the acid produced will be either the phosphorous or the phosphoric.

*Experiment 33.* If *nitric acid* be poured on *phosphorous*; or *nitric acid* heated in a flask and *phosphorous* gently added, *phosphoric acid* will be formed.

*Rationale.* The nitric acid is decomposed; nitric oxyd gas is evolved, and the phosphorous unites with a portion of oxygen, and forms phosphoric acid.

*Experiment 34.* If *oxymuriatic acid* be added to *phosphorus*, the latter will be changed into *phosphoric acid*.

*Rationale.* Here the oxygen of the oxymuriatic acid unites with the phosphorus, and the oxymuriatic is accordingly changed into the common muriatic acid.

*Experiment 35.* If a glass tube be provided, about thirty or forty inches in length, with one of its ends closed, and filled with mercury; and then immersed in a mercurial trough, the mercury will descend several inches, or until an equilibrium is established with the pressure of the air. A vacuum will therefore be formed. If a piece of *phosphorus* be thrown up, no combustion will ensue; but if *oxygen gas* be passed up, as soon as it comes in contact, and the temperature gently raised, inflammation will ensue, exhibiting a beautiful phenomena. See Experiment 17.

*Rationale.* In vacuo, phosphorus does not burn, but in oxygen gas, as in other experiments, combustion takes place, and phosphoric acid is produced.

*Remark.* Phosphorus, besides the combinations already stated, is susceptible of union with a number of bodies. The solid white sublimate obtained by introducing phosphorus into oxymuriatic acid gas, Mr. Davy considers as a compound of muriatic and phosphoric

acids, to which the name of *murio-phosphoric acid* has been given. Phosphorus unites with carbon, and forms phosphuret of carbon, and with many of the alkalies, earths, and metals, which will be hereafter noticed. These combinations are given in the following table of the

*Primary Compounds of Phosphorus.*

- a. With oxygen.
  - 1. Oxyd of phosphorus.
  - 2. Phosphorous acid.
  - 3. Phosphoric acid.
- b. With azote. Phosphuretted azotic gas.
- c. With hydrogen. Phosphuretted hydrogen gas.
- d. With sulphur. Phosphuret of sulphur.
- e. With metals. Metallic phosphurets.
- f. With salifiable bases. Alkaline and earthly phosphurets.

## SECTION III.

### OF SULPHUR.

*Experiment 1.* If iron pyrites or *sulphuret of iron* be broken into small pieces and put into large earthen tubes, connected with a square vessel of cast iron, containing water, as a receiver, and exposed to the action of heat; *sulphur* will be obtained.

*Rationale.* Pyrites used in this experiment are a compound of sulphur and iron, and are known by the name of martial pyrites. When they are exposed to heat, they are decomposed, sulphur is disengaged, and the metal remains in the distilling vessel.

*Remark.* The sulphur procured in this manner accumulates on the water in the receiver, from which it is taken and melted in large iron ladles, the earthy matter is thus partly separated. It is again melted, and poured into cylindrical wooden moulds, hence it takes

that form, and is called in commerce *roll sulphur*. This, for the purpose of medicine, is purified by sublimation, as we shall presently notice.

Sulphur is found abundantly in the earth, but principally in combination with metals. With lead, copper, tin, zinc, arsenic, &c. it forms native sulphurets. With alumina and lime, it forms the different *schist*, known by the name of *alum ores*. It exists in the neighbourhood of volcanos, also in masses, in gypsum, marle, sometimes in primitive rocks, and Van Humboldt has discovered it along with quartz in a mountain of micaceous schistus. It has also been detected in the albumen of eggs, in mineral waters, and in vegetable substances.

*Experiment 2.* If *roll sulphur* be put into a vessel, to which a subliming head is attached, and heat applied, the sulphur will rise, or sublime, in a fine powder, forming the *flowers of sulphur*.

*Rationale.* The heat causes the sulphur to be vaporized, the vapour of which condenses, whilst the foreign matter remains behind.

*Remark.* In the large way flowers of sulphur are formed by conducting the process with a gentle heat in a close room, where the sublimed sulphur is collected. At a temperature of  $170^{\circ}$  sulphur begins to evaporate, which may be shown by placing it on a heated shovel; at  $190^{\circ}$  it begins to melt, and at  $218^{\circ}$  it becomes as liquid as water.

*Experiment 3.* Boil one part of *flowers of sulphur* in twenty parts of distilled water in a glass vessel for about a quarter of an hour, and then decant the water; or,

*Experiment 4.* Pour boiling water on the *sulphur*, decant the fluid, and dry the residue; it will form the *washed sulphur* of the shops.

*Rationale.* Sulphur itself is insoluble in water, but that fluid has the property of dissolving any saline matter, or sulphurous acid which flowers of sulphur generally contain.

*Experiment 5.* If three parts of *nitro-muriatic acid*, be poured and digested on one of *flowers of sulphur*, previously diluted with one part of distilled water, the fluid afterwards decanted, and the residue washed in distilled water, *pure sulphur* will be obtained.

*Remark.* The *nitro-muriatic* has the property of dissolving any foreign matter, which was insoluble in water, when the sulphur passed the operation of washing. Hence the sulphur is purified.

*Experiment 6.* If *sulphur* be melted in a deep earthen vessel, and the part which remains fluid below the surface be allowed to escape, by piercing a hole near the edge of the vessel, the sulphur will crystallize in a needle-shaped octahedral figure.

*Remark.* The method of crystallizing sulphur was contrived by Rouelle. If the experiment be made in a glass vessel, or upon a flat plate of iron, the crystals will be perceived, beginning to shoot when the temperature sinks to 220°.

*Experiment 7.* Put purified *sulphur* into *alcohol*; it will remain unaltered, nor will the alcohol be changed; but,

*Experiment 8.* Put *flowers of sulphur* into a matrass furnished with an alembic; suspend within it a cup or wide-mouthed bottle containing alcohol, then put on the alembic, and adjust a vial to the beak; lute the joinings, and apply the heat of a lamp, sulphur will thus be dissolved, and distil over with the alcohol.

*Rationale.* The union of sulphur with alcohol takes place in consequence of the two meeting in a vaporized state forming *phosphorized alcohol*.

*Experiment 9.* If to the product of Experiment 8, water be added, the sulphur will be precipitated.

*Rationale.* This is a proof that sulphur is dissolved. The water unites to the alcohol, and the sulphur being insoluble in diluted spirit, is precipitated.

*Experiment 10.* One part of *sulphur* added to eight of *sulphuric ether* will be dissolved.

*Experiment 11.* Threads dipped in melted *sulphur*, and afterwards inflamed, previously placed in a cup, and then covered with a jar, will burn, and evolve a

white smoke. This will be absorbed, and a diminution of volume in the jar will ensue. The water, if now examined, will have a suffocating odour and taste, and turn the blue colour of litmus paper red.

*Rationale.* This experiment being an instance of the slow combustion of sulphur, exhibits the production of an acid, the sulphurous, by the union of the sulphur with the oxygen of the atmosphere. The sulphurous acid gas, the product of combustion, is absorbed by the water. See Sulphurous Acid Gas.

*Experiment 12.* Introduce a mixture of one part of *nitrate of potash* and six of *sulphur*, placed in a copper spoon, and lighted, into a vessel of atmospheric air placed over water, and a rapid combustion will ensue.

*Rationale.* The sulphur, in this case, is further oxygenized; for the nitric acid of the *nitrate of potash* is decomposed, and furnishes oxygen gas, into which the sulphur is plunged the instant of its inflammation. The product is, therefore, sulphuric acid; or,

*Experiment 13.* If *sulphur* be burnt in *oxygen gas*, the same product will be formed.

*Remark.* The combustion of sulphur was attributed by Stahl to a principle, or substance, which he called *phlogiston*; and that all bodies which contained it, he affirmed were inflammable. This theory was unsatisfactory, and it was not until the time of Lavoisier that it was properly explained. His experiments were conclusive. He proved that the air was diminished, and that the body absorbed or combined with the sulphur was oxygen. Hence it is, that sulphur is acidified in the process of combustion.

*Experiment 14.* If *sulphur* be boiled in *nitric acid*, *sulphuric acid* will be formed.

*Rationale.* The nitric acid is decomposed, a part of its oxygen unites with the sulphur, forming with it sulphuric acid, whilst another portion is dissipated in union with azote constituting nitric oxyd or nitrous gas.

*Remark.* From well attested experiments, it seems that sulphuric acid is composed of 42.3 sulphur, and

57.7 oxygen, and that sulphurous acid contains 53 sulphur and 47 oxygen in the hundred. See Sulphuric and Sulphurous Acids.

*Experiment 15.* If *sulphur* be melted in an iron ladle, and in this state poured into water, it will be found, when cold, of a red colour, and as soft as wax.

*Remark.* In this state, sulphur is employed to take off impressions from seals and medals. These casts are known by the name of *sulphurs*. Sulphur, thus treated, is said to be combined with a portion of oxygen forming an oxyd of sulphur. This is more particularly the case when sulphur is made viscid and red by long boiling.

*Experiment 16.* If common *sulphur* be sublimed into a vessel filled with the vapour of water, the sulphur will form into flowers of a white colour.

*Rationale.* In this experiment the colour of the sulphur is changed by its combination with water, forming the *lac sulphuris* or *milk of sulphur*.

*Experiment 17.* Into a solution of *sulphuret of potash* pour diluted *nitric* or *muriatic acid*, and the *sulphur* will be precipitated of a white colour.

*Rationale.* The acid unites with the alkali, and the sulphur is precipitated in union with a portion of water, which, when collected, washed, and dried, forms the milk of sulphur as in the last experiment.

*Remark.* When *lac sulphuris* is exposed to a low red heat in a retort, or evaporating dish, it soon acquires the colour of common sulphur, and, when the retort is used, a quantity of water will be found in its beak. If also a little water is dropped into melted sulphur, the portion in contact with the water immediately assumes the white colour of *lac sulphuris*. Hence it is said that the orange, or greenish yellow is the natural colour of sulphur.

*Experiment 18.* If charcoal, according to Messrs. Clement and Desormes, be heated to redness in a porcelain tube; and, when it has been continued in this state for a short time, a portion of *sulphur* be made to come in contact with it, excluding at the

same time atmospheric air, a substance passes through in the form of a liquid.

*Remark.* Lampadius obtained this liquid by distilling a mixture of pyrites and charcoal, which he called *alcohol of sulphur*. Some suppose it to be a compound of sulphur and hydrogen. With Berthollet we may conclude, that this conjecture is correct, for that chemist made a number of experiments on the subject, and proved that it is composed of sulphur and hydrogen without any perceptible mixture of carbon, and that it contains a greater proportion of sulphur than sulphuretted hydrogen. It has therefore been called *super-sulphuretted hydrogen*. Clement and Desormes considered it as a compound of sulphur and charcoal. There is a certain state only in which this preparation is formed; for if the proportions be not correct, or either of the materials not sufficient, a compound of sulphur and hydrogen will be formed, which will take the aeriform state.

*Experiment 19.* Into a vial or tube introduce some *sulphur*, melt it, and add *phosphorus*, stopping the vial at the same time, and a compound of phosphorus and sulphur will be formed.

*Remark.* This combination, which was first noticed by Margraaf, is, if the proportions of sulphur be sufficient, a sulphuret of phosphorus. When properly prepared it has a yellowish white colour, and a crystallized appearance. The compound of the two is more combustible than phosphorus.

*Experiment 20.* If *sulphur* and *phosphorus* be put into a flask, and filled with water, and heat applied, a combination of the two will be formed.

*Remark.* The heat should be gradual, otherwise an explosion may follow, as the water sometimes is said to be decomposed.

*Remark.* Sulphur, though considered a simple, is affirmed to be a compound substance, especially from some experiment made by Mr. Clayfield, in which hydrogen is a component part. Sulphur unites, as we formerly remarked, with a variety of substances; as will appear from the following table of

*The Primary Compounds of Sulphur.*

- a. With oxygen.
  - 1. Oxyd of sulphur.
  - 2. Sulphurous acid.
  - 3. Sulphuric acid.
- b. With azote. Sulphuretted azotic gas.
- c. With hydrogen.
  - 1. Sulphuretted hydrogen.
  - 2. Super-sulphuretted hydrogen.
- d. With water. Milk of sulphur.
- e. With phosphorus. Sulphuret of phosphorus.
- f. With oil. Sulphurized oil.
- g. With alkalies.
  - 1. Sulphuret of potash.
  - 2. Sulphuret of soda.
  - 3. Sulphuret of ammonia.
- h. With earths.
  - a. Sulphuret of barytes.
  - b. Sulphuret of strontian.
  - c. Sulphuret of lime.
  - d. Sulphuret of magnesia.
  - e. Sulphuret of alumina.
- i. With metals.
  - a. Sulphuret of iron.
    - 1. Common sulphuret of iron.
    - 2. Super-sulphuret of iron.
  - b. Sulphuret of arsenic.
    - 1. Red arsenic.
    - 2. Yellow arsenic.
  - c. Sulphuret of lead.
    - 1. Sulphuret of lead.
    - 2. Super-sulphuret of lead.
  - d. Sulphuret of tin.
    - 1. Sulphuret of tin.
    - 2. Sulphuretted oxyd of tin.
  - e. Sulphuret of antimony.
    - 1. Sulphuret of antimony.
    - 2. Super-sulphuret of antimony.
  - f. Sulphuret of silver.
  - g. Sulphuret of bismuth.

- h.* Sulphuret of copper.
  - 1. Common sulphuret of copper.
  - 2. Super-sulphuret of copper.
- i.* Sulphuret of mercury.
  - 1. Ethiops mineral.
  - 2. Vermillion.
- k.* Sulphuret of palladium.
- l.* Sulphuret of rhodium.
- m.* Sulphuret of nickel.
- n.* Sulphuret of tellurium.
- o.* Sulphuret of uranium.
- p.* Sulphuret of molybdenum.
- q.* Sulphuret of tungsten.

As it respects the preparation, and chemical properties of these substances, such as have not been given will be noticed under their appropriate heads.

## SECTION IV.

### OF BORACIUM.

*Experiment 1.* Put equal weights of the metal called *potassium* and dry *boracic acid* into a copper tube, and expose it for some minutes to a slight red heat. When cold, wash the mass out with water, saturate the *potash*, which is formed, with muriatic acid, and throw the whole upon a filter. The olive coloured matter is to be washed and dried. It is *boracium*.

*Rationale.* According to the experiments of Davy, Thenard and Gay Lussac, that boracic acid is a compound of boracium and oxygen, it appears that in this process the boracic acid is decomposed; its oxygen unites with the potassium, forming potash, whilst the boracium is disengaged. On adding muriatic acid, the alkali is dissolved, and then detached from the boracium.

*Remark.* The olive coloured matter, or boracium, is suspected by Mr. Davy to contain a little oxygen,

and that, when deprived of this principle, it combines with metals, and forms compounds capable of conducting electricity. He infers, therefore, that if it were pure it would be of a metallic nature. Boracium is opaque, brittle, does not scratch glass, is a non-conductor of electricity, and has some resemblance to charcoal. When exposed to a strong heat in a metallic vessel, it remains unaltered, if common air or oxygen be excluded. It has now the property of sinking in sulphuric acid.

*Experiment 2.* If *boracium* be heated in common air to a temperature of about  $600^{\circ}$ , it inflames, and produces *boracic acid*; or,

*Experiment 3.* If it be exposed to *oxygen gas*, under the same circumstances, the same result will take place.

*Rationale.* The boracium unites with oxygen at a high temperature, and forms boracic acid; whilst the heat and light of the decomposed gas are set at liberty. In the former experiment the oxygen is presented by the atmospheric air.

*Experiment 4.* If *boracium* slightly heated, be placed in contact with *oxymuriatic acid gas*, inflammation will ensue, and the products will be *boracic acid* and *oxyd of boracium*.

*Rationale.* At a moderate temperature, boracium decomposes oxymuriatic acid gas; a part of it unites with a part of the oxygen of the gas and forms boracic acid, whilst another portion combines with the remaining part of the oxygen, and produces a black coloured matter, or oxyd of boracium, the oxymuriatic being reduced to the common muriatic acid.

*Experiment 5.* If *boracium* be added to *nitric acid*, and heat applied, it is changed into *boracic acid*.

*Rationale.* The nitric acid is partially decomposed; nitric oxyd gas is disengaged, and the boracium is converted into boracic acid.

*Experiment 6.* If *boracium* be treated in the same manner in *sulphuric acid*, the same result will ensue.

*Rationale.* The sulphuric acid parts with a portion of its oxygen, which converts the boracium into boracic acid, whilst a disengagement of sulphurous acid takes place.

*Experiment 7.* If *boracium* be added to *potash* or *soda* in solution, a compound is formed of a pale olive colour; or,

*Experiment 8.* If the same articles be put into a crucible and melted, the like combination will be formed.

*Remark.* It appears, therefore, that boracium is susceptible of combination with some of the alkalies in the same manner as sulphur, forming what I would call *boraciurets*.

The properties of this substance have not been sufficiently investigated to afford extensive experiments, although we are considerably indebted to Mr. Davy and the French chemists for some interesting facts. Mr. Davy has lately given the name of *caron* to boracium.

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## SECTION V.

### OF HYDROGEN.

Hydrogen, as the base of hydrogen gas, is a simple substance, and is therefore classed among the simple combustibles. But as we only know it in the state of combination, as for instance in hydrogen gas, its properties can not here be investigated. In the work it has accordingly been considered in the character of a compound body, that of gas; for an account of which, see the Preparation and Properties of Hydrogen Gas. Under the latter we have noticed its properties, and also some of its combinations, in the formation of oils, fats, ardent spirits, ether, and other inflammable substances of which it constitutes a part.

## PART IX.

### OF ALKALIES.

Alkali is a word of Arabian origin, and was introduced into chemistry after its application to a plant which still retains the name of *kali*. This plant, when burnt, the ashes washed in water, and the water evaporated to dryness, furnishes a white substance, which was called *alkali*. According to *Albertus Magnus*, the word signifies the "dregs of bitterness." Alkali, in chemical language implies all those substances which possess the following properties: viz. a caustic taste, volatilized by heat, capable of combining with acids, and of destroying their acidity, soluble in water even when combined with carbonic acid, and capable of converting vegetable blues to green. The alkalies properly so called are three, namely, potash, soda and ammonia. The two first are called *fixed alkalies*, because they require a red heat to volatilize them; the last is called *volatile alkali*, because it readily assumes the gaseous form. The general properties of the alkalies may be learnt from the following experiments.

*Experiment 1.* Take an ounce of a solution of *potash*, and add to it about half an ounce of *sulphuric acid*, or until it is saturated; evaporate it gently for a few minutes; or lay the mixture aside, and when cold, crystals will be formed, possessing characters distinct from either the alkali or the acid.

*Rationale.* The acid and alkali combine, destroy the individual properties of each other, and a mild salt, viz. sulphate of potash, is formed from these two corrosive substances.

*Experiment 2.* If *soda* be treated in the same manner, a union will ensue and form a mild salt, as in the last experiment.

*Rationale.* The sulphuric acid combines with the soda, and forms sulphate of soda.

*Experiment 3.* To soda add *muriatic acid*, and the alkali and acid will lose their separate properties, as before.

*Rationale.* The muriatic acid combines with the soda, forming muriate of soda.

*Experiment 4.* Make an *infusion of red cabbage* and put it into three wine glasses. To one add a solution of *alum*, and a purple colour will be produced, to the second a little solution of *potash*, a green will follow, and to the third a few drops of *muriatic acid*, which will change it to a crimson.

*Rationale.* As the action of acids is contrary to alkalis, it is evident that the alum, which is a super salt, and muriatic acid, changes the infusion to purple and crimson, whilst the alkali converts it to green, owing to the circumstances already noticed under the head of light.

*Experiment 5.* If to the *tincture of litmus*, which is of a blue colour, a few drops of any *acid*, say *muriatic*, be added, its colour will be changed to a vivid red, but on adding a solution of *potash*, this will be destroyed, and its original colour will be produced.

*Rationale.* Litmus is changed to red by acids, but if alkali be added, the acid is taken up, forming with it neutral salt (muriate of potash) and consequently the litmus regains its former colour.

*Experiment 6.* If paper be stained with *litmus*, and if this paper be first immersed in a weak *acid* it will be changed to red, and then immersed in a solution of alkali, the original colour will be resumed.

*Rationale.* The same as before.

*Experiment 7.* If paper stained with an infusion of *turmeric*, be dipped into an alkaline solution, it will be changed to brown. If it now be immersed in an acid, its original colour will re-appear.

*Rationale.* The alkali changes the affinities with the rays of light, hence brown is the consequence; but the presence of an acid destroys the new affinities, and produces the original colour.

*Remark.* This paper will detect the presence of soda, though it should amount to no more than  $\frac{1}{2200}$ th part of the water.

*Experiment 8.* Alkali dropt into the tincture of turmeric will exhibit the same appearance, and the addition of an acid will produce the original colour.

*Rationale.* The same as the preceding.

*Experiment 9.* If into a solution of *potash* pieces of animal flesh be put, the latter will be so much corroded as to be soon entirely dissolved.

*Rationale.* The theory of this phenomena will be given hereafter.

*Experiment 10.* If a solution of *alkali* be added to the *syrup* or *infusion of violets*, it will produce a *green* colour.

*Rationale.* As the natural colour of vegetables is affected by various agents, as the preceding experiments exemplify, in this instance the blue colour is discharged, and that of green is formed, which is owing to the causes before mentioned.

*Remark.* The original colour may be restored by adding a few drops of acid; in that case the alkali is saturated: but, if more acid than is necessary be added, the infusion or syrup will be changed to red.

*Experiment 11.* If oil and water be added, no union will ensue, but if caustic *potash*, *soda*, or *ammonia* be mixed with them, a combination will take place.

*Remark.* This property of alkali serving as a media between oil and water, answers to one of its characteristic properties.

The three alkalies have been discovered native in combination with acids, forming salts, as in nitrate of potash, carbonate of soda, sulphate of soda, glauberite, (sulphate of soda and sulphate of lime) muriate of soda, subborate of soda, and muriate of ammonia.

## SECTION I.

## OF POTASH.

*Experiment 1.* If wood be burnt, and the residue, or ashes, be washed in water, or *elixated*, and the solution evaporated, a substance will remain which is known by the name of *potash*; or,

*Experiment 2.* If *lye*, or caustic alkali, obtained by passing water through a mixture of wood ashes and lime, be evaporated to dryness, potash will be the result.

*Rationale.* When vegetable substances are submitted to the action of heat in distilling vessels, its component elements, oxygen, hydrogen, and carbon, which formed a three-fold combination in a state of equilibrium, unite two and two, in obedience to the affinities which act conformable to the degree of heat employed. Thus, at the first application of the fire, whenever the heat produced exceeds the temperature of boiling water, part of the oxygen and hydrogen unite and form water; soon after, the rest of the hydrogen and part of the carbon combine into oil; and, lastly, when the fire is pushed to a red heat, the oil and water, which had been formed in the early part of the process, become again decomposed, the oxygen and part of the carbon, unite to form carbonic acid, a large quantity of hydrogen gas is set free, and nothing but charcoal remains behind.

In the combustion of vegetables in the open air a great part of these phenomena occur; but in this case the presence of the air introduces three new substances, the oxygen and azote of the air, and caloric; and of these, two at least produce considerable changes in the results of the operation.

In proportion as the hydrogen of the vegetable, or that which arises from the decomposition of the water, is forced out in the form of hydrogen gas by the progress of the fire, it is set on fire immediately upon get-

ting into contact with the air, water is again formed, and the greater part of the caloric of the two gases becoming free produces flame. When all the hydrogen gas is driven out, burnt, and again reduced to water, the remaining carbon continues to burn, but without flame; it is formed into carbonic acid, which carries off a portion of caloric sufficient to give it the gaseous form; the rest of the caloric, from the oxygen of the air being set free, produces the heat and light observed during the combustion of the carbon.

The whole vegetable is thus reduced to water and carbonic acid, and nothing remains but a small portion of gray matter called ashes, being only the really fixed principles which enter into the constitution of vegetables. The ashes seldom exceeds a twentieth part of the weight of the vegetable, and contain the substance known by the name of potash, or fixed vegetable alkali. On adding water to the ashes, this substance is extracted, which appears in a concrete form by evaporation. The residue, after the action of water, is insoluble, and contains generally earthy matter, and some metallic oxyds. That potash, obtained by this process, is always more or less saturated with carbonic acid, is evident from the product. It is accounted for thus: as the potash does not form, or at least is not set free, but in proportion as the carbon of the vegetable is converted into carbonic acid by the addition of oxygen, either from the air or water, it follows that each particle of potash, at the instance of its formation, or at least of its liberation, is in contact with a particle of carbonic acid, and as there is a considerable affinity between these two substances, they naturally combine together. Although the carbonic acid has less affinity with potash than any other acid, yet it is difficult to separate the last portions from it. This is usually accomplished, however, by using quicklime, which has the property of taking it from the alkali, rendering the latter caustic, and of forming with it an insoluble compound.

*Remark.* This alkali was formerly obtained by burning vegetables in pots; hence it acquired the name of

*potash.* Potash, as it occurs in commerce, is always impure, containing a number of foreign substances. When heated to redness many of its impurities are burnt off; it becomes whiter than before, and is then known in commerce by the name of *pearl-ash*.

It is still, however, impure, and it can only be separated from its impurities by another process, which will be noticed directly.

All vegetables yield less or more of potash in consequence of combustion, but it is furnished in various degrees of purity by different vegetables. In the *Annales de Chimie*, tome xix. 157, is a table of the quantities of alkali obtained from different kinds of wood. Directions for burning vegetables, in a proper manner for this purpose, will be found in the same volume, page 194.

Potash is prepared in large quantities in wine countries, by the incineration of wine lees and must. This article is known in France by the name of *cendres gravelées*.

Potash is formed in what are called nitre beds, which are collections of the refuse matter of vegetable and animal substances. See NITRATE OF POTASH. It is asserted, and we believe the observation to be true, that the ashes which is left by vegetables in combustion, pre-existed in them before they were burnt, forming what may be called the skeleton, or osseous part of the vegetable. But it is quite otherwise with potash; this substance has never yet been procured from vegetables but by means of processes or intermedia capable of furnishing oxygen and azote, such as combustion. As potash is a compound substance, having a peculiar metal for its basis, it is more remarkable that combustion should produce a metal in combination with another elementary principle, forming potash. This subject is extremely obscure. Potash is said to exist in minerals: it has been discovered in aluminous schistus, in combination with acids, in pumice, leucite, zeolite, felspar, &c.

Potash was known to the ancient Gauls and Ger-

mans. They were the inventors of soap, and Pliny says they made it of ashes and tallow.\* Aristophanes and Plato mention a liquor which appears to have been a lye made of the ashes of the beech tree. The Alchemists were acquainted with it. Potash has been known under several names. It was called *vegetable alkali* because it is obtained from vegetables, and because it was long thought to be peculiar to the vegetable kingdom. It was called also *salt of tartar*, because it may be obtained by burning the salt called *tartar*. It is also the *tartarin* of Kirwan, the *veg-alkali* of Pearson, the *kali* of Klaproth, and the *lixivia* of Black. In chemical language, potash signifies the pure alkali, in commerce the impure alkali. Some chemists have given the name of potass to the pure alkali, and potash to the alkali of commerce. The latter contains nearly one fifth by weight of carbonic acid, besides other impurities. Potash is not a simple substance, but is a compound body, having for its basis, as we shall afterwards state, a peculiar metal called potassium.

The union of acids with potash forms a class of bodies called salts, which are either sub, neutral, or super salts. See SALTS OF POTASH.

*Experiment 3.* Prepare *caustic lye* of potash, by using quicklime, evaporate it in iron pots, and if any crystals should form, separate them, and continue the evaporation until it becomes solid: pour over this, placed in a jar, some very strong *alcohol*, and the potash alone will be dissolved, leaving any sulphate of potash, earthy matter, &c. undissolved. Decant the pure liquor, and distil it in a retort till it becomes colourless. Evaporate it then in a silver basin, and very pure potash will be prepared.

*Rationale.* The lime renders the alkali caustic by robbing it of carbonic acid; the caustic alkali on evaporation throws off some saline bodies, as sulphate of potash; the potash is then dissolved by the alcohol, leaving all the salts with which it might be intermixed,

such for instance as are insoluble in alcohol, at the bottom of the vessel. On evaporating the liquor, the alcohol is dissipated, leaving the alkali in a perfectly pure state.

*Remark.* This process for preparing pure potash, was recommended by Berthollet. Mr. Lowitz has given the following as less expensive.\*

*Experiment 4.* Prepare a lixivium of *potash*, freed from *carbonic acid* in the usual manner, and evaporate it to a thick pellicle. After the cooling, the foreign salt which has crystallized is to be separated, and the evaporation of the lixivium is to be continued in an iron pot. During this second evaporation the pellicle of foreign salts must be carefully taken off by an iron skimmer. When no more pellicle is formed, and the matter ceases to boil, it is removed from the fire and suffered to cool, continually stirred with an iron spatula. It is then to be dissolved in double the quantity of distilled water, and the solution filtered, and evaporated in a glass retort till it begins to deposit regular crystals. If the mass should consolidate ever so little by cooling, a small quantity of water is to be added, and it must be heated again to render it fluid. After the formation of a sufficient quantity of regular crystals, the fluid, which is very brown, is to be decanted, and the salt, after being suffered to drain, must be redissolved in the same quantity of water. After the fluid has stood for some days, it is to be decanted, and subjected to another evaporation and crystallization. This process must be repeated as long as the crystals afford, with the least possible quantity of water, solutions perfectly limpid.

*Rationale.* The theory of the action of quicklime in rendering potash caustic, has already been noticed. The process, therefore, is nothing more than the separation of foreign salts, owing to their different solubility, from the alkali by repeated solution, evaporation, and crystallization.

\* Nicholson's Journal, i. 14.

*Remark.* This process, however, is imperfect when pure alkali is to be formed; that of solution in alcohol, as in the first process, is to be preferred. This also causes the alkali to assume a brown colour. Klaproth, to prepare pure alkali, boiled equal parts of salt of tartar and carrara marble, or oyster shells, burnt to lime, with a sufficient quantity of water, in a polished iron kettle. The ley was then strained through clean linen, and though still turbid, was reduced by boiling, till it contained about one half of its weight of potash. It was then passed a second time through a linen cloth, and set by in a glass bottle. After some days when the ley had become clear of itself, it was decanted off from the sediment into another bottle. The specific gravity of caustic ley is to that of distilled water as 1090 to 1000. The *water of potash*, and the *water of pure kali* of the Dispensatory, are the same as caustic ley.

Dr. Black discovered, in 1756, the cause of the causticity of potash, and that potash of commerce consisted of pure alkali and carbonic acid.

The crystals of potash, formed according to the process of Lowitz, are generally octahedral in groups, and contain 0.43 water of crystallization. When potash, thus crystallized, is exposed to a red heat in a silver crucible, it becomes fused, and affords a white mass extremely caustic and deliquescent. An expeditious process for preparing pure potash, which I have frequently employed, is the following:

*Experiment 5.* Put into a Wedgwood mortar an ounce or two of *caustic potash* or common caustic of the shops, pulverize it, and pour on it a sufficient quantity of *alcohol*; after it has stood an hour or two filter the solution, and evaporate it in a silver cup.

*Remark.* As a re-agent, potash thus prepared is sufficiently pure. The solid alkali may be dissolved in pure water.

*Experiment 6.* Take *caustic ley*, and evaporate it over a fire in a very clean iron vessel till it begins to thicken. Then pour it out upon an iron plate, and while it is congealing cut it into proper pieces, or pour it into

iron moulds, and *common caustic* of the shops will be formed.

*Experiment 7.* Evaporate *caustic ley* to one third, then add powdered *lime* till it becomes thick, and the *milder common caustic* will be prepared.

*Experiment 8.* If to a transparent solution of the potash of commerce, *lime water* be added, the mixture will become turbid, and a precipitate will gradually subside.

*Rationale.* As lime renders alkalies caustic, and as this is owing to the absorption of carbonic acid by the lime, this experiment shews that the moment the potash, which contains carbonic acid, comes in contact with lime, the latter robs it of carbonic acid, with which it forms a turbid precipitate or carbonate of lime.

*Experiment 9.* Collect the precipitate of the last experiment, and add to it *muriatic acid*, an effervescence will ensue.

*Rationale.* The muriatic acid unites with the lime, and the carbonic acid is disengaged, proving that it is carbonic acid which was taken from the potash.

*Experiment 10.* If dry *potash* be exposed to the air in an open vessel, it becomes fluid, increases in weight, and gradually assumes the state of *liquid carbonate of potash*.

*Rationale.* The affinity subsisting between potash and water is considerable; hence on exposure to air, the alkali absorbs moisture from the air and becomes liquid, at the same time (as carbonic acid is always present in the atmosphere) it imbibes the carbonic acid, and is gradually changed into a liquid carbonate of potash.

*Remark.* By this process the old pharmaceutical writers made a preparation described under the name of *oleum tartari per deliquium*.

*Experiment 11.* Put *potash* into a crucible, apply heat until it becomes red hot, the alkali will melt, swell, and evaporate slowly in a white acrid smoke. If a stronger heat be used, it will give it a greenish tinge.

*Remark.* As potash evaporates only at a red heat, it has received the name of *fixed* alkali.

*Experiment 12.* If *potash* and *silex* be melted together, they unite, and form a compound called glass.

*Remark.* Potash, therefore, acts as a flux: when siliceous substances are melted in this way, the product is glass, an account of which will be given in its proper place. But the density of the compound depends on the proportion of the potash; for,

*Experiment 13.* If three or four parts of *potash* be melted with one of *silex*, the result will be a mass soluble in water, forming, when so dissolved, the *liquid siliceous potash* or *liquor of flints*. This is prepared in the following manner:

*Experiment 14.* Take one part of *silex* reduced to a fine powder (or pure sand) and four parts of *potash*; introduce them into a crucible, and expose them to a violent heat. The sand and potash will now melt, puff up, and continue to swell till the alkali has dissolved the *silex*. As long as the effervescence lasts, the crucible is to be left uncovered, when it ceases it is to be covered, and the heat augmented. Pour the contents on an iron plate. Pulverise the mass, and dissolve it in water.

*Remark.* The *silex* may be separated from the alkali by the addition of an acid, by which means pure *silex* is obtained. See *Silica*.

*Experiment 15.* If a slip of woollen cloth, or a piece of muscular flesh, be immersed into a solution of *potash*; the animal substance will soon become destroyed, and form a homogeneous compound.

*Remark.* Hence potash acts powerfully upon animal substances.

*Experiment 16.* If a solution of *potash* be added to *nitro muriate of platina*, a yellow precipitate will be formed; but,

*Experiment 17.* If soda be added, no precipitate will appear.

*Rationale.* The potash unites with the acid, and precipitates the metal of a yellow colour.

*Remark.* As the solution of platina is precipitated by potash, and not by soda, the presence of that alkali may be known on adding the solution of platina. Hence the nitro-muriate of platina may be employed as a reagent to discover the presence of potash.

*Experiment 18.* If to a solution of *potash*, *tartaric acid* be added, crystals will be formed and gradually fall to the bottom.

*Rationale.* The tartaric acid unites with the alkali, and forms a salt of difficult solubility called supertartrate of potash, or cream of tartar.

*Remark.* On this property is founded the use of this acid in discovering the presence of potash. The latter, to shew the effect, should be considerably diluted, and the acid should be added in sufficient quantity, otherwise a neutral tartrate will be formed, which is very soluble.

*Experiment 19.* If equal parts of *arnotto* and *potash* be boiled in water until the whole are dissolved, a liquid will be formed, which is sold under the name of *nankin dye*.

*Remark.* Hence it is that potash is used in the art of dying; in order to extract the colouring matter, and to serve, in some cases, both as a solvent and a mordant. It also acts as a precipitant to separate metallic oxyds from their solution in acids.

The use of potash in the arts is extensive; in the preparation of colours, such as Prussian blue, French and mineral greens, Scheele's green, in the formation of potters' blue from cobalt, soap, alum, in bleaching linen, in scouring wool, &c. potash is used.

*Experiment 20.* When three parts of *sulphur* and one of *potash* are triturated together in a glass mortar, the sulphur acquires a green colour, the mixture becomes hot, and exhales an alliaceous odour. This compound gradually attracts moisture from the atmosphere, and is totally soluble in water, which answers to some of the characters of *sulphuret of potash*; or,

*Experiment 21.* If two parts of *potash* and one of *sulphur* be heated in a crucible, they melt and combine, and form a sulphuret of potash.

*Rationale.* If the potash of commerce be used, the carbonic acid is dissipated by the heat; the sulphur and alkali melt, unite, and form a sulphuret of a brown colour, not unlike the liver of animals. Hence it was formerly called *hepar sulphuris* or liver of sulphur; but when exposed to the air it soon becomes green, and even white.

*Remark.* When the fusion is complete the sulphuret is to be poured upon a marble slab; and as soon as it becomes hard, it must be put into a well closed bottle. The sulphuret is hard and brittle. Its taste is acrid, caustic, and bitter, and it leaves a brown stain upon the skin. It is decomposed by heat in the following manner:

*Experiment 22.* Put *sulphuret of potash* into a crucible, invert over it another crucible, having a small opening in its bottom; then apply heat and the *sulphur* will sublime.

*Rationale.* In this case, the action of heat decomposes the sulphuret, and the sulphur is dissipated leaving the alkali behind.

*Experiment 23.* If in a solution of *sulphuret of potash*, syrup or infusion of violets be poured, its colour will be changed to green.

*Remark.* Hence it has some of the characters of uncombined alkali.

*Experiment 24.* Dip a piece of white calico in an aqueous solution of *acetate of lead*, and then drop a little solution of *sulphuret of potash* upon it. If this be now placed in the palm of the hand, the lead will be observed gradually to revive, and will soon be reduced to its metallic state; or,

*Experiment 25.* Immerse a slip of white silk in a solution of *sulphuret of potash* prepared with alcohol. If a drop of an aqueous solution of *sulphate of manganese* be now applied, films of metallic manganese, bright as silver, will instantly appear.

*Rationale.* Though it is asserted that sulphuret of potash has the property of decomposing metallic oxyds, yet we are disposed to think, that this reduction is

owing to sulphuretted hydrogen, which it is well known possesses this property by carrying off the oxygen, as we remarked in treating of the properties of this gas. In contact with moisture, sulphuretted hydrogen is produced from alkaline sulphurets.

*Experiment 26.* Expose *sulphuret of potash* to the air, or moisten it with water; its colour will become changed, and a fetid gas will be evolved, called *sulphuretted hydrogen*.

*Rationale.* This is owing to the decomposition of water, in the same manner as was stated in the article on sulphuretted hydrogen gas, which see.

*Remark.* The sulphuretted hydrogen thus formed, partly unites with the remaining sulphuret, and converts it into *hydroguretted sulphuret of potash*, which has a brownish green colour. This preparation may also be formed in the following manner:

*Experiment 27.* Introduce into a flask two parts of *potash* and one of *sulphur*; add to these a sufficient quantity of water, and boil them together.

*Rationale.* The sulphur unites with the alkali; the compound decomposes water; sulphate of potash and sulphuretted hydrogen are formed, and the remaining sulphuret unites with the sulphuretted hydrogen, and produces hydroguretted sulphuret of potash.

*Experiment 28.* Introduce a solution of *potash* into a retort, and put in a piece of *phosphorus*, apply heat, and *phosphuretted hydrogen gas* will come over and take fire.

*Rationale.* Though potash cannot be combined with phosphorus in any manner at present known, so as to exhibit a distinct compound, yet if it be boiled with phosphorus, a combination is first formed, which then acts upon the water, decomposes it, and emits phosphuretted hydrogen gas, a phosphate of potash remaining in the retort.

*Experiment 29.* If *zinc*, *molybdenum*, or *iron* be put into a solution of *potash* and heat applied, it will gradually be oxydized.

*Remark.* Potash does not combine with any of the metals. Some metals, however, which possess a strong affinity for oxygen, when put into a solution of potash, are gradually oxydized, and these oxyds partially soluble.

*Experiment 30.* To red oxyd of iron put a solution of potash; in a short time it will be changed into the black oxyd.

*Remark.* It appears, therefore, though this phenomena has not been explained, that the solution has the property of abstracting oxygen, or of reducing the per into the prot oxyd of iron. The metallic oxyds which are soluble in potash according to Bergman and others, are, of lead, tin, nickel, arsenic, cobalt, manganese, zinc, antimony, tellurium, tungsten, and molybdenum.

*Experiment 31.* If four parts of crystallized potash reduced to powder, and three of uncompressed snow, be hastily mingled together, the mixture becomes fluid, and an intense degree of cold is produced; but,

*Experiment 32.* If equal weights of potash, freed of water by exposing it to heat, and dense sulphuric acid be mixed together, a great degree of heat will be instantly produced, and, if the experiment be made in the dark, flashes of light will be seen to pass through the mixture.

*Rationale.* The cause of the production of heat and cold in mixture, has already been noticed in treating of caloric: the same principles apply to these experiments. In the first, as the crystallized potash contains a quantity of water, the mixture with snow causes heat to be absorbed, which consequently, reduces the temperature, but in the second, in which dry potash and sulphuric acid are employed, the latent becomes sensible heat, and, of course, the temperature is raised.

*Experiment 33.* Procure a piece of potash, made perfectly pure, breath on it, in order to moisten it, and place it on an insulated plate connected with the negative side of a powerful galvanic battery. Then bring a metallic wire from the positive side of the battery in contact with the upper surface of the alkali, and a vivid

action will soon be observed. Small globules of the appearance of mercury will be seen, some of which will burn with an explosion and bright flame as soon as they are formed. These are *potassium*.

*Rationale.* The potash is decomposed; oxygen gas is separated at the extremity of the positive wire, and *potassium* is formed at the other.

Like other combustible substances, the combustible base is repelled by positively electrified surfaces, and attracted by negatively electrified surfaces; and the oxygen follows the contrary order. Hence their separation and evolution.

*Remark.* Heretofore various opinions have been entertained respecting the composition of potash, in which the chemists of Europe were engaged in order to ascertain the correctness of these conjectures. But the researches of Sir Humphrey Davy have shown, that potash is a compound body, having a peculiar metal for its basis, to which he has given the name of potassium, united with oxygen.

It has been supposed, ever since our countryman, Dr. Woodhouse, made an experiment with potash, that this alkali had an inflammable basis. I am disposed to believe that the Dr. was the first who hazarded this conjecture as to the inflammable nature of potash *when treated in certain ways*. The Dr. found that a mixture of pearl ash with soot, calcined by a very intense heat in a covered crucible, when cold, caught fire on the affusion of water; the experiment was repeated with charcoal with the same result; and the inflammation probably arose from the action of the base of the alkali on the water.\* The pyrophori, which takes fire spontaneously in the air, Mr. Davy considers as a triple compound of potassium, sulphur and charcoal.

Potash, when dry, is a non-conductor of electricity, but it becomes a conductor when slightly moistened on the surface. Hence in this side it is acted upon by the galvanic influence.

\* Nicholson's Journal, xxi. p. 290.

Besides analysis, Mr. Davy proved by synthesis the composition of potash. He accordingly found, that potash is composed of about six parts of potassium and one of oxygen, or nearly 86 parts of potassium and 14 of oxygen in the hundred. For a number of facts respecting potassium, we are indebted to this philosopher. From its composition, potash has been called the *per oxyd of potassium*. Besides the agency of galvanism in decomposing potash, two French chemists, Gay Lussac and Thenard, have succeeded in separating the potassium by means of iron filings, in the following manner.

*Experiment 34.* Into the middle of an iron gun barrel is to be put a quantity of clean and dry iron filings or turnings. An iron tube, containing potash as dry as possible, should be ground to one end of the gun barrel, and having a small hole through which the potash may run slowly when melted. To the other extremity a tube of safety, containing mercury or naphtha, ought also to be luted, and great care should be taken that all the lutings be air tight. The gun barrel being laid across a furnace, the iron turnings within it are brought to a white heat, while the potash is kept cold by means of ice; then the potash is brought into fusion, and made to flow slowly through the iron turnings. When the process is at an end, a portion of potassium nearly pure is found near the tube of safety; but the greatest part of it is alloyed with the iron turnings.\*

*Rationale.* The potash is deprived of its oxygen, and potassium is disengaged, which appears partly in a free state, and partly in combination with the iron in the form of an alloy.

*Remark.* During the operation hydrogen gas is emitted, which has led to some conjectures as to its origin, it is said to be owing to the decomposition of water, but it has not been satisfactorily ascertained. Thomas Cooper, Esq. professor of chemistry in the college at Carlisle, Pennsylvania, repeated this experiment, and succeeded, I think after several attempts, in procuring

\* Phil. Mag. xxii. 89 and 276.

the metal.\* John Redman Coxe, M. D. professor of chemistry in the university of Pennsylvania, and myself also performed it, but in our attempt we failed. The professor, however, persevered, and finally prepared it. The cause of the failure in the first attempt, was owing to the arrangement of the apparatus, and some unforeseen circumstances. That potassium was formed was evident, from the appearance of the iron, as it was coated with a white covering, which was the alloy before mentioned. My brother, Dr. E. Cutbush, succeeded in procuring it, by using the heat of a blacksmith's forge. I have not heard of any other attempts in this country, except by a gentleman in New York, who was also successful. Galvanism, I believe, has not been tried. The general properties of potassium are: It is white like mercury. At  $50^{\circ}$  it is a soft malleable solid; at  $60^{\circ}$  it is imperfectly fluid; at  $100^{\circ}$  it melts and is perfectly fluid. At  $32^{\circ}$  it is hard and brittle. Its specific gravity does not exceed 0.6, hence it is lighter than water. In the open air, it is covered with a crust of potash in a few minutes. It decomposes water. It may be converted into prot oxyd, or per oxyd of potassium according to the quantity of oxygen presented to it. It inflames in oxymuriatic acid gas. It combines with phosphorus, sulphur, and the metals.

*Experiment 35.* Expose a piece of potassium in a small quantity of oxygen gas, and heat it gently, it will be changed into prot oxyd of potassium of a reddish brown colour; but,

*Experiment 36.* Make a piece of potassium very hot, and introduce it into a small glass vessel of oxygen gas, it will burn with a brilliant white flame, and form the per oxyd of potassium or potash.

*Rationale.* In the former experiment the potassium unites with a smaller dose of oxygen; in the latter it combines with a larger, producing flame, and is converted into potash.

\* See Port Folio, and Henry's Chemistry, 2 vols. 1810, in which a plate is given of the apparatus.

*Experiment 37.* Introduce a piece of potassium into alcohol, ether, or naphtha, instead of sinking, it will keep on the surface.

*Remark.* Hence its specific gravity is inferior to any of these liquids.

*Experiment 38.* Drop a piece of potassium into a jar of oxymuriatic acid gas, it will burn spontaneously and emit a bright red light, forming, at the same time, a white salt.

*Rationale.* The oxygen of the oxymuriatic acid gas unites with the potassium, and forms potash, which then combines with a portion of muriatic acid arising from the decomposition of the oxymuriatic gas, and generates muriate of potash.

*Experiment 39.* Potassium thrown into water, decomposes it, and produces flame. The result is the formation of potash; or,

*Experiment 40.* If a globule be placed upon ice, it will spontaneously burn with a bright flame and perforate a deep hole in the ice, which will contain a solution of potash.

*Rationale.* In both instances the water is decomposed; its oxygen unites with the metal, to the reproduction of potash, while its hydrogen is liberated, which inflames and reproduces water.

*Experiment 41.* Add muriate of lime to water, and put into the solution a piece of potassium; inflammation will ensue as before, and the water will become turbid.

*Rationale.* Potash is formed in the same manner as before noticed, which, having a greater affinity for muriatic acid than lime, unites with it, forming muriate of potash, and separates the lime in a precipitate.

*Experiment 42.* Drop a piece of potassium upon a slip of reddened litmus paper previously moistened, and, after it burns, the paper will be restored to its original blue colour.

*Rationale.* The potassium unites with oxygen; the potash formed acts upon the reddened litmus, removes the acid which occasioned the redness, and restores it to its former colour, that of blue.

*Experiment 43.* If *potassium* be thrown into *nitric acid*, it takes fire, and potash is formed, which combines with the remaining acid, and forms *nitrate of potash*.

*Rationale.* In this experiment, the potassium decomposes a part of the acid; the oxygen of the latter forms with it potash, which combines with the remaining acid, and produces nitrate of potash, at the same time nitric oxyd gas is disengaged.

*Experiment 44.* Introduce into an iron retort, a mixture of *carbonate of potash or soda* with flour or charcoal and linseed oil; and raise the fire until a blue light is perceived in the interior of the vessel: to this a copious vapour soon succeeds, which consists of the *metallic base* of the alkali. It may be collected, by introducing a clear iron rod, on which it condenses, with drawing the rod before it becomes too hot, and plunging it into oil of turpentine, when the metallic crust may be detached. By repeatedly introducing rods of iron, a quantity may be collected.\*

*Rationale.* The carbon of the flour, if it be used, as well as of the oil, according to Curadaw, decomposes the alkali, which parts with its carbonic acid by the action of heat, and is decomposed; its oxygen is disengaged, and potassium is formed.

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## SECTION II.

### OF SODA.

*Experiment 1.* Take the plant called *salsola soda*, burn it, and lixivate the ashes; evaporate the lixivium to dryness, and the impure *soda* will be formed.

*Remark.* Different species of *salsola* especially the *salsola soda* when burnt, afford this alkali. Soda is called *fossil* or *mineral alkali*, because it was thought to

\* Nicholson's Journal, xxiii. Supplement.

be peculiar to the mineral kingdom. It was known to the ancients under the name of *nitrum*. The soda of commerce is also called *barilla*, because the plant from which the alkali is obtained bears the name in Spain. The *algæ*, especially the *fuci* contain also a considerable quantity of soda. In England the ashes of this plant is called *kelp*; in France they are called *varec*. The *salsola soda*, which grows among the cliffs on the sea coast, appears to be endowed with the property of decomposing sea salt. If this be true, the process of vegetation must separate the muriatic acid, and absorb the soda. Hence it acquired the name of *salt-wort*. Dr. Barton informed me, that he discovered the *salsola kali* in large quantities not many miles distant from the city of Philadelphia.\*

The Spaniards cultivate a number of marine plants, as the *salsola soda*, the *salicornia herbacea*, &c. in salt marshes, for the sake of the soda. After being cut down they are dried like hay. A deep pit is then prepared, and a bundle or two of the dried vegetables set on fire are thrown into it. When well kindled other bundles are thrown in until the pit is filled. When the incineration is completed, the soda is found in the bottom, caked into a solid mass. It is purified by solution, filtration, and evaporation.

It is surprising that the *salsola kali* should grow in an inland situation, so far from salt water. Dr. Barton having discovered this plant in immense quantities in New-Jersey, in the neighbourhood of Gloucester, where it is known by the name of *sea briar*, naturally inferred, that as it was so far distant from salt water it would yield no soda; and indeed in this conjecture he had the testimony of fact, for Jacquin observes, that plants yielding soda in salt marshes, when removed to inland situations afford only potash by incineration, and that those plants which grow in inland places, when trans-

\* Jameson, in his Mineralogy of the Scottish Isles, has given a full account of the manufacture of kelp. See also Repertory of Arts. vol. xii.

ferred to a saline soil, as on the sea coast, in the course of time produce soda.

The union of acids with soda forms salts, which are either sub, neutral, or super salts, see SALTS OF SODA.

Soda exists native in combination with sulphuric, muriatic and boracic acids. With the sulphuric acid it forms Glauber's salt, with the muriatic, common salt, and with boracic acid, borax. It is also found in minerals, as in the *whinstone*, *volcanic lava*, and *crysolite*. It has also been discovered in the *bile* of animals, and in other secretions. It is obtained from sulphate of soda in the following manner.

*Experiment 2.* According to Accum, if 560 parts of *potash* in solution, be ladled into a boiling solution of 500 parts of *sulphate of soda*, agitated together, and quickly heated; then drawn off into cisterns, lined with thick sheet lead, and allowed to cool in a temperature which should not exceed  $55^{\circ}$ , *carbonate of soda* will be formed.

*Rationale.* The sulphate of soda is decomposed by the carbonate of potash; the sulphuric acid unites with the potash, forming sulphate of potash, and the carbonic acid, which was contained in the potash, passes to the soda, and forms carbonate of soda.

*Remark.* The separation of the carbonate of soda is effected in the following manner: the fluid, after it has been suffered to cool, is drawn off, and the mass of salt washed with cold water, to free it from impurities, and again put into the boiler with clean water. This second solution is also evaporated at a low heat, as long as any pellicles of sulphate of potash form on its surface, and fall to the bottom of the fluid. The fire is then withdrawn, and the fluid ladled out in the cistern to crystallize. Unless the fluid be allowed to cool pretty low before it is removed to crystallize, the salt obtained will contain sulphate of potash.

*Experiment 3.* If *acetate of lime* in solution be added to *sulphate of soda*, a decomposition will ensue, and *acetate of soda* be formed, which, if exposed to heat, will leave the *soda* behind.

*Rationale.* Acetate of lime and sulphate of soda decompose each other; sulphate of lime, which precipitates as the liquor cools, and acetate of soda, also formed, remains in solution. On filtering the fluid, the sulphate of lime is separated, and the acetate of soda remains in solution. On evaporating this, and subjecting it to heat, the acetic acid is partly disengaged in a pure state, and partly decomposed.

*Remark.* Besides these modes of obtaining soda from the sulphate; litharge and acetate of lead have been used, as well as charcoal assisted by heat. The muriate of soda is sometimes decomposed by potash, and sometimes by lime for the same purpose. Soda obtained by any of these processes is not chemically pure; containing, besides carbonic acid, several other foreign ingredients. It may be rendered pure, however, by using the same means as described under the article of Potash.

*Experiment 4.* Expose *soda* to the atmosphere; in the course of a short time it will become fluid, not however so considerably as potash. In a few days, it will change from this state, and become dry again.

*Rationale.* Soda not only absorbs moisture, but also carbonic acid: when it has acquired a sufficient quantity, and probably when it has absorbed enough of carbonic acid, the affinity for water appears to change. Instead of its taking any more from the atmosphere, it appears to part with it; hence it becomes dry, and effervesces on the addition of acids.

*Experiment 5.* Dissolve *soda* in water, evaporate the solution, and, if properly treated, crystals may be obtained.

*Remark.* The properties of soda, in many particulars, is the same as those of potash. It unites with sulphur, forming sulphuret of soda, and also sulphuret with the sulphuretted hydrogen. The sulphuret and hydroguretted sulphuret of soda possess the properties of the sulphuret and hydroguretted sulphuret of potash. In its action on metals, metallic oxyds, &c. it also agrees with potash.

*Experiment 6.* Let fall into a solution of *soda* a few drops of oxalic acid; a salt will be obtained of difficult solubility.

*Rationale.* The oxalic acid and soda forms a salt, the oxalate of soda, which is of very difficult solubility; but, on the contrary, with potash the same acid produces a salt, the oxalate of potash, which is very soluble. Hence oxalic acid has been recommended as a test to discover the presence of soda in a solution of fixed alkali. See Potash.

*Experiment 7.* To a solution of pure *soda* add olive oil and shake the mixture; a compound will be formed, which, if allowed to stand, will become hard, being the *soap of soda* or *hard soap*.

*Remark.* The theory of this combination, as well as the preparation of soap, will be noticed hereafter.

*Experiment 8.* If *soda* be treated in the same manner as *potash* by the galvanic battery, a metal will be obtained, called *sodium*.

*Rationale.* Analogous to that of obtaining potassium.

*Remark.* Notwithstanding the opinion of chemists, especially of Fourcroy, Desormes and Morveau, respecting the composition of soda, Mr. Davy has proved that their ideas were erroneous, and that it is composed like potash, of a peculiar metal united with oxygen. It is considered a metallic per oxyd, to the metal of which Mr. Davy has given the name of sodium. From a number of experiments on the combination of sodium with oxygen, made in the same manner as those on the combination of potassium with the same principle, Mr. Davy has shown, that soda is composed of about seven parts sodium, and two of oxygen, or nearly of sodium 78, and oxygen 22, in the hundred.

The phenomena which sodium exhibits, are nearly similar to those of potassium. It is a white metal like silver, and at the common temperature of the atmosphere is solid. It is malleable. It begins to melt at  $120^{\circ}$ , and becomes fluid at  $180^{\circ}$ . It is not volatilized in a red heat. It conducts electricity and heat in the

same manner as potassium. Its specific gravity is 0.9348. It combines with oxygen; for on exposure to air it is soon covered with a crust of soda, but as the alkali does not thoroughly deliquesce, the nucleus is not so soon destroyed as happens to potassium. No combustion takes place when sodium is thrown upon water, although it decomposes that fluid, which is said to be owing to its insolubility in hydrogen gas, as that gas is formed in the decomposition of water. It burns, however, in contact with a small quantity of water. Melted with dried soda, a protoxyd of sodium of a brown colour is formed, and a division of oxygen between the soda and the base takes place. It burns in oxymuriatic acid gas, and unites with the sulphur, phosphorus, and the metals, like potassium.

One part of it renders forty parts of mercury solid, and of the colour of silver. The amalgam of sodium combines with the other metals and with sulphur, forming triple compounds. Thrown into the mineral acids it is converted into soda. In nitric acid it produces flame; but in sulphuric and muriatic acids it occasions an evolution of heat.

The process of Thenard and Gay Lussac, by which potash is decomposed, does not succeed so well with soda. Mr. Davy says, that this is owing to hydrogen contributing materially to the result by the affinity it exerts to the alkaline base, and to the base of soda being scarcely soluble in this gas. Caraudau, however, asserts, that his process with charcoal, noticed in the article on potash, succeeds as well with soda as with potash. By exposing mixtures of soda and potash to ignited iron, Mr. Davy has obtained alloys, which appear to be ternary compounds of the two alkaline basis with iron.

## SECTION III.

## OF AMMONIA.

*Experiment 1.* If sixteen parts of *muriate of ammonia*, thirty-two of fresh prepared *quicklime*, and ninety-six of *water*, or one pound of *muriate of ammonia*, two pounds of *quicklime*, and six pounds of *water*, according to the *Edinburgh Pharmacopea*, be distilled, a product will be obtained called *water of caustic ammonia*.

*Rationale.* In the article on the properties of ammoniacal gas we stated, that when ammoniacal gas was absorbed by water, a liquor is formed of a pungent odour, known under the name of spirit of sal ammoniac. In this case the ammonia is liberated from its combination with muriatic acid, which then unites with the water, and forms liquid ammonia. The lime, therefore, decomposes the muriate of ammonia; it unites with the muriatic acid, forming muriate of lime, which remains in the distilling vessel, and the ammonia is disengaged in the state of gas. The heat, as it causes this decomposition, also evaporates the water. The aqueous vapour accordingly absorbs the gas, and condenses with it in the state of liquid ammonia, commonly called caustic spirit of sal ammoniac.

*Remark.* The quicklime is first slacked, and when it is obtained in the form of powder, it is then added to the muriate of ammonia dissolved in the water. The whole is then introduced into a retort, and distilled into a refrigerated receiver with a very gentle heat, till twenty ounces of the liquor are drawn off. Some other particulars must be observed, which will recur to the operator. According to the London college, one pound of sal ammoniac, two of quicklime, and one gallon of water are treated in the same manner. The Dublin college adopt the following formulæ: sixteen ounces of sal ammoniac, two pounds of quicklime, and six pounds of water.

*Experiment 2.* Receive the gas, as it comes from a mixture of *muriate of ammonia* and *quicklime*, into a vessel containing water, so as to confine it ; when the water is saturated, it will be changed into a pungent caustic liquor similar to Experiment 1.

*Rationale.* This is a direct combination of ammoniacal gas with water, similar to an experiment given under the Properties of Ammoniacal Gas, which see.

*Remark.* Gottling proposed a method of obtaining liquid ammonia, by receiving ammoniacal gas into a vessel of water, which he accomplished with more facility by using pressure. He employed an earthen ware cucubit, with a tubulated capital. To the spout of the capital, one end of a bent glass tube is accurately luted, while the other end is introduced to the bottom of a tall narrow mouthed glass phial, containing the requisite quantity of water. Into the cucubit he puts two parts of finely powdered lime, and one of muriate of ammonia, and then applies the heat. He does not shut the tubulature until the smell of ammonia becomes manifest, and opens it again as soon as the process is finished, and before the vessels begin to cool, as otherwise the solution of ammonia would flow back into the cucubit, and spoil the whole operation. The management of the tubulure requires much caution. We think the apparatus might be improved by substituting Welter's tubes of safety.

*Experiment 3.* If four pounds of *alcohol*, four ounces of *muriate of ammonia*, and six ounces of *carbonate of potash*, be introduced into a retort and distilled, a liquor will come over, which is called *spirit of ammonia* or *ammoniated alcohol*.

*Rationale.* Muriate of ammonia, decomposed by carbonate of potash affords a product known by the name of carbonate of ammonia : this differs in the proportions of the ingredients, hence it generally contains a variable quantity of ammonia, in consequence of the carbonate of potash (of the kind generally used) being never saturated with carbonic acid. In the experiment therefore, the muriatic acid of the muriate of ammonia unites with the potash, forming muriate of potash,

which remains in the retort, and the carbonic acid of the carbonate of potash combines with the ammonia, thus disengaged and forms carbonate of ammonia. This is volatilized together with the alcohol. The two then unite in distillation, and produce the ammoniated alcohol. As the ammonia is necessarily combined with carbonic acid, in order to make the same preparation free from that acid, the following formulæ has been used :

*Experiment 4.* Mix sixteen ounces of *quicklime* and eight ounces of *muriate of ammonia*, and introduce the mixture into a glass retort ; then add thirty-two ounces of *alcohol*, and distil to dryness.

In this process, therefore, the quicklime decomposes the muriate of ammonia, and the ammoniacal gas, thus disengaged, unites with the alcohol. It has also been prepared by simple mixture, as follows :

*Experiment 5.* To two parts of *alcohol* add one part of *caustic liquid ammonia* ; and shake the mixture.

*Experiment 6.* If one part of *muriate of ammonia*, one of *carbonate of potash*, and two of *water* be distilled, a product will be obtained, which is the common *water of ammonia*, or *spirit of sal ammoniac* of the Dispensatories.

*Rationale.* The carbonate of potash and muriate of ammonia mutually decompose each other ; the muriatic acid unites with the potash, forming muriate of potash, and the carbonic acid combines with the ammonia ; but as the ammonia is in excess, or the carbonate of potash is not saturated with the acid, the result is a liquor, which, properly speaking, holds in solution subcarbonate of ammonia.

*Experiment 7.* If bones, horns, hoofs, &c. be distilled, a product will be obtained consisting of *ammonia* and *animal oil*.

*Remark.* When the solid parts of animals are exposed to distillation, with a heat sufficient to decompose them, we obtain ammonia, and an empyreumatic oil. This arises, principally, from a new arrangement of the elementary principles : azote unites with hydrogen, forming ammonia ; hydrogen and carbon form

animal oil; and the ammonia unites in part with carbonic acid, produced from the union of carbon and oxygen. The residue, if carbonized, affords *ivory* or *bone black*.

As the *liquor* obtained by distilling bones is always impure, containing an empyreumatic animal oil, it is purified by one or more distillations. It is then known in the shops by the name of *spirit of hartshorn*. Ammonia was not known to the ancients. The alchemists were acquainted with it; though in an impure state. Basil Valentine described the method of obtaining it. The name of *volatile alkali* was given to it; it was called *hartshorn*, because it was often obtained by distilling the horn of the hart; *spirit of urine*, as it was procured from urine, &c.

The union of acids with ammonia forms a class of salts. See SALTS OF AMMONIA.

*Experiment 8.* If five parts of *muriate of ammonia*, five of *sulphur*, and six of *quicklime* be distilled, *sulphuret of ammonia* will be formed.

*Rationale.* The lime decomposes the *muriate of ammonia*; *muriate of lime* is formed, and the ammonia unites with the sulphur in the distillation, forming *sulphuret of ammonia*.

*Remark.* The *sulphuret of ammonia* decomposes water, and constitutes *hydroguretted sulphuret of ammonia*, known formerly by the name of *fuming liquor of Boyle*.

*Experiment 9.* If *liquid ammonia* be poured on the oxyds of silver, copper, tin, nickel, zinc, bismuth or cobalt, the metal will be dissolved.

*Rationale.* Ammonia has the property of dissolving some of the metallic oxyds, and forms with them peculiar compounds, which have been called *ammonia-rets*. The solution of metallic oxyds, however, depends on the degree of the oxydizement of the metal. Thus, the prot oxyd of iron is soluble, but the per oxyd is insoluble. The per oxyd of cobalt, according to Thenard, is insoluble.

*Remark.* If ammonia is digested on the oxyds of mercury, lead, or manganese, it is decomposed; its

hydrogen unites with a portion of oxygen of the oxyd and forms water, and azotic gas is emitted. If considerable heat be applied nitric acid is also formed, from the union of azote with oxygen.

*Experiment 10.* If *liquid ammonia* be added in excess to a solution of *sulphate of copper*, *ammoniaret of copper* is formed.

*Rationale.* The first portion of ammonia unites with the sulphuric acid of the sulphate, forming sulphate of ammonia; the other portion combines with the oxyd of copper, thus separated, and forms a solution of *ammoniaret of copper*.

*Remark.* If the products of the experiment be evaporated to dryness, and the dry mass be exposed to a gentle heat, the sulphate of ammonia is volatilized, leaving the *ammoniaret* behind, forming the *cuprum ammoniacum* of the shops. There is danger, however, that the heat would separate a portion of the ammonia, and partly decompose the oxyd, forming water as before observed. Oxyd of copper prepared in the first instance, and then united with ammonia, appears to be the best process.

*Experiment 11.* Add *liquid ammonia* to a solution of *gold* prepared with nitro-muriatic acid diluted with three times its weight of water; collect the precipitate, which is of a yellow colour, wash it and dry it gently upon filtering paper. It is the *fulminating gold* known also by the name of *aurate of ammonia*. This powder is to be kept in a vial. A few grains explodes, when heated or rubbed, with great violence.

*Rationale.* The ammonia first decomposes the solution of gold; it unites with the acid; the oxyd of gold, thus separated, combines with a portion of ammonia, and forms the fulminating gold. When heated to a temperature between  $248^{\circ}$  and  $54^{\circ}$ , or when struck violently with a hammer, it explodes. The rationale of this phenomena is as follows: the hydrogen of the ammonia unites with the oxygen of the oxyd, and forms water; the gold is reduced, and the azote is evolved in the form of gas. The great expansibility of this gas explains the violence of the explosion. See GOLD.

*Experiment 12.* To a solution of *nitrate of silver* add *lime water*; collect the precipitate; pour upon it pure liquid ammonia, and allow it to remain for 12 hours; it is then to be decanted off, and the black powder, on which it stood, is to be placed cautiously, and in very small portions upon bits of filtering paper. This powder is the fulminating silver. When dry the slightest touch causes it to fulminate.

*Rationale.* The lime water decomposes the solution of silver; the oxyd of silver is treated with ammonia, which unites with it. It is therefore a compound of ammonia and oxyd of silver. On exposing the compound to a slight friction, the hydrogen of the ammonia unites with the oxygen of the oxyd and forms water, azotic gas is disengaged, and the silver is reduced, at the same time explosion takes place. See SILVER.

*Experiment 13.* According to Fourcroy, if *liquid ammonia* be suffered to stand on *red oxyd of mercury*, the oxyd will assume a white colour. If it be collected, washed, and dried, and placed upon ignited coals it will detonate with considerable violence. This is the *ammoniacal fulminating mercury*.

*Rationale.* The ammonia unites with the oxyd, forming a compound of ammonia and oxyd of mercury. When exposed to heat, the hydrogen of the ammonia combines with the oxygen of the oxyd, and forms water, the mercury is revived, azote is disengaged, and explosion ensues. See MERCURY.

*Remark.* The decomposition of ammonia by electricity and galvanism, was noticed when treating of ammoniacal gas; for information on this subject see that article. When the Stahlian theory of Chemistry was in vogue, in which the imaginary element of phlogiston was considered an important subject of chemical investigation, it was supposed that ammonia contained that principle. Scheele and Bergman both concluded, that it is composed of azote and phlogiston. But the experiments of Priestley led to the inference, that ammonia consisted of azote and hydrogen; which was afterwards sanctioned by Berthollet in a very able and luminous memoir published in 1785. He announced

that it consisted of 121 parts of azote and 32 of hydrogen. According to Dr. Austin's calculation it is composed of 120 parts of azote and 32 of hydrogen. Or 100 parts of ammonia are composed of about 80 parts of azote, and 20 of hydrogen. Mr. Davy has since confirmed the experiments of Berthollet, and, beside, has rendered it probable, that this alkali contains oxygen. A new metal has been obtained from ammonia, to which the name of *ammonium* has been given, in the following manner :

*Experiment 14.* Place a globule of *mercury* in a hollow cut in a moistened piece of *sal ammoniac* ; expose it to the energy of a powerful galvanic battery. It increases in bulk and arrives to the consistence of butter. Its specific gravity is reduced to 3.000. The mercury has therefore been amalgamated with some metallic body. If the amalgam be thrown into water, the mercury resumes its original state, hydrogen gas is emitted, and the water is impregnated with a weak solution of ammoniac. The metal, thus united with the mercury, has been called *ammonium*, or the base of ammonia.

*Remark.* Berzelius and Ponten placed quicksilver, negatively electrified in the galvanic circuit, in contact with a solution of ammonia. The mercury expanded, and became a soft solid. It was supposed, therefore, that this was occasioned by the addition of metallic matter ; that the ammonia having been decomposed by the galvanic influence, its *oxygen* abstracted, and its metallic base left combined with the quicksilver. From this substance, quicksilver and ammonia are reproduced by exposure to the atmosphere, oxygen being absorbed ; and the same products are obtained by placing it in water, hydrogen being evolved. Mr. Davy\* has confirmed this conclusion, and obtained the amalgam readily, by subjecting quicksilver, in contact with muriate or carbonate of ammonia, to the action of the negative galvanic wire. A similar result was obtained by employing the deoxydizing power

\* Phil. Trans. 1808.

of the base of potash or soda, either of these bases being united with quicksilver, and this compound being made to act upon muriate of ammonia; the amalgam increased to six or seven times its original volume, and the compound seemed to contain more of the ammoniacal base than that procured by electrical powers. This amalgam thrown into water, as before noticed, produces ammonia and evolves hydrogen, which pre-supposes the absorption of oxygen. For particulars on this subject I would refer the reader to Mr. Davy's paper in the Philosophical Transactions, and also to a chemical work, which he has lately edited, the supplement to Murray's Chemistry, and the Appendix to Thomson's Chemistry.

In the opinion of Mr. Hembel, the metals obtained from the alkalies are nothing more than the alkalies in a purer state than we have heretofore been able to obtain them. There is indeed some truth in this opinion.

## PART X.

### OF EARTHS.

Although earth in common language signifies the solid parts of the *globe*, and sometimes the *mould* in which vegetables grow, yet the term here is meant to express a class of bodies, which have a variety of common properties. Substances possessing the following characters, are classed under this head.

1. Fixed, incombustible, and incapable while pure of being altered by the fire.

2. No taste or smell; at least when combined with carbonic acid.

3. Insoluble in water, or nearly so; or at least becoming insoluble when united with carbonic acid.

4. A specific gravity not exceeding 4.9.

5. Not altered when heated with combustibles.

6. When pure, capable of assuming a white powder.

They unite also with acids, with the alkalies, with sulphur, phosphorus, metallic oxyds, and with each other, either by fusion or solution in water. But these properties are not completely general.

The earths were heretofore considered as elementary substances; but, not to state the opinions or conjectures of chemists respecting them, Mr. Davy was led by analogy arising from his experiments on the alkalies, to institute a series on this class of bodies, in which he proved that they were compounds of peculiar metallic basis and oxygen. The proportion of oxygen and metal has not yet been ascertained in any of the earths. The inflammable base appears uniformly at the negative surface of the Voltaic circuit, and the oxygen at the positive surface. Baron Born was of opinion many years ago, that the earths were compound bodies.

Bergman includes all substances, except the metals, with the earths, which require more than one thou-

sand parts of water for their solution. The earths have been divided into two classes, namely, of alkaline earths and earths proper. The first possess the general properties of alkalies, such as changing vegetable blues to green, and of neutralizing acids. Lime, magnesia, barytes, and strontian are of this class. The earths proper, which do not change vegetable blues, nor neutralize acids, are five in number, viz. alumina, yttria, glucina, zirconia, and silica. The combination of the earths give rise to stones, and to different kinds of pottery, as bricks, tiles, crucibles, flint ware, yellow ware, queen's ware, Wedgewood ware, porcelain, &c.

An enumeration of the different minerals, arising from the combination of two or more of the primitive earths, may be noticed in this place. We shall use the arrangement adopted by professor Cooper.\*

## EARTHS AND STONES.

1. OR DIAMOND GENUS.	<i>Ruby Family.</i>
Diamond.*	Spinell.
2. OR ZIRCON GENUS.	Sapphire.
Zircon.	<i>Schorl Family.</i>
Hyacinth.	Topaz.
3. OR SILICEOUS GENUS.	Emerald.
<i>Garnet Family.</i>	Beryl.
Chrysoberil,	Precious.
Chrysolite.	Schorloid.
Olivine.	Schorl.
Augite.	Black.
Vesuvian:	Electric.
Leucite.	Thunerstone.
Melanite.	Eisenkiesel.
Garnet.	<i>Quartz Family.</i>
Precious.	Quartz.
Common.	Amethystine.

\* Introductory Lecture, 8vo. p. 215.

\* See Carbon.

Rock crystal.  
 Milk.  
 Common.  
 Prase.  
 Hornstone.  
   Splintery.  
   Conchoidal.  
 Petrified wood.  
 Gun flint.  
 Chalcedony.  
   Common.  
   Cornelian.  
 Heliotrope.  
 Plasma.  
 Chrysoprase.  
 Siliceous schist.  
   Common.  
   Lydian or touch stone.  
     *Zeolite Family.*  
 Obsidian.  
 Cats eye.  
 Prehnite.  
 Zeolite.  
   Farinaceous.  
   Fibrous.  
   Radiated.  
   Lamellar.  
   Cubic.  
 Cross stone.  
 Lapis lazuli.  
 Lazulite.

4. OR ARGILLACEOUS  
GENUS.

Pure Alumine.  
 Porcelain earth.  
 Clay.  
   Common.  
   Potters.  
   Indurated.  
   Slate.

Cimolite.  
 Jasper.  
   Egyptian.  
   Ribband.  
   Porcelain.  
   Common.  
 Opal  
   Precious.  
   Common.  
   Semi.  
   Ligniform.  
 Pearl stone.  
 Pitch stone.  
 Adamantine spar.  
 Feldspar.  
   Compact.  
   Common.  
   Undecomposed.  
   Decomposed.  
   Adularia.  
   Labrador.  
 Polishing slate.  
 Tripoli.  
 Alum stone.  
 Alum earth.  
   *Clay slate Family.*  
 Alum slate.  
   Common.  
   Glossy.  
 Bituminous shale.  
 Drawing slate.  
 Whetstone slate.  
 Clay slate.  
   *Mica Family.*  
 Lepidolite.  
 Mica.  
 Lapis ollaris. }  
   Potstone. }  
 Chlorite.  
   Earthy.

Common.  
Slaty.  
Foliated.  
*Traph Family.*

Hornblende.  
Common.  
Basaltic.  
Labrador.  
Slate.

Basalt.  
Wacke.  
Clinkstone.  
Lava.

*Lithomarge Family.*

Pumice stone.  
Green earth.  
Lithomarge.  
Friable.  
Indurated.

Sculpture stone.  
Rock soap.  
Yellow earth.

5. OR MAGNESIAN GENUS.

*Soap stone Family.*

Bole.  
Native talc earth.  
Sea froth.  
Fuller's earth.

*Talc Family.*

Nephrit.  
Common.  
Indian hatchet.

Steatite.  
Serpentine.  
Common.  
Precious.

Talc.  
Earthy.  
Common.  
Indurated.

Asbestos.  
Rock cork.  
Amianthine.  
Common.  
Rock wood.

Cyanite.  
Arrow stone.  
Radiated.  
Common.  
Glassy.  
Tremolite.  
Asbestiform.  
Common.  
Glassy.

6. OR CALCAREOUS GENUS.

A. Carbonates of lime.

Agaric mineral. }  
Rock milk. }  
Chalk.

Limestone.  
Compact.  
Common.  
Globular or, }  
Oviform, }  
Lamellar.  
Granular.  
Spathose.  
Fibrous.  
Pisolite.

Earth froth.  
Slate spar.  
Bitter spar.  
Brown spar.  
Fetid limestone.  
Marle.

Earthy.  
Lithomarge.  
Bituminous marle slate.  
Arragonite.  
B. Phosphate of lime.

Apatite.  
 Asparagus stone.  
 C. Borated lime.  
 Boracite.  
 D. Fluuate of lime.  
   Fluor.  
   Earthy.  
   Compact.  
   Sparry.  
 C. Sulphate of lime.  
 Gypsum.  
   Earthy.  
   Compact.  
   Lamellar.  
   Foliated.  
   Fibrous.  
   Crystallised.  
   Lamellar gypsum.

Selenite of some.  
 7. OR BARYTIC GENUS.  
 Witherite.  
 Heavy spar.  
   Earthy.  
   Compact.  
   Granular.  
   Curved lamellar.  
   Straight lamellar.  
   Not decomposed.  
   Decomposed.  
   Columnar.  
   Fibrous.  
   Bolognian spar.  
   Prismatic barytes.

8. OR STRONTIAN GENUS.  
 Strontianite.  
 Cœlestine.

In this arrangement of stones it is evident, that the particular genus takes its rise from the particular earth, which does or is supposed to constitute the greater part of the stone. This again is divided into families, species, and sometimes into subspecies. This varies, however, in different systems of arrangement. Rocks, which are generally aggregated stones, have been classed in the following order:

FIRST CLASS.  
*Primitive Rocks.*  
 Granite.  
 Gneiss.  
 Mica slate.  
 Clay slate.  
   Common.  
   Flint.  
   Whetstone.  
   Chlorite.  
   Talc.  
 Sienite.  
   Common.  
   Schistose.

} Slate.

Porphyry.  
   Clay.  
   Graystone.  
   Hornstone.  
   Pitch stone.  
   Obsidian.  
   Feldspar.  
 Porphyry state.  
 Quartz.  
 Primitive limestone.  
 Serpentine.  
 Topaz rock.

} Porphyryized.

SECOND CLASS.  
*Transition Rocks.*

Transition clay slate.  
Grauwacke.

Schistose.

Transition limestone.

Hornblende slate.

Greenstone.

Mandelstone. }

Amygdaloid. }

#### THIRD CLASS.

Secondary Rocks. }

Stratiform Rocks. }

Trap formation.

Basalt.

Basaltic porphyritic.

Gray stone.

Basaltic amygdoloid.

Wackee.

Basalt tufa.

Stratified clay slate.

Common.

Alum schist.

Stratified lime stone.

Compact.

{ Oolite.

{ Zoogenstein.

Fetid stone.

Marle.

Bituminous marle  
schist.

Sandstone.

Common.

Siliceous.

Argillaceous.

Marly.

Ferruginous.

Breccious.

Stone coal.

Slate clay.

Stone coal.

Bituminous schist.

Chalk.

Gypsum.

Rock salt.

Ferruginous clay.

Clay (letten.)

#### FOURTH CLASS.

*Alluvial Rock.*

Sand.

Gravel.

Fine sand.

Quick sand.

Mud.

Common clay.

Bituminous wood.

Fossil wood.

Aluminous earth.

Tufa (soft friable earth.).

#### FIFTH CLASS.

Volcanic rocks.

Lava.

Vitreous.

Compact.

Cellular.

Scoriaceous.

Spongiform.

Pumice stone.

Volcanic ashes.

Puzzolana.

Volcanic tufa.

Piperino.

Terras.

Pseudo-volcanic rocks.

Laniform earthy scoria.

Porcelain jasper.

Half burnt clay.

Argillaceous iron  
(scapiforme.)

## DIVISION I.

## OF THE ALKALINE EARTHS.

## SECTION I.

## OF LIME.

*Experiment 1.* If *limestone*, either amorphous or crystallized, as calcareous spars, marble, or oyster-shells be pulverised, and introduced into a crucible, or porcelain or earthen retort, and exposed for some time to a strong heat, quicklime or more properly *lime* will be prepared. If the air, which is disengaged, be collected, by adapting to the neck of the retort a bent tube of glass conveyed under a bell, it will be found to be carbonic acid gas. See the Preparation of Carbonic Acid Gas.

*Rationale.* As limestone, calcareous spars, marble, &c. are carbonates of lime, or composed of lime and carbonic acid, on exposure to an intense heat, the carbonic acid is disengaged, leaving the lime in the crucible or retort in the state of quicklime. If the air which is disengaged be examined, it will prove to be carbonic acid gas or fixed air.

*Remark.* The operation of burning lime, as it is called, in the large way, depends on this principle. It is conducted in kilns. If the native carbonate are pure, no vitrification takes place. Lime, which has been partially vitrified, is known by the name of *over-burnt lime*.

*Experiment 2.* Pulverise marble and dissolve it in *acetous acid*; to the solution, previously filtered, add *carbonate of ammonia*. When the precipitate subsides, collect it, wash it, and expose it to a white heat for some hours, and pure *lime* will be obtained.

*Rationale.* The impure carbonate of lime is decomposed by the acetous acid, carbonic acid is disengaged, and acetite of lime remains in solution. When carbonate of ammonia is added, carbonate of lime is precipitated, and acetite of ammonia remains in solution. When the former is collected, and exposed to heat, the carbonic acid is disengaged, and the lime remains in the crucible. Or, pure lime may be obtained in the following manner :

*Experiment 3.* Dissolve oyster-shells in *muratic acid*, filter the solution, and add to it ammonia as long as a precipitate appears ; filter it again. The liquor is now to be mixed with a solution of *carbonate of soda* : the powder which falls being washed and dried, and heated violently in a platinum crucible, is pure lime.\*

*Rationale.* The lime of the shell is dissolved by the acid, the muriate of lime which is thus formed, is decomposed by carbonate of soda, muriate of soda remains in solution, and carbonate of lime is precipitated. On exposing this to heat, the carbonic acid is disengaged, and the lime is left.

*Remark.* Pure lime is of a white colour, moderately hard, but easily reduced to a powder. It is caustic. Its specific gravity is 2.3. It is infusible. As lime was observed to lose in weight in calcination, Van Helmont particularly made an experiment to ascertain what the volatile product was. He as well as others supposed it to be pure water. While, this subject engaged the attention of philosophers, Dr. Black published a set of experiments in 1756. He found that it was the same air disengaged from it during calcination, as was produced by the action of acids, an idea which he drew from Dr. Hales. This air Dr. Black called fixed air. The investigations of Priestley and others afterwards demonstrated, that this gas was the same as carbonic acid gas of the moderns.

*Experiment 4.* When water is poured on fresh burnt lime it swells, falls to pieces, and is soon reduced to a

\* Thomson.

very fine powder; at the same time much heat is produced, and a part of the water flies off in vapour.

*Rationale.* The evolution of heat in the process of slacking lime, is owing to a condensation of the water, which combines with it; for part of the water unites with the lime, and thus becomes solid. The water parts with its caloric of fluidity, and is appreciable by the senses. When two parts of lime and one part of ice, each  $32^{\circ}$ , are mixed, they combine rapidly, and their temperature is elevated to  $212$ . It is inferred, therefore, that a considerable quantity which exists in water, even in the state of ice, is given out at the same time.

*Remark.* Slacked lime well dried, according to Dalton, is composed of three parts of lime and one part of water. Mr. Lavoisier found, that 1000 parts of lime, when slacked, were converted into 1287 parts. This compound has been called *hydrate of lime*. When the quantity of lime slacked is great, the heat produced is sufficient to set fire to combustibles. Vessels loaded with lime have been burnt by this means. If considerable quantities of lime be slacked, light as well as heat is emitted. When lime is reduced to the consistence of cream, by water, it is called *cream of lime*. The peculiar odour emitted during the slacking of lime, is owing to a portion of the lime being carried off with the aqueous vapour.

*Experiment 5.* Expose fresh burnt lime to the atmosphere, it will attract moisture, fall to powder, and gradually resume the state of carbonate of lime.

*Rationale.* The disintegration of lime is owing to the absorption of water; and its gradual conversion into carbonate of lime, is attributed to the absorption of carbonic acid.

*Experiment 6.* If water be added to quicklime it will, besides combining with a portion forming hydrate of lime, unite with it in a liquid state. This liquid is *lime water*.

*Remark.* Water, at the common temperature of the atmosphere, dissolves less than 0.002 parts of its weight

of lime. One ounce of water contains about one grain of lime. The solution is limpid.

Lime water is usually prepared by slacking the lime to a thin paste, and a sufficient quantity of boiling water afterwards added. This mixture is to be stirred repeatedly, the lime allowed to settle, and the clear liquor decanted for use. Lime water has a pungent alkaline taste, and changes the infusion of violets or cabbage to green.

*Experiment 7.* If lime water be exposed to the atmosphere, a crust will form on the surface, and, when it is sufficiently large, will fall to the bottom.

*Rationale.* This phenomena ensues in consequence of the absorption of carbonic acid from the atmosphere; a carbonate is formed, and is gradually precipitated.

*Remark.* It is owing to the separation of lime from its solution by carbonic acid, that gives rise to the numerous calcareous concretions or incrustations, as are found in caverns, and springs, constituting *stalactites*, &c. In Tuscany, artists employ certain waters which hold a large quantity of lime in solution, to form *basso relievos*, which they do by filling their moulds with the water.

*Experiment 8.* Expose lime water to an atmosphere of carbonic acid, and the same phenomena will ensue as in Experiment 7.

*Remark.* This is owing to the same cause.

*Experiment 9.* Take the vial made use of in the last experiment, with its contents, and convey an additional portion of carbonic acid into it. The carbonate of lime will be dissolved, and the liquor rendered transparent; or,

*Experiment 10.* If a small quantity of water saturated with carbonic acid be added to lime water; a carbonate of lime will be precipitated; but on adding more of the aerated water, the turbidness will disappear.

*Rationale.* A small quantity of carbonic acid, whether as a gas, or in solution in water, precipitates lime from lime water as a carbonate; a still further addition dissolves the precipitate, forming a super carbonate of

lime. Hence lime sursaturated with carbonic acid is soluble in water.

*Experiment 11.* Expose the limpid solution of the last experiment, in a flask, to the action of the heat, and it will again become turbid.

*Rationale.* The action of heat carries off the excess of carbonic acid, and the remaining compound of lime and acid, not being soluble, is precipitated.

*Experiment 12.* To the precipitate of the last experiment, add muriatic acid, and the whole will become transparent.

*Rationale.* The carbonate of lime is decomposed by the muriatic acid; carbonic acid is disengaged in effervescence, and muriate of lime is formed.

*Experiment 13.* If a solution of carbonate of potash be added to lime water; the mixture will become turbid, and the precipitate will gradually subside.

*Rationale.* The carbonic acid of the carbonate passes to the lime, at the same time, in proportion to the quantity of lime water used; the alkali is rendered caustic. See POTASH.

*Experiment 13.* If a tumbler half full of lime water, be breathed into by means of a pipe or tube, the lime water will grow turbid.

*Rationale.* In respiration a quantity of carbonic acid is formed, which in this case as it passes from the lungs is absorbed by the lime water.

*Experiment 15.* Into a glass of lime water put a few drops of oxalic acid, oxalate of ammonia, or oxalate of potash, and the lime will be precipitated.

*Rationale.* The oxalic acid, whether free or in a combined state, has the property of separating lime; hence it combines with it, and forms an insoluble precipitate of oxalate of lime. Oxalic acid is therefore a test for lime.

*Experiment 16.* Mix in a wine glass equal quantities of a saturated solution of muriate of lime, and a saturated solution of carbonate of potash, both transparent fluids, stir the mixture, and a solid mass will be the product.

*Rationale.* This effect takes place by compound affinity: the muriatic acid having an affinity for the potash, unites with it, forming muriate of potash, whilst the carbonic acid combines with the lime, and produces carbonate of lime.

*Experiment 17.* If sulphate of magnesia be added to lime water, a precipitation will take place.

*Rationale.* The precipitate produced is a mixture of sulphate of lime and a portion of magnesia, which occurs in consequence of the lime taking the acid from the sulphate of lime, whilst that portion of magnesia thus dislodged from the sulphuric acid is separated.

*Experiment 18.* If lime water be added to a solution of alum, a precipitation will ensue.

*Rationale.* The sulphuric acid of the super sulphate of alumina and potash (alum) unites with the lime forming sulphate of lime, and if the lime water be added in sufficient quantity, the precipitate will consist of sulphate of lime and alumina.

*Experiment 19.* If four parts of liquid muriate of lime, according to Tromsdorf, and one part of lime be boiled together until a drop on cooling assumes the consistence of syrup; then filtered through a cloth into an earthen vessel, kept covered; as the liquid cools needle shaped crystals of pure lime will shoot in it.

*Remark.* This experiment is said to succeed only on a large scale, and when several pounds of muriate of lime are employed. The crystals, although considered by Tromsdorf as pure lime, have since been shewn to be merely a sub muriate of lime.

*Experiment 20.* Three parts of oyster-shell pulverised, and mixed with one of sulphur; and exposed in a crucible to a moderate heat forms Canton's phosphorus. See LIGHT.

*Experiment 21.* If a mixture of one part of sulphur and two of lime be heated for at least an hour in a covered crucible, a compound will be formed called *sulphuret of lime*.

*Remark.* The mixture should not be rammed tight in the crucible. A reddish sulphuret is the product,

which in the old nomenclature, is called *calcareous liver of sulphur*. When it is exposed to the air, or moistened with water, its colour is changed to a greenish yellow, sulphuretted hydrogen is formed, and hydroguretted sulphuret of lime is produced. See the Preparation of Sulphuretted Hydrogen Gas.

*Experiment 22.* If the same mixture as in Experiment 19, be boiled in about ten times its weight of water, or if quicklime be sprinkled with sulphur and then moistened, hydroguretted sulphuret of lime will be formed.

*Rationale.* The sulphur unites with the lime, water is decomposed, and its hydrogen in part combines with the sulphuret, forming the hydroguretted sulphuret.

*Remark.* When hydroguretted sulphuret of lime is exposed to the air, oxygen is absorbed, which combines at first with the hydrogen, and afterwards with sulphur, and, according to Berthollet, converts the compound into sulphate of lime. The hydroguretted sulphuret has the property of dissolving charcoal by the assistance of heat.

*Experiment 23* Put into the bottom of a glass tube, close at one end, one part of phosphorus; and, holding the tube horizontally, introduce five parts of lime in small lumps, so that they shall be about two inches above the phosphorus. Then place the tube horizontally among burning coals, so that the part of it which contains the lime may be made red hot, while the bottom of the tube containing the phosphorus remains cold. When the lime becomes red hot, raise the tube, and draw it along the coals till that part of it which contains the phosphorus is exposed to a red heat. By this means a union will ensue, and *phosphuret of lime* will be formed. This process was invented by Doctor Pearson: or,

*Experiment 24.* According to Van Mons, introduce into a flask some carbonate of lime in powder: put it in a sand bath, and expose it to a heat sufficient to expel the carbonic acid. Towards the end of the process introduce gradually a third part of phosphorus,

taking care to keep the lime in a red heat. When the whole of the phosphorus is introduced, shut up the matrass with a stopper, provided with a valve to let the gas escape, but permitting none to enter, and let the fire be immediately withdrawn. The product is phosphuret of lime ; or,

*Experiment 25.* According to Dr. E. Cutbush,\* put a portion of lime, divided into small pieces, into a Hessian crucible, and expose it in a common furnace until the lime becomes red hot. The phosphorus intended to be used, being dried by means of a spongy paper, is then put into another crucible, sufficiently capacious to contain the quantity of lime. The ignited lime is removed from the furnace, and placed in the crucible containing the phosphorus, which is to be expeditiously covered with an inverted crucible sufficiently large to receive that which now holds the lime and phosphorus, care being taken to prevent the access of atmospheric air, by surrounding the edge of the inverted crucible, in contact with the brick or tile on which it rests, with some soft clay or lute. When the contents have remained a sufficient time to become cold, a *phosphuret of lime* will be found in the crucible.

*Rationale.* In the process of Dr. Pearson, a direct combination of the phosphorus and lime takes place, but the lime must be made extremely hot to ensure success : in that of Van Mons, the carbonate of lime is first decomposed by the heat, leaving more or less of an atmosphere of carbonic acid, which prevents the combustion of the phosphorus, but this very frequently fails : in the process of Dr. Cutbush, which is more expeditious and certain, although some waste of the phosphorus ensues, the union of the two is accomplished without being subject to the difficulties of either of the others.

*Remark.* Phosphuret of lime is generally of a deep brown colour. When thrown into water, it decompo-

\* Eclectic Repertory, vol. ii. p. 367.

ses that fluid, and evolves phosphuretted hydrogen gas. See the Preparation of Phosphuretted Hydrogen Gas.

Dr. Cutbush observes, that the phosphuret prepared according to the last process is of different hues, from a dark chocolate colour to that of pink: a portion thrown into water continued to act three hours: the water into which it had been thrown, when filtered, emitted an alliaceous odour, and converted vegetable blues into green, in consequence of the lime held in solution. He supposes, that the red powder which was found in the inverted crucible, was a phosphuret of carbon; for, he adds, "I have tested this powder by inflaming a portion of its oxygen gas; a small quantity of phosphoric acid was formed, the remaining gas being passed into lime water, on agitation, produced a turbid appearance, indicative of the formation of carbonic acid by the union of the carbon of the phosphuret with oxygen."

*Experiment 26.* If red oxyd of mercury be boiled with lime water, and the fluid then evaporated, small transparent yellow crystals will be formed.

*Remark.* The compound, resulting from the union of the oxyd of mercury and lime, has been called by some *mercuriate of lime*. Lime water has the property of dissolving other metallic oxyds, as the red oxyd of lead and litharge. This compound blackens wool, the nails, the hair, and the white of eggs: the colour of the skin, silk, the yolk of eggs nor animal oil, are affected by it. It is a common practice with *perruke-makers*, to blacken hair by boiling it with lime and litharge.

*Experiment 27.* If lime and silicia be exposed to a strong heat they melt; or if lime and alumina be treated in the same manner, fusion will ensue.

*Remark.* Hence we learn the utility of calcareous substances, such as oyster-shells, limestone, &c. in the fusion of some iron ores, especially the argillaceous ores: it acts as a flux by melting the argil, and thus separating it from the iron.

*Experiment 28.* If lime, previously slacked, be mix-

ed with siliceous sand, the cement or mortar for building will be formed.

*Remark.* The use of lime in the preparation of mortar, is one of its most important applications. The hardening of mortar is a species of crystallization, owing to the slow absorption of carbonic acid and water. The best proportions for forming mortar are, it is said, one part of lime and two of sand mixed in the usual way. Dr. Higgins, however, says that three parts of fine sand, four parts of coarser sand, one part of quicklime recently slacked, and as little water as possible, will form the best mortar. The Doctor also recommends the addition of bone-ashes, which he adds in the same proportion as lime. A little manganese added to mortar gives it the property of hardening under water; so that it may be employed advantageously for a variety of purposes.

Morveau's *water mortar* consists of four parts of blue clay, six parts of black oxyd of manganese, and 90 parts of limestone, first calcined to expel the carbonic acid, and afterwards mixed with 60 parts of sand and a sufficient quantity of water. Puzzollano and basalt have both been used for the same purpose. My brother William, of the corps of engineers, informed me, that in erecting the batteries at New York, the borings of cannon, &c. was successfully used in making water mortar. It is a common custom to employ the scales of iron in preparing mortar to stand the weather.

*Experiment 29.* Put an ounce of calcareous marl into a flask, and add a certain weight of diluted muriatic acid. When the effervescence ceases, weigh the whole to ascertain what portion of its weight it has lost by the escape of the fixed air. If the ounce has lost only 40 grains, it may be concluded that the ounce of marl contained only 100 grains of calcareous earth.

*Rationale.* The action of the muriatic acid decomposes the carbonate of lime of the marl, and the quantity of carbonic acid is shewn by the diminution of weight, and, therefore, concluding from similar experiments, the proportion of lime may be determined.

*Remark.* Calcareous earth is used as a manure ; and marls, generally, are employed, in consequence only of the calcareous earth they contain. It is said, that unless they contain more than 30 per cent. of lime, they are of no value to the agriculturalist.

Beccher and Stahl supposed, that the earths and metallic oxyds were of a similar nature ; and indeed it was the favourite opinion of Lavoisier, that all the earths might be metallic oxyds. Besides other opinions respecting the earths generally, it was imagined that lime was composed of carbon, hydrogen, and azote. Mr. Davy, however, by instituting some experiments on lime by means of the galvanic battery, has shewn that it has a metallic base, which he called *calcium*. When calcium was heated in the open air, it burnt brilliantly, and quicklime was formed. Mr. Davy inferred, therefore, that lime is composed of calcium and oxygen.

## SECTION II.

### OF MAGNESIA.

*Experiment 1.* If sulphate of magnesia be dissolved in water, and a solution of carbonate of potash added, a precipitate will be formed, which is the magnesia of the shops.

*Rationale.* When carbonate of potash is added to sulphate of magnesia, a double decomposition ensues ; the sulphuric acid of the sulphate unites with the potash, forming sulphate of potash, which remains in solution, and the carbonic acid of the carbonate combines with the magnesia, forming sub-carbonate of magnesia, which precipitates.

*Remark.* Equal weights of the carbonate and sulphate are generally employed, but, according to the Pharmacopea, they are separately dissolved and fil-

tered; then mixed, and eight parts of water added. The temperature is raised to complete the decomposition. The fluid, when strained through a linen, leaves the magnesia, which is washed and dried. The sulphate of potash, which passes the filter, may be evaporated and crystallized. Two circumstances in conducting the process should be attended to. 1st. Heat should be used in order to expel a part of the carbonic acid, which retains a portion of the magnesia in solution. 2dly. The large quantity of water is necessary to dissolve the sulphate of potash. This however contains some undecomposed carbonate of potash; for 100 parts of crystallized carbonate of potash are sufficient for the decomposition of 125 parts of sulphate of magnesia; and as the carbonate of potash of commerce contains a larger proportion of alkali than the crystallized carbonate, a still less proportion should be used. There are sources of impurity, one of which arises from the silica, which the potash of commerce generally contains. This may be separated, by suffering the alkali to deliquesce, before it is used. The sub-carbonate is composed of about 48 acid, 40 magnesia, and 12 of water. It is decomposed by all the acids, potash, soda, barytes, lime and strontian, the sulphate, phosphate, nitrate, and muriate of alumina, and the super-phosphate of lime.

A Roman canon about the beginning of the seventeenth century exposed a white powder to sale at Rome which he called magnesia alba, for the cure of all diseases. The preparation was kept secret; but in 1707 a process was published for obtaining it by calcining the lixivium, which remains after the preparation of nitre. A process also appeared, a few years after, which consisted in precipitating the magnesia from the mother ley of nitre by means of potash. This powder was supposed to be lime, until the contrary was demonstrated by Hoffman. Dr. Black, in 1755, made a number of interesting experiments on magnesia. Margraff, Bergman and others also wrote on the same subject.

*Experiment 2.* If a solution of crystallized carbonate of potash be added to another of sulphate of magnesia, carbonate of magnesia will gradually be deposited in brilliant hexagonal crystals, terminated by an oblique hexagonal plane.

*Rationale.* As the potash, in the crystallized carbonate, is fully saturated with carbonic acid, when it is added to sulphate of magnesia, the carbonic acid passes to the magnesia, which gradually precipitates or forms in crystals, whilst the sulphuric acid attaches itself to the alkali.

*Remark.* Crystallized carbonate of magnesia is composed of 50 acid, 25 magnesia, and 25 water in the hundred, and is soluble in about 480 times its weight of water.

*Experiment 3.* If carbonate of magnesia be put into a crucible, and kept in a red heat for two hours, the *calcined magnesia* of the shops will be formed.

*Rationale.* When carbonate of magnesia is exposed to heat, it loses its carbonic acid which escapes in the form of gas, together with the water it generally contains.

*Remark.* According to Dr. Black, magnesia, in calcination loses  $\frac{7}{12}$ ths of its weight. It should always be kept from the air. Magnesia may be obtained free from carbonic acid in the following manner

*Experiment 4.* To a solution of sulphate of magnesia add caustic or pure potash, and collect, wash, and dry the precipitate.

*Rationale.* The alkali unites with the sulphuric acid of the sulphate, and the magnesia is precipitated in a pure state.

*Remark.* Magnesia is a soft white powder, of little taste, totally destitute of smell, and the specific gravity, according to Kirwan, of 2.3.

*Experiment 5.* If tincture of cabbage be added to a mixture of one part of magnesia and six of water, the mixture will instantly become green. See Earths in General.

*Experiment 6.* Magnesia and water, when mixed, do not adhere together, but it has, nevertheless, a

strong affinity for that fluid. See the Remark to experiment 1. One hundred parts of magnesia thrown into water, and then dried, are increased in weight to 118 parts.

*Experiment 7.* If magnesia be formed into a cake with water, according to Darcet, and then exposed to a violent heat, the water is entirely driven off, and the magnesia contracts in its dimensions; at the same time, it acquires the property of shining in the dark when rubbed upon a hot iron plate.

*Experiment 8.* If water be added to magnesia and then filtered, it will be found that a minute portion is dissolved.

*Remark.* Mr. Kirwan says that it requires 7900 times its weight of water at the temperature of  $60^{\circ}$ , to dissolve it.

*Experiment 9.* If pure magnesia be exposed to the air, it will, in time, increase in weight.

*Rationale.* This is owing to the absorption of carbonic acid and water. If an acid be added, the former will be disengaged with an effervescence.

*Experiment 10.* If carbonate of magnesia be digested in fresh prepared lime water, it will be found that the lime will have taken the carbonic acid from the magnesia; for the water, on filtering it, will be found to have lost all the properties of lime water.

*Experiment 11.* If two parts of magnesia and one of sulphur be exposed to a gentle heat in a crucible, union will ensue, and *sulphuret of magnesia* will be formed.

*Experiment 12.* If muriate of magnesia be dissolved in alcohol, and the alcohol then set on fire, it will produce a very beautiful orange coloured flame.

*Remark.* Magnesia combines with the acids forming magnesian salts, which will be noticed hereafter. As this earth occurs in many stones, its separation from other earths is important in chemical analysis. We shall, therefore, give the processes for separating magnesia from other earths.

*Experiment 13.* To a stone, containing magnesia and lime previously pulverised, add concentrated sul-

phuric acid. Apply a sand heat till the acid ceases to rise, and then raise the heat so as to expel the excess of acid. Weigh the dry mass, and digest it in twice its weight of cold distilled water. Filter the fluid, and add to it carbonate of potash, collect the precipitate, wash it and expose it to a strong heat; its weight will give the quantity of magnesia in the stone. The substance which remains on the filter, when washed in a little water, and dried in a low red heat, will give the quantity of lime by deducting from its weight 59 per cent.\*

*Rationale.* The sulphuric acid unites with the magnesia and lime, forming sulphate of magnesia, and sulphate of lime: on adding water, the former is dissolved, which passes the filter, and the latter remains behind. The sulphate of magnesia is then decomposed by carbonate of potash, by compound affinity, and the quantity of magnesia ascertained. By deducting 59 per cent. from the sulphate of lime, will give the proportion of lime.

*Experiment 14.* To a stone containing magnesia and alumine add nitric or muriatic acid, and effect a solution. To this solution, when cold, add carbonate of ammonia, which will separate the alumine. The remaining fluid, after separating the precipitate, is to be treated with carbonate of potash as before noticed.

*Rationale.* The solution of magnesia and alumine, when treated with carbonate of ammonia, is decomposed: the alumina is precipitated, and, as carbonate of ammonia in a lower temperature, does not decompose magnesian salts, the magnesia is held in solution. Or,

*Experiment 15.* To a solution of the two earths add succinate of soda, and the alumine will be precipitated.

*Remark.* Iron, should it occur, may be separated by digesting the earths in nitric acid, and exposing the solution, previously evaporated to dryness, in a crucible to a low red heat during one hour. The iron will thus be highly oxydized. On adding diluted nitric acid it will remain behind.

\* Klaproth's Analytical Essays, vol. i. 76,

*Experiment 15.* If to a solution containing magnesia and manganese, hydrosulphuret of potash be added; the latter will be precipitated.

*Remark.* The manganese is precipitated as a hydrosulphuret, which, when exposed to heat, and weighed, will give its quantity. To the remaining solution potash is to be added, which will separate the magnesia.

Magnesia, like lime, is a metallic per-oxyd, to the base of which Mr. Davy has given the name of magnium. When moistened magnesia is exposed to the action of galvanism in contact with mercury, the earth is reduced, and its base unites with the mercury. Moistened sulphate of magnesia succeeds much better than the pure earth. Magnium is a white metal, having the appearance of silver. When the amalgam of magnium is exposed to the air it gradually absorbs oxygen, and the magnium is converted into magnesia. The metal decomposes water and generates magnesia.

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### SECTION III.

#### OF BARYTES.

*Experiment 1.* Dissolve native carbonate of barytes in diluted nitric acid, evaporate the solution, and suffer it to crystallize. Put the crystals into a china cup, or silver crucible, and after exposing it to a dull red heat for at least one hour, transfer the greenish solid contents into a well stopped bottle. This is *pure barytes*.

*Rationale.* The nitric acid decomposes the carbonate of barytes, carbonic acid is disengaged, and nitrate of barytes is formed. On exposing this to the action of heat, the nitric acid is separated, which is decomposed into its constituent parts, and the barytes remains behind.

*Experiment 2.* If powdered sulphate of barytes be boiled in a flask, for about two hours, in a solution

of twice or three times its weight of carbonate of potash, and the powder then collected, washed, and exposed in a crucible to a strong heat, *pure barytes* will be formed.

*Rationale.* The carbonate of potash decomposes the sulphate of barytes; the sulphuric acid passes to the potash, forming sulphate of potash, which remains in solution, and the carbonic acid unites with the barytes forming carbonate of barytes, and remains in the form of an insoluble powder. When this is exposed to a violent heat, the carbonic acid is expelled in the form of gas.

*Experiment 3.* If one part of sulphate of barytes be mixed with eight of charcoal, both reduced to powder, and exposed in a crucible for some hours, to a red heat, and the powder then taken and dissolved in diluted nitric acid, the solution filtered, and then treated in the same manner as Experiment 1, *pure barytes* will be procured.

*Rationale.* The charcoal decomposes the sulphuric acid of the sulphate, carbonic acid is disengaged, and sulphuret of barytes is formed. On adding nitric acid in the state of dilution, the sulphur will be disengaged, sulphuretted hydrogen gas evolved, and nitrate of barytes will remain in solution. On exposing this to heat as in Experiment 1, the same effect will ensue.

*Experiment 4.* Proceed as in the last experiment with sulphate of barytes and charcoal; dissolve the residue in water, filter it, and add a solution of carbonate of soda to the filtered liquor. Collect the precipitate, and expose it to a strong heat in a crucible, and *pure barytes* will remain. Or take the powder which precipitates, and mix it with charcoal powder, make the mixture into balls, and heat it strongly as before. When these balls are treated with boiling water, a portion of barytes is dissolved, which crystallizes as the water cools.

*Rationale.* The sulphate is decomposed by charcoal as before. The carbonate of soda precipitates the barytes, which is exposed to heat to disengage the carbo-

nic acid, or it is mixed with charcoal and treated as before mentioned, by which the barytes is left in a free state.

*Remark.* Barytes was discovered by Scheele in 1774. The heavy mineral, of a foliated texture and brittle, which is found in Europe and America, and sometimes as a gangue to ores, was known by the name of *ponderous spar*. It was examined by Gahn, who discovered that it contained sulphuric acid, and the new earth discovered by Scheele. Bergman confirmed the experiments of Gahn, and gave the earth the name of *terra ponderosa*. Morveau called the earth *barote*, and Kirwan barytes. Various papers have appeared on this earth. Barytic earth has a caustic taste, and is a violent poison. It tinges vegetable blues green, and decomposes the animal bodies like the fixed alkalies, though with less energy. Its specific gravity, according to Fourcroy, is 4. When heated it becomes harder. Before the blow-pipe, on charcoal, it fuses, bubbles up, and runs into globules. Sulphate of barytes is very plentiful in the Devonshire lead mines; the workmen call it *Cauk*. Casciarole, an Italian shoemaker, discovered that if sulphate of barytes be calcined in a peculiar way it will acquire a phosphorescent quality, and will shine even in water. It is known by the name of bologna phosphorus. See page 49.

Barytes has been proposed as a medium for decomposing muriate of soda in a cheap way. The method of using it may be seen in the *Annales de Chimie*, tome xix. See also a paper of Vauquelin's on this subject in the *Journal de Phys.* 1794, p. 297.

Though this earth has been accounted highly poisonous, yet Dr. Johnson says, that he has seen a delicate female take thirty drops of a saturated solution of muriate of barytes *repeatedly* in the course of a day without even nausea. He therefore concludes, that it would require at least 2 or 3 drams to do mischief.

Barytes is a basis of a *water paint*, which was discovered by Mr. Hume, and sold under the name of

Hume's permanent white, which it is said, will mix with any other colour without injury.

The union of barytes with acids forms a class of salts. See Salts of Barytes.

*Experiment 5.* Expose barytes to the air, it will attract moisture and carbonic acid, and acquire weight.

*Remark.* In this process the barytes swells and emits heat, and, after it is *slacked*, it attracts carbonic acid, and increases 0.22 in weight.

*Experiment 6.* Pour water upon barytes, it will exhibit the same phenomena as quicklime, and be dissolved, forming *barytic water*. On evaporating the solution, it will crystallize in the form of needles; but more commonly in hexagonal prisms, having two broad sides, with two intervening narrow ones, and terminated at each end by a four sided prism.

*Remark.* Water is capable of dissolving 0.05 parts of its weight of water. The crystals of barytes contain 53 parts of water, and 47 of barytes. When exposed to heat, they undergo the *watery fusion*. A stronger heat disengages all the water. Crystallized barytes is soluble in  $17\frac{1}{2}$  parts of water at the temperature of  $60^{\circ}$ . If the temperature be increased, the water will dissolve a larger quantity. Exposed to the air the crystals effloresce, and become pulverent.

*Experiment 7.* Add tincture of cabbage to barytic water, and its colour will be changed to *green*.

*Experiment 8.* In the same manner mix some tincture of Brazil wood; the red colour will be altered to that of *violet*.

*Experiment 9.* Immerse a slip of turmeric paper, or add some of the tincture to barytic water, and a *brown* colour will be produced.

*Experiment 10.* Mix one part of olive oil with three of a concentrated aqueous solution of barytes, they will unite into a saponaceous mass, rendering the oil miscible with the water.

*Remark.* These are the general characters of barytes, which answers to the alkalies properly so called.

*Experiment 11.* If a solution of barytes be exposed to the air, it will acquire a pellicle like lime water,

which, when it increases sufficiently, will fall to the bottom of the vessel ; or,

*Experiment 12.* Mix water impregnated with carbonic acid with barytic water, and the whole will become turbid.

*Rationale.* Barytes having a strong attraction for carbonic acid, when it comes in contact with that acid, unites with it, forming carbonate of barytes, which, being insoluble, precipitates.

*Experiment 13.* If barytes with half its weight of silica be exposed on charcoal to the action of the heat, produced by a blow pipe, it will melt with the silex and form a globule of glass.

*Experiment 14.* If a mixture of barytes and sulphur be exposed in a crucible to the action of heat, they will unite, and form sulphuret of barytes.

*Remark.* The sulphuret of barytes is of a brownish colour ; it decomposes water, a portion of sulphuretted hydrogen gas is evolved, and a hydrosulphuret is formed. Boiling water poured upon the sulphuret dissolves it, and the solution, on cooling, deposits a great number of crystals, either in six-sided prisms or in hexagonal plates, which Berthollet has called, from their being composed of sulphuretted hydrogen and barytes, hydrosulphuret of barytes. The liquor still retains a portion in solution.

*Experiment 15.* If phosphorus and barytes be introduced into a glass tube close at one end, and the tube heated upon burning coals, as in making phosphuret of lime, a phosphuret of barytes will be formed.

*Remark.* The phosphuret of barytes decomposes water, in the same manner as phosphuret of lime.

*Experiment 16.* If a few crystals of barytes be added to alcohol, and, when the solution has been formed, the alcohol inflamed, it will burn of a yellow colour.

*Experiment 17.* If a grain of sulphate of soda be dissolved in a wine glass full of distilled water, and a few drops of muriate of barytes added, a turbidness will ensue, and a white precipitate will result.

*Rationale.* The sulphuric acid unites with the ba-

rytes, forming sulphate of barytes, which, being insoluble, is precipitated. Hence the soluble salts of barytes have been used as a test for sulphuric acid and its combinations.

*Remark.* Sulphate of barytes is one of the most insoluble substances which chemistry presents, requiring for its solution about 4300 times its weight of water. The nitrate or muriate of barytes is generally used as a re-agent.

*Experiment 18.* If a stone which is supposed to contain barytes, be dissolved in diluted nitric acid, the solution filtered, and sulphate of soda added, and if a white precipitate should be formed, insoluble in water, barytes may be inferred.

*Rationale.* The nitric acid effects the solution of barytes; and on adding sulphate of soda, it is precipitated in the form of sulphate of barytes.

*Remark.* By this means barytes may be known and separated from other earths, but as strontian is also precipitated by sulphuric acid, its presence may be known in the following manner:

*Experiment 19.* If a mixture of barytes and strontian exist in the same solution, add sulphate of soda till the precipitate ceases, decant the supernatant liquid, wash the sediment on a filter, and dry it, then digest it in four times its weight of pure carbonate of potash, and a sufficient quantity of water, in a gentle heat during three or four hours. On the powder pour nitric acid, of the specific gravity 1.4, diluted with an equal weight of distilled water, which will dissolve the strontian, and not the barytes.\*

*Rationale.* In this experiment the sulphuric acid combines with the barytes and strontian, which are precipitated in the state of insoluble sulphates. On digesting the precipitate in carbonate of potash, the sulphate of barytes as well as the sulphate of strontian, is decomposed, a sulphate of potash formed, which remains in solution, and the carbonates of barytes and strontian exist in the form of an insoluble powder. On add-

ing nitric acid, the strontian is taken up, leaving the barytes.

*Remark.* Several other modes of separating barytes from strontian may be seen in *Klaproth's Essays*.

Mr. Davy has succeeded in decomposing barytes by the agency of galvanism, and has shown, that it is a metallic per oxyd. To the metal, which forms its base, he has given the name of *barium*. Its colour is white. On exposure to the air it becomes tarnished, by absorbing oxygen, and is converted into barytes. It sinks in water, and is about four or five times heavier than that liquid. It decomposes water, and emits hydrogen. The proportion of barium and oxygen in barytes has not been ascertained.

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## SECTION IV.

### OF STRONTIAN.

*Experiment 1.* If carbonate of strontian be exposed to heat in a crucible, the *strontian* will be obtained in a pure state ; or,

*Experiment 2.* If carbonate of strontian be dissolved in nitric acid, and exposed to heat in the same manner as stated for obtaining barytes, *strontian* will be procured ; or,

*Experiment 3.* If sulphate of strontian be mixed with one sixth part of its weight of charcoal powder, and kept for some hours red hot in a crucible ; the mass then dissolved in water, filtered, and nitric acid poured into the solution as long as a precipitate ensues ; the nitrate of strontian evaporated and crystallized, and the crystals exposed in a silver crucible to heat till all the nitric acid is expelled, pure *strontian* will be produced.

*Rationale.* In the first process the carbonic acid is disengaged by the heat, leaving the strontian in the

crucible: in the second, the carbonate is decomposed by nitric acid, which is afterwards expelled; and in the third, the sulphuric acid is decomposed by the coal, carbonic acid is disengaged, and the sulphuret of strontian is decomposed by nitric acid, which is disengaged by the heat.

*Remark.* Strontian was discovered in a mineral brought from the lead mines of Strontian in Argyleshire, England, a specimen of which was brought to Edinburgh in 1787, and was generally considered as a carbonate of barytes until Dr. Crawford in 1790, in his treatise on muriate of barytes, mentioned that it might contain a new earth, from its chemical characters being in some respects different from those of barytes. Dr. Hope instituted some experiments in 1791, which demonstrated that the mineral was a compound of carbonic acid and a peculiar earth, to which the Doctor gave the name of strontites.

Klaproth made some experiments on it, and drew the same conclusions as Dr. Hope, though he was unacquainted with the experiments of the Dr. Mr. Kirwan in 1793, discovered many interesting properties of this new earth, which afterwards appeared in the Transactions of the Irish Academy. Pelletier, Vauquelin and Fourcroy also investigated it. Klaproth gave to the new earth the name of strontian. Strontian is found abundantly in many situations, either combined with carbonic acid or sulphuric acid. Strontian, obtained according to the foregoing processes, is of a grayish white colour, and of an acrid and alkaline taste. Its specific gravity is 1.647. It converts vegetable blues to green. Before the blow pipe it possesses some peculiar properties.

*Experiment 4.* Strontian sprinkled with water, becomes hot, and falls to powder like lime in the act of slacking: on adding more of that fluid the strontian dissolves, forming *strontian water*.

*Remark.* One part of strontian will dissolve in 162 parts of water at the temperature of 60°. The solution is transparent, and converts vegetable blues to

green. If hot water be used it will dissolve it in larger quantities, and on cooling, it will separate in a crystallized form in thin quadrangular plates. But the form of the crystals varies. They contain 68 parts in the hundred of water, and are soluble in 51.4 parts of water at the temperature of 60°. On exposure to the air, they effloresce, and absorb carbonic acid.

*Experiment 5.* If sulphur and strontian be melted in a crucible, they unite and form sulphuret of strontian.

*Experiment 6.* To the sulphuret, thus prepared, add water, and a solution will be made, which, on evaporation, will afford crystals of *hydrosulphuret of strontian*, the remaining liquor will be an *hydroguretted sulphuret*.

*Remark.* It is evident that when the sulphuret is added to water, that fluid is in part decomposed, sulphuretted hydrogen is partly disengaged, and another portion unites with the strontian forming the compounds already noticed.

*Experiment 7.* If one part of phosphorus be mixed with six of strontian, in an iron or earthen tube closed at one end, and the mixture heated gradually to a dull red heat, a phosphuret of strontian will be formed.

*Remark.* This phosphuret decomposes water like the phosphuret of lime.

*Experiment 8.* If nitrate of strontian be put into alcohol, and the alcohol inflamed, it will burn with a carmine-red colour.

*Experiment 9.* If a mixture of nitrate of strontian and charcoal powder, in the proportion of one part of the former to three of the latter, be inflamed, it will burn of a carmine colour.

*Remark.* This property of producing a flame of a carmine colour, is one of the most striking effects of this earth.

*Experiment 10.* If sulphuric acid be poured into a solution of oxymuriate of strontian, an increase of temperature takes place, accompanied with an evolu-

tion of light. If the acid be poured in the dry oxymuriate, no light is produced.

*Remark.* This singular fact was discovered by Messrs. Davy and Clayfield.

*Experiment 11.* If strontian be dissolved in nitric or muriatic acid, the solution will be decomposed on adding sulphuric acid, or the sulphates.

*Remark.* The precipitate which appears when sulphuric acid is added, has rendered the solutions of strontian useful as re-agents to discover that acid and its combinations.

Mr. Davy has decomposed strontian, and proved that it has a metallic base which he calls *strontium*. It is a white metal, heavier than water, and decomposes that fluid, absorbing oxygen, and is converted into strontian.

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## DIVISION II.

### OF THE EARTHS PROPER.

The earths proper are five in number, namely, alumina, yttria, glucina, zirconia and silica, and differ from the alkaline earths in not possessing the characters of alkali, such as causticity, solubility in water, effect on vegetable colours, and the like.

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## SECTION I.

### OF ALUMINA.

*Experiment 1.* If one part of the alum of commerce be dissolved in six parts of boiling distilled water, and when cold, liquid ammonia added until no further pre-

precipitate ensues; and the whole then heated, and poured on a filter, the precipitate washed until the water comes off tasteless, then put into a basin, and muriatic acid added to it in small quantities at a time till the whole is dissolved; the solution now evaporated, till a drop of it, when suffered to cool on a plate of glass, yields minute crystals; these crystals (of alum) separated by decanting the fluid; this fluid then decomposed by adding to it liquid ammonia; and the precipitate thus obtained, when washed and dried will be pure *alumina*.

*Rationale.* The alum being a triple salt, consisting of alumina, potash and sulphuric acid, is decomposed by the ammonia, which unites with the acid forming sulphate of ammonia, and precipitates the alumina. As the precipitate may contain sulphate of alumina, it is dissolved in muriatic acid, and the solution (muriate of alumina) evaporated in order to separate the alum. The muriate of alumina is then decomposed by the ammonia, muriate of ammonia is formed, and the alumina is precipitated. By washing the precipitate the muriate of ammonia is separated, as it passes off in solution.

*Experiment 2.* If to a solution of alum, carbonate of potash be added until the precipitate ceases, and the precipitate collected, washed and dried, then exposed to a strong heat for one hour in a crucible, *alumina* will be obtained.

*Rationale.* When carbonate of potash is added to a solution of alum, the alkali unites with the sulphuric acid of that salt, and forms sulphate of potash, whilst the carbonic acid combines with the alumina, and forms a precipitate of carbonate of alumina. When this is exposed to heat, the carbonic acid is expelled, and the alumina remains untouched.

*Remark.* This process, however, is imperfect; for the alumina thus procured, when exposed to heat with charcoal, afterwards treated with a diluted acid, will emit sulphuretted hydrogen gas. The former is there-

fore preferred. In order to free alumina from sulphuric acid, the following method is proposed by Guyton.\*

*Experiment 3.* After the precipitate is obtained from alum by carbonate of potash, dissolve it in nitric acid; add to the solution nitrate of barytes as long as any precipitate is formed; separate the precipitate by the filter, evaporate the liquor to dryness, and expose it to a strong heat till all the nitric acid is expelled.

*Rationale.* The nitric acid unites with the alumina, and the carbonic acid is disengaged. The addition of nitrate of barytes separates the sulphuric acid which might remain, by forming with it sulphate of barytes. This is detached by the filter, and the nitric acid is afterwards expelled by the action of heat.

*Remark.* The earth obtained from alum was supposed by Stahl and Neuman to be lime; but in 1727 Geofroy, junior, proved that the earth of alum constitutes a part of clay. Margraff, in 1754, demonstrated that the basis of alum is an earth of a peculiar nature. Hence it was called *argil*: it was afterwards named *alumina*, because it may be obtained from alum. Macquer, Bergman, Scheele, and more lately Saussure, have investigated the properties of this earth.

Saussure gave it the name of *spongy alumina*. If the earthy salt (alum) be dissolved in as little water as possible, and the alumina then precipitated, the earth is light, friable, and very spongy, hence its name; but if a large quantity of water be used to effect the solution, the alumina is obtained in a brittle transparent yellow coloured mass, splitting in pieces like roll sulphur when held in the hand. In this state it forms the *gelatinous alumina* of Saussure. Alumina has little taste, and, when pure, has no smell; but if it contains oxyd of iron, it emits, when breathed upon, a peculiar odour, which is known by the name of the *earthy smell*. Common clays have this property. The specific gravity of alumina is 2.00. When heated, alumina contracts by heat. Mr. Wedgwood took advantage of this

\* Ann de Chim. xxxii. 64.

property, and constructed an instrument called a *pyrometer* for measuring high degrees of heat. See page 61. This instrument, however, is liable to error.

*Experiment 3.* Pour water on alumina, and, after standing some time, filter it off: it will be found that its properties are unaltered.

*Remark.* Water, therefore, has no sensible effect on alumina; but alumina may be diffused through it with great facility. It is said in its usual state to be combined with more than its own weight of water.

Alumina does not combine with oxygen or azote. Charcoal it is said will combine with alumina. This combination forms a black substance, which is very frequently found native. Alumina and oxyd of iron often occurs of a yellow colour, which is known by the name of ochre.

*Experiment 4.* Mix fresh prepared lime water and alumina; if the mixture be filtered, it will be found that the lime is taken from the water.

*Remark.* This experiment proves, that alumina possesses a strong attraction for lime. For the fusibility of different mixture of alumina and lime, see Kirwan's Mineralogy, vol. i. 65. Barytes and strontian also combine with alumina, both when heated with it in a crucible, and when boiled with it in water: alumina, magnesia, and lime, form, when melted, what is called porcelain; but this is produced in a particular way.\*

*Experiment 5.* If one part of alumina be boiled for some time with six of potash, soda, &c. in a sufficient quantity of water, a combination will take place; and,

*Experiment 6.* If to this solution sulphuric acid be added, the alumina will be precipitated.

*Rationale.* The alumina is dissolved by the alkali in Experiment 1, and, in the second, is precipitated from its solution by sulphuric acid; sulphate of potash is formed, and the alumina is precipitated. If more acid be added, the alumina is dissolved.

\* See Kirwan, vol. i. p. 72.

*Experiment 7.* If to a solution of alumina in potash we add another of silica in the same alkali, and suffer the mixture to stand for a few hours, a precipitate composed of alumina and silica will be formed.

*Remark.* A considerable degree of affinity exists between alumina and silica, and the unsuspected formation of this compound in many analytical experiments on minerals has often produced a number of deceitful and embarrassing appearances. We are indebted to the indefatigable Klaproth for shewing, that when to a solution of pure silica, in caustic potash, is added a solution of alumina equally pure in the same menstruum, the liquor immediately assumes a reddish brown colour, and after standing an hour or two, coagulates. By the addition of a little warm water, this jelly is resolved into a fluid, and being thus mixed with muriatic acid to the exact saturation of the alkali, a copious precipitate is deposited, consisting of the two earths in a state of combination: if now a slight excess of acid is dropped in, the silica as well as the alkali will be perfectly dissolved. Carbonate of potash will again cause the precipitate to appear, and this, even separated by the filter and dried, will be entirely soluble in diluted sulphuric acid, without the smallest deposition of silica. If the sulphuric solution is now gently evaporated, crystals of alum will be deposited, and the remainder will assume the form of a clear jelly.

*Experiment 8.* If one part of alumina and six of potash and soda, with a sufficient quantity of water, be digested with heat, a solution of the alumina will take place.

*Experiment 9.* If to this solution an acid be added, the alumina will be precipitated.

*Rationale.* The alumina is dissolved by the alkali in the first experiment, and then precipitated from the solution by the acid in the second; the acid and alkali unite into a peculiar compound.

*Remark.* This is a method sometimes employed to prepare pure alumina. Alkalized alumina has been employed as a preferable mordant to common alum,

in the fixing of those colours that are injured by the presence of sulphuric acid.

*Experiment 10.* If to a watery infusion of cochineal, fustic, quercitron bark, or madder, a few drops of a solution of alum be added, the colouring matter will be precipitated in the form of a lake.

*Remark.* The affinity that subsists between alumina and vegetable or animal colouring matter, is singularly powerful. The colouring matter in this experiment is precipitated with the aluminous base of the earthy salt, leaving the supernatant liquor wholly colourless. Alumina unites with acids, and forms a class of salts. See Salts of Alumina.

*Experiment 11.* Put equal parts of brown sugar and alum into a crucible, and expose the mixture over a fire until it is melted, and reduced to dryness. Pulverise the mixture, and introduce it into a common vial coated with clay, to which a glass tube, open at each end, is luted, to allow the escape of the gases that are produced. Set the vial in a crucible surrounded by sand, and expose the whole to heat. When the gas or vapour has ceased to be evolved, which may be known by its not taking fire on presenting a lighted candle, the crucible may be removed from the fire; and the end of the tube closed by a little moist clay. The preparation thus formed is *pyrophorus*.

*Remark.* The pyrophorus, called by some the pyrophorus of Homberg, is a black powder, which takes fire on exposure to the air. It is supposed to be a compound of alumina, sulphur, and charcoal. Gren, in his Principles of Chemistry, vol. i. p. 256, accounts for the spontaneous accension of pyrophorus in the following manner: part of the charcoal decomposes, in a red heat, part of the sulphuric acid of the alum, and becomes converted into carbonic acid gas, which escapes; the sulphuric acid is thus partly converted into sulphur, which sublimes and burns. During these changes, the potash, which is present in the alum of commerce, unites to a part of the sulphur, and forms with it a sulphuret of potash, and there remains the superfluous part of the coal that had been blended with the

alum. Dry potash, charcoal sulphur, and alumina are therefore the constituent parts of the pyrophorus. On exposure to the air, the potash rapidly attracts its moisture, and is heated with it. This heat is sufficient to inflame the sulphur; because sulphur is already by its own nature, when combined with alkaline substances, by far more disposed to decompose oxygen gas. This ignition of the sulphur in the pyrophorus is communicated to the coaly particles, that, at the beginning of its preparation, were mingled with the sulphate of alumina. Thus far is the theory of Mr. Gren. See page 51.

Sauvigny attributed the combustibility of pyrophori to the sulphuric acid, heating by the moist air, and inflaming the disengaged sulphur.

Proust denied the presence of sulphuric acid; and Mr. Bewly imputed it to the attraction of the nitrous acid from the air, and the heat generated by its union. Pyrophori may be made in a variety of ways, as follows: Five parts of burnt alum and one of charcoal intimately mixed; or three parts of alum with one of sugar, honey, or flour, melted together, and kept over the fire until it has become blackish, being put in an earthen bottle, about two thirds full, and kept in a red hot state, surrounded with sand in a crucible, as long as a blue flame is perceived at the mouth of the bottle.

Bewly obtained pyrophorus by nearly filling the bowl of a tobacco pipe with two parts of alum, one of charcoal, and one of salt of tartar, pressing it down and filling up the bow with fine sand, and exposing it to a heat for three quarters of an hour, a longer time doing it no injury. He also obtained it from powdered charcoal, with double or treble its weight of calcined blue or green vitriol, or of sulphate of zinc, and from a mixture of charcoal, well calcined sulphate of potash, or of soda, and from potash and vegetable or animal coal. A pyrophorus, it is said, is immediately formed by rubbing together in a mortar 54 grains of sulphur, 36 of very dry willow charcoal, and 3 of common phosphorus.

*Experiment 12.* If to a solution containing alumina and magnesia, malate of potash be added, a white precipitate will appear, of difficult solubility, which on examination, will be found to be a compound of malic acid and alumina.

*Rationale.* When malate of potash is added to a solution containing alumina and magnesia, a double decomposition ensues: the acid which held the earths in solution will unite with the alkali, whilst the malic acid in its turn unites with the alumina and magnesia, forming earthy malates; but as the malate formed with the alumina is insoluble, that compound is precipitated, whilst the malate of magnesia remains in solution.

*Remark.* Alumina, in the state of common clay, is employed for various purposes, on account of its aptitude for moulding into different forms, and its property of hardening in the fire; such as for making bricks, earthen ware, porcelain, crucibles, &c. The subject of Pottery will be noticed hereafter. For securing the bottoms and sides of canals and reservoirs of water, alumina is of much value. This earth composes in a great measure those tenaceous earths called *arable soils*. In combination, it is employed by the dyer and calico-printer, as a mordant for fixing various colours.

It was supposed by Baron, that alumina was a metallic oxyd, which led to several experiments, and much speculation. Sir Humphrey Davy has succeeded in decomposing it by the galvanic influence, and proposes to give to its base, as it is a metal, the name of *aluminum*. Little, however, is known on the subject.

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## SECTION II.

### OF YTTRIA.

*Experiment 1.* Take the mineral called *gadolonite*, reduce it to powder, and add a mixture of nitric and muriatic acid till it is decomposed, evaporate the so,

lution nearly to dryness, and filter it. To the liquor thus obtained, add water; by this means the silica is left behind. Filter again, and evaporate the fluid to dryness, and expose the dry mass for a considerable time in a close vessel. Now dissolve the mass in water, filter the solution, and add to it liquid ammonia; pure *yttria* will be precipitated.

*Rationale.* The nitro-muriatic acid dissolves the *yttria*, which, after some intermediate operations, is precipitated by ammonia, which takes the place of the *yttria*.

*Remark.* This earth may also be obtained from a mineral called *yttrotantalite*, which is a compound of tantalum and *yttria*.

A mineral was discovered about the year 1771 by Captain Arhenius, in the quarry of Ytterby in Sweden, a description of which was published in *Crell's Annals and Miner's Lexicon*, and was analysed by professor Gadolin in 1794, who found it to contain a new earth. The experiments of this chemist were afterwards repeated, and his conclusions confirmed. Mr. Ekeberg gave to the new earth the name of *yttria*. Vauquelin and Klaproth also repeated the experiment of the professor. *Yttria* is a white powder, whose specific gravity is 4.842. It is precipitated from its solution in acids by ammonia and prussiate of potash. In pure alkalies it is not soluble. It is precipitated by tannin.

It differs from glucina in not being soluble in fixed alkalies, nor being precipitated by the succinates. From analogy it is supposed that this earth is a metallic per oxyd. Ekeberg treated *yttria* with muriatic acid, and obtained oxymuriatic acid gas. Mr. Davy is of opinion, that *yttria* is not a distinct *primitive* earth, but a modification of some other earth.

## SECTION III.

## OF GLUCINA.

*Experiment 1.* Pulverise the beryl, or the emerald, and add to the powder thrice its weight of potash, and melt the mixture in a crucible. Dissolve the mass in muriatic acid, and evaporate the solution to dryness. To this add water, and the silica, which constitutes more than half the weight of the stone, will remain behind; add now to the filtered liquor carbonate of potash, until the precipitate ceases to appear. Wash the precipitate, and then dissolve it in sulphuric acid. Add to the solution sulphate of potash; evaporate it to the proper consistency, and set it by to crystallize. Alum will gradually form. To the fluid now remaining, add a solution of carbonate of ammonia in excess, then filter, and boil the liquid for some time. A white powder gradually appears, which is *glucina*.

*Rationale.* When the beryl or emerald is treated with potash, the glucina as well as silica is fused and combines with the alkali. When to this mass muriatic acid is added, muriate of glucina is formed, and the silica is separated. If any other earths be present, they are also dissolved. All the earths present are then precipitated by means of carbonate of potash, which takes place by compound affinity. On adding sulphuric acid, the glucina and alumina, if it be present, are dissolved. When sulphate of potash is added to this solution, and then evaporated, crystals of alum or supersulphate of alumina and potash will form on cooling. After these are separated, as the alumina is thus detached, the addition of carbonate of ammonia separates the glucina gradually in the form of a white powder.

*Remark.* Vauquelin is the discoverer of this earth which he obtained from the beryl, a transparent stone of a green colour and a considerable degree of hardness, in the year 1798, when prosecuting some ex-

periments on that stone at the request of the Abbe Haüy. To this newly discovered earth the name of *glucina* was given. Klaproth has since confirmed the experiments of the French philosopher. This earth has been obtained from the emerald as well as from the beryl or *aigue-marine*. It has also been detected in the gadolinite.

Glucina is a light white powder, without either taste or smell. It is infusible by heat. Its specific gravity is 2.976. It is soluble in alkalies; also in all the acids except the carbonic and phosphoric, and forms with them saccharine and slightly astringent salts; hence its name from the Greek, which signifies sweet or saccharine, because it gives that taste to the salts it forms. It is fusible with borax. It is not precipitated by the hydro-sulphurets, nor by the prussiate of potash, but by all the succinates. Its affinity for acids, which is intermediate between magnesia and alumina may be seen in the table of affinity.

Sulphuretted hydrogen dissolves it, and forms with it a hydrosulphuret. Mr. Davy has tried to decompose glucina, and, from the result of his experiments with the galvanic influence, is of opinion, that it is a metallic per-oxyd, to the metal of which he proposes to give the name of *glucium*.

*Experiment 2.* If equal parts of glucina and alumina be dissolved in nitric acid, two salts will be formed, which, on evaporation, will shew distinct characters. The nitrate of glucina has a saccharine taste; and the nitrate of alumina is not sweet, nor does it produce any precipitate with tincture of galls.

*Experiment 3.* If tartrate of potash be added to a solution of nitrate of glucina, no change will be procured; but,

*Experiment 4.* If the tartrate be added to a solution of nitrate of alumina, a flaky precipitate will be formed.

*Rationale.* In the first no decomposition ensues, but in the second nitrate of potash, and tartrate of alumina are formed, the latter of which precipitates. Hence the obvious difference between glucina and alumina.

*Experiment 5.* To a solution of nitrate of glucina add some oxalate of potash, no change will take place even after some days; but,

*Experiment 6.* On adding the same reagent to nitrate of alumina, a very copious white precipitate will be produced.

*Rationale.* In the first case no decomposition ensues, but in the second, nitrate of potash and oxalate of alumina are formed; the latter being insoluble, is precipitated.

*Experiment 7.* To a solution of nitrate of glucina add prussiate of potash, no precipitate will appear; but,

*Experiment 8.* If we add prussiate of potash to nitrate of alumina, a change will take place.

*Rationale.* Analogous to the preceding.

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## SECTION IV.

### OF ZIRCONIA.

*Experiment 1.* Reduce zircon or the hyacinth, to powder, mix it with thrice its weight of potash, and fuse it in a crucible. Wash the mass in pure water, till the whole of the potash is extracted; then dissolve the residuum as far as possible in diluted muriatic acid. Boil the solution to precipitate any silica that may have been dissolved, then filter, and add a quantity of potash. The zirconia precipitates in the state of a fine powder.

*Rationale.* The fusion of the mineral, with the potash, is intended to separate principally silica. For when the mass is washed in pure water, the potash as well as the silica is extracted. The residuum is treated with muriatic acid, and the solution is boiled in order to separate any more silica that may have been taken up. After this the addition of potash precipitates

the zirconia, from its solution, as the alkali unites with the acid, forming muriate of potash.

*Remark.* Klaproth discovered this earth in 1793, in the zircon or jargon, a gem first brought from Ceylon, but also found in other countries. This stone has been discovered in the United States, by Mr. Solomon W. Conrad of this city, a specimen of which he politely presented me. Since the experiments of Klaproth, many others have been made, which confirmed the inferences of that philosopher.

Zirconia is a white powder; has neither taste nor odour; and is infusible before the blow pipe. Its specific gravity is 4.3, it is insoluble in water, but has a considerable affinity for that fluid. It has a strong affinity for several metallic oxyds, particularly per oxyd of iron; it is insoluble in liquid alkalies, neither can it be fused along with them by means of heat, but it is soluble in alkaline carbonates. Zirconia combines with acids and forms salts, which have a peculiar astringent taste; many of them are insoluble in water. Mr. Davy has attempted to decompose zirconia, in which he partly succeeded, and proposes to give its base, which he supposes to be metallic, the name of *zirconium*.

*Experiment 2.* If zirconia be gradually introduced into diluted sulphuric acid, it will be dissolved, and form a peculiar salt.

*Remark.* This salt is decomposed by heat, leaving the zirconia behind. Acids do not affect it, but alkalies and earths decompose it: charcoal, at a high temperature, converts it into a sulphuret, which when dissolved in water and evaporated, yields crystals of hydrosulphuret of zirconia.

*Experiment 3.* If nitric acid be added to zirconia, and digested for some time, a compound called nitrate of zirconia will be formed.

*Remark.* The nitrate, however, generally exists as a supernitrate, for the acid in the salt is mostly in excess. If the solution be evaporated in a very gentle heat, and afterwards exposed, it will shoot into crystals. The nitrate is decomposed by sulphuric acid, which

forms with the earth a white precipitate, soluble in an excess of that acid; by carbonate of ammonia; and by an infusion of galls, which affords a white precipitate soluble in an excess of the infusion. The vegetable acids generally we are told, will take zirconia from the nitric acid, and form with it insoluble compounds.

*Experiment 4.* If zirconia be introduced into muriatic acid, it will unite with it, and form muriate of zirconia.

*Remark.* Muriate of zirconia is decomposed by sulphuric, phosphoric, citric, tartaric, oxalic, and saccolactic acids. A number of experiments were instituted by Klaproth and Vauquelin, in which the properties of zirconia in general are enumerated; for an account of these experiments, see Klaproth's *Beiträge*, and Vauquelin's paper in the *Annales de Chimie*, tom. xxii. p. 179.

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## SECTION V.

### OF SILICA.

*Experiment 1.* Put into a crucible one part of pounded flint or quartz, and three parts of potash, previously mixed, and apply a heat sufficient to melt them. Dissolve the mass in water, saturate the potash with muriatic acid, and evaporate to dryness. Towards the end of the evaporation the liquid assumes the form of a jelly; and when all the moisture is evaporated, a white mass remains behind. After washing this mass with a large quantity of water, the residue is pure *silica*.

*Rationale.* When potash is in the proportion of three or four to one of flint or quartz, a compound is formed, which is soluble in water. On dissolving the mass in water and adding muriatic acid, the alkali is taken from the silica, muriate of potash is formed, and the silica is separated. On evaporating the mixture, and afterwards

washing it well with water, the muriate of potash is dissolved and carried off, whilst the silica remains in a state of purity.

*Remark.* If gun flints are used they may readily be pulverised, by heating them red hot and plunging them into water; by this means they are rendered brittle. In precipitating the silica an excess of acid should be used, in order that all the foreign earths which are present may be separated. The mixture of flint and potash may be fused in a silver crucible, and the silica may be directly separated by dissolving the mass in water, and adding to the solution muriatic acid as long as any precipitate is formed. This is to be collected, washed, and dried. If too much water be used as 24 parts to one, no precipitation will take place, unless evaporation be used. Pure silica may be obtained by separating it from fluoric acid.

Silica is found in a variety of stones. It almost wholly constitutes *quartz* and *rock crystal*. See the Table of Stones.

Glauber describes this earth. Different opinions were entertained respecting it; but it was not until the time of Scheele and Bergman, that its properties were fully known.

Silica is a fine powder, without either taste or smell. Its specific gravity is 2.66. It has been exposed to the action of fire assisted by oxygen gas, without any alteration. It has been fused, however, by means of the blow pipe. The temperature necessary for this purpose, is equal to 4043° of Wedgwood.

Silica is insoluble in water. When precipitated from potash by muriatic acid, it retains a considerable quantity of water, even if exposed to a gentle heat. Silica forms a paste with water, which is not ductile, but constitutes a loose, friable and incoherent mass. It exists in a crystallized state in the rock crystal. It may artificially be prepared, by dissolving it in fluoric acid, and suffering the solution to remain undisturbed. The crystals, thus obtained, are irregular, but some of them are in cubes with their angles truncated. By a similar

process, Bergman and Seigling obtained crystals from this earth. Silica does not combine with oxygen, with azote, nor with the metals; but with metallic oxyds it unites by fusion, and forms various coloured glasses and enamels. These will be noticed in treating of the metals.

*Experiment 2.* If barytic water be poured into a solution of silica in potash, a precipitate will appear, which, on examination, will be found to be composed of the two earths.

*Experiment 3.* If barytes and silica be exposed in a crucible to heat, they will unite, and form a compound of a greenish colour.

*Remark.* Hence there is a strong affinity between barytes and silica. Mr. Kirwan has made a number of experiments on the mixture of these earths.

*Experiment 4.* Silica and strontian exposed to heat, will unite in the same manner as in the last experiment.

*Experiment 5.* If lime water be poured into a solution of silica in potash, a precipitate is formed, which is composed of silica and lime.

*Experiment 6.* Silica and lime exposed to heat, forms a peculiar compound, and if the quantity of lime be inferior to that of silica, a *glass* will be the result.

*Remark.* Silica and lime have, therefore, a considerable affinity for each other. Mr. Kirwan has given several experiments on this subject.

*Experiment 7.* If equal parts of magnesia and silica, when melted, which requires a considerable temperature, forms a white enamel.

*Experiment 8.* When equal portions of silicated and aluminated potash be mixed, the compound will assume the consistence of jelly.

*Experiment 9.* Silica and alumina exposed to a strong heat, unite, and form a kind of opaque glass, or rather enamel.

*Remark.* Hence there is a considerable affinity between these earths. Porcelain, stone ware, brick, tile,

and other similar mixtures, are composed chiefly of this compound. Silica and alumina, in various proportions, constitute *clays*.

The earths, frequently, when mixed in different proportions and exposed to heat, are capable of uniting.

Mr. Davy has rendered it probable, that silica is a per oxyd. This earth was exposed to the galvanic influence, and, from his experiments, he inferred, that it is a compound of oxygen and a peculiar metal, to which he has given the name of *silicium*. But this conclusion is not altogether satisfactory.

*Experiment 10.* If silica, put into a flask, and sulphuric, nitric, muriatic, or acetic acid added, and heat applied; on decanting the acid, none of the earth will be taken up. A proof that the acid has dissolved nothing.

*Experiment 11.* If one part of silica be put into a leaden bottle with twelve parts of fluoric acid; the bottle closed with a wax stopper; and suffered to stand for a few days, agitating it frequently, the silica will be dissolved. See the Properties of Fluoric Acid Gas.

*Experiment 12.* If one part of silica, minutely divided, and twenty parts by weight of a concentrated solution of potash or soda be boiled in a silver vessel, the earth will be dissolved. See Potash.

*Experiment 13.* If glacial acid of phosphorus and silica be exposed on charcoal to the action of the heat produced by a blow pipe, the mixture will melt, and form a globule of transparent glass.

*Experiment 14.* Silica and borax, treated in the same manner, will also produce a compound of a vitreous appearance.

## PART XI.

### OF SOAPS.

#### SECTION I.

##### OF ALKALINE SOAPS.

*Experiment 1.* If one part of the soda of commerce, deprived of carbonic acid by passing the solution through lime, be boiled with six parts of olive oil or tallow, a compound will be formed called *soap of soda*, or hard soap. Or,

*Experiment 2.* Let one part of lime, (previously slacked) and two of soda, be boiled in twelve parts of water for half an hour; filter the lixivium through a linen cloth, (pouring back the fluid upon the cloth till it passes clear) and evaporate it till its specific gravity be about 1.375, or, which is the same, till a vial which would contain one ounce of water, will hold an ounce and three eighths of the fluid; this having been done, soap may be made by mere mixture of this ley with olive oil, in the proportion of one part of the former to two of the latter, in a glass or stone ware vessel. This mixture being beat up with a wooden spatula, soon becomes consistent, and if left to stand for four or five days, forms a white hard soap. Or,

*Experiment 3.* Prepare a ley from wood ashes, making it caustic by means of lime, and let the ley be sufficiently strong to float a new laid egg. Boil oil or tallow with this ley, until a saponaceous compound is formed. Continue the heat till it acquires a considerable consistence, and seems to be separating from the fluid below. Now add a sufficient quantity of muriate of soda, or common salt, and boil the materials for three or four hours, and *soap of soda* or hard soap will

form on the surface. The liquor on which it floats is called *waste ley*, and is to be drawn off. The soap is now melted for the last time with ley, or even with water; it is then allowed to cool for a short time, and afterwards cast into wooden frames. The soap thus acquires a compact appearance.

*Rationale.* Hard soap is a combination of oil or fatty matter with soda. In the first and second experiment the alkali is united directly with the oil or tallow. In the third, it is combined by compound affinity. The alkali obtained from wood ashes is potash. This is first combined with the tallow, or fatty matter, and forms soap of potash or soft soap. On adding muriate of soda, or common salt, the muriatic acid unites with the potash, forming muriate of potash, which remains in solution as the *waste ley*, whilst the soda combines with the oil, or tallow, in the state of soap of soda, or hard soap, and floats on the fluid.

*Remark.* The tallow for making soap is reckoned good if 13 cwt. yield a ton of white soap. Soap is mentioned by Pliny and Galen. The term is said to be derived from the old-German word *seife*. The Gauls and Germans seem to have known this compound for a long time. A soap boiler's shop with soap in it was discovered in the city of Pompeii, overwhelmed by Vesuvius, A. D. 79. See Miss Starke's Letters from Italy.

Whale oil has been tried as a substitute for tallow, but with little effect. Tallow is therefore generally employed. In France and the south of Europe olive oil is made use of. The soap, formed by the combination of tallow and soda, is of a white colour. The general properties of soap are too well known to require any description. It dissolves in alcohol, and is partly precipitated by water. A specimen of white soap analysed by Darcet, Lelievre, and Pelletier, was found to contain 60.94 oil, 8.56 alkali, and 30.50 water.

*Experiment 4.* If soap, before it grows hard, be mingled with ley, so as to disperse it through it, or if

a solution of sulphate of iron be poured into it, the *mottled soap*, as it is called, will be formed.

*Rationale.* When sulphate of iron is used, part of the alkali quits its combination with the animal oil, and unites with the sulphuric acid, forming sulphate of soda, whilst the iron is deposited in the state of oxyd, which gives the variegated colour to the soap.

*Experiment 5.* If to soap, before it becomes hard, resin be added, a soap of a yellow or brown colour, will be produced, forming the *brown soap*. In making yellow soap, resin is used in the proportion of about one part to three or four parts of tallow. The resin makes the soap more deterstive, and enables the manufacturer to sell it cheaper.

*Experiment 6.* If to white soap, in its fluid state, essential oils, as caraway, rose, bergamot, &c. be added, the *scented soaps* of the perfumers will be formed. The *Windsor soap* appears to be scented with the oil of caraway.

*Experiment 7.* If soap be prepared with a superabundance of alkali, a compound will be formed, which has been sold in this city for the purpose of removing certain stains from stuffs.

*Experiment 8.* If, by employing an excess of soda, in the preparation of soap, and giving it a brown colour; the *oriental soap*, for washing with sea water, will be formed.\*

*Experiment 9.* If white soap be dissolved in alcohol, a solution will be prepared similar to the *liquid shaving soap* of the perfumers.

*Remark.* Chaptal has proposed wool in the place of oil in the making of soap. The ley is formed in the usual manner, and, when it is boiling hot, shreds of woollen cloth of any kind are thrown into it. They are soon dissolved. Others are thrown in, and, when the ley will dissolve no more, a soap is formed of an excellent quality. The muscles of fish has been substituted for tallow or oil in the manufacture of soap.

\* A specimen of this soap I examined, and found it to contain a larger quantity of alkali than the ordinary soap.

*Experiment 10.* If oil, fat, tallow or any unctuous animal substance be boiled with the caustic ley of potash, prepared of a sufficient strength, a saponaceous compound will be formed, called *soap of potash, or soft soap.*

*Remark.* Potash, when used in the formation of soap, has the property of making it fluid. In the preparation of soft soap, some employ whale oil. A little tallow is occasionally used, which, by management is dispersed through the soap, forming white spots.

*Experiment 11.* If oil be added to liquid ammonia, a compound will be formed, on mixture, which is known by the name of *soap of ammonia*; Or,

*Experiment 12.* If carbonate of ammonia in solution be mixed with the soap of lime, the soap of ammonia will be formed.

*Rationale.* The carbonic acid of the carbonate of ammonia unites with the lime, forming carbonate of lime, whilst the ammonia in its turn combines with the oil of the soap of lime, and forms soap of ammonia; or,

*Experiment 13.* If a solution of sal ammoniac be poured into another of common soap in water, soap of ammonia will be the result.

*Rationale.* The muriatic acid of the muriate of ammonia combines with the soda of the common soap, and forms muriate of soda, whilst the unctuous matter unites with the ammonia, and constitutes the soap of ammonia.

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## SECTION II.

### OF EARTHY SOAPS.

*Experiment 1.* If lime water be mixed with oil, a compound will be formed, called the *soap of lime.*  
Or,

*Experiment 2.* If to water containing any of the calcareous salts, a solution of soap be added, the soap of lime will be prepared.

*Rationale.* In the first experiment a direct combination of lime and oil takes place; in the second, it results from the mutual decomposition. The acid of the calcareous salt, having a greater affinity for the alkali of the soap, unites with it, whilst the lime in its turn combines with the oil, forming the soap of lime.

*Experiment 3.* If the solutions of sulphate of magnesia and common soap be mixed, the *soap of magnesia* will be prepared.

*Rationale.* The sulphuric acid of the sulphate unites with the alkali of the soap, and the magnesia combines with the oil, forming the soap of magnesia.

*Experiment 4.* If to a solution of common soap, another of alum be added, the *soap of alumina* will be the result.

*Rationale.* The sulphuric acid of the alum unites with the alkali of the soap, and the alumina, thus disengaged, combines with the oil, as in the former experiments.

*Remark.* Any of the earthy soaps may be formed, by pouring the solution of the earth into another of common soap. Hence the reason that all waters holding an earthy salt in solution are unfit for washing. They decompose the soap, and form one insoluble in water. Such waters are called hard. Hence the use of a solution of soap as a re-agent.

Earthy salts are insoluble in alcohol, except soap of magnesia, which dissolves both in alcohol and fixed oils.

## SECTION III.

## OF METALLIC SOAPS.

*Experiment 1.* If to a solution of corrosive muriate of mercury, another of common soap be added, the *soap of mercury* will be formed, and gradually precipitate.

*Rationale.* The muriatic acid of the muriate unites with the soda of the soap, forming muriate of soda, and the oil in its turn combines with the oxyd of mercury, forming the soap of mercury.

*Experiment 2.* If the solutions of sulphate of zinc and soap be mixed, the *soap of zinc* will be prepared.

*Rationale.* The sulphuric acid of the sulphate unites with the alkali, and the oxyd of zinc combines with the oil.

*Experiment 3.* If nitrate of cobalt and soap be mixed in the same manner, the *soap of cobalt* will result.

*Experiment 4.* A solution of tin added to another of soap, forms the soap of tin.

*Experiment 5.* A solution of sulphate of iron treated in the same manner, produces the *soap of iron*.

*Experiment 6.* Sulphate of copper mixed in the same manner, gives the *soap of copper*.

*Experiment 7.* Acetate of lead treated as before, affords the *soap of lead*.

*Experiment 8.* Nitrate of silver used in the same manner, forms the *soap of silver*.

*Experiment 9.* Muriate of gold treated as before, will yield the *soap of gold*.

*Experiment 10.* Sulphate of manganese with soap, will afford the soap of manganese.

*Rationale.* The theory of all these experiments, is analogous to the first.

## PART XII.

### OF STONE WARE.

Clay vessels consist of alumina and silica, in various proportions, as clays are composed essentially of these earths. By stone ware we would include, by way of system, all the different kinds of pottery, such as bricks and tiles, pots and crucibles, the stone ware so called, and porcelain.

#### 1. *Bricks and Tiles.*

The oblong masses of baked clay, used as a substitute for stones in building, are known by the name of bricks, and tiles, which are much thinner, are prepared for covering the roofs of houses. Bricks have been known from time immemorial.

In the making of brick, the common blue clay is mostly used; the goodness of the brick depends upon the clay. If the clay contains too little sand, the bricks are liable to crack in cooling; too much, on the contrary, prevents the proper degree of cohesion. The manufacture of bricks is too well known to require description. The red colour of the brick depends upon iron which the clay contains.

Dr. John Pennington, in his *Chemical and Economical Essays*, page 34, observes, that he analysed a portion of the Potters' clay of Philadelphia, and found it to contain

54	Silica,
26	Alumina,
3	Lime,
17	Iron.

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100

#### 2. *Pots and Crucibles.*

In various processes it is necessary to employ vessels of a particular kind, as in the fusion of glass, metals, and the like. Crucibles are used for many chemical operations. These are of various sizes. The large

crucibles are generally conical, with a small spout, for the convenience of pouring out; the small ones are truncated triangular pyramids, and are commonly sold in nests. The Hessian crucibles are composed of clay and sand, and when good, will withstand an intense heat for many hours, without softening or melting. Those which ring clearly when struck, and are of an uniform thickness, and have a reddish brown colour, without black spots, are reckoned the best. Wedgwood's crucibles are made of clay, mixed with baked clay finely pounded, and are superior to the Hessian. The black lead crucibles, formed of clay and plumbago, are very durable, resist sudden changes of temperature, and may be repeatedly used.

### 3. *Different kinds of Pottery.*

Earthen ware is of ancient date. According to the Old Testament, it was known at an early period to the Jews. The art of manufacturing clay vessels, seems to have originated among the Asiatic nations. Stone ware vessels differ from each other in their fineness; hence it is distinguished by a variety of names, such as *flint ware*, *yellow ware*, *queens ware*, *Wedgwood's ware*, &c.

There are two parts of which vessels of stone ware consist. 1. The body of the vessel, called the *biscuit*. 2. The glassy covering with which it is coated, called the *glaze*. The biscuit is composed of two ingredients: the first is a fine white clay, known by the name of *tobacco pipe* clay, and *potters' clay*, and the second a fine white sand. The particular manner of managing the clay would be unnecessary to notice; suffice it to say, that it is formed into vessels and burnt, when it forms the *biscuit ware*. This resembles a tobacco pipe in appearance, and like it absorbs water with avidity. Hence it could not be used before it is glazed. Ordinary pottery is glazed with oxyd of lead, or by throwing common salt over it in the furnace. Galena, or sulphuret of lead, is employed to glaze tiles and other coarser pottery, as well as the oxyd of lead; for when laid upon the biscuit, and exposed to the proper temperature, the sulphur is dissipated and the lead oxydized. This oxyd,

then vitrifies, and in that state has a tendency to combine with the earthy bodies. The brown glaze on the coarse stone ware, is nothing more than glass of lead. Common salt, or muriate of soda, is employed to glaze the surface of fine stone ware vessels. When the biscuit is sufficiently baked, a quantity of common salt is introduced into the kiln. The heat converts this salt into a vapour; it penetrates the *seggars* through holes left on purpose, and surrounds the biscuit with an atmosphere of salt. The salt, by combining with the surface of the biscuit, disposes it to vitrification.

The method of glazing stone ware with salt, was introduced into England, by two brothers from Holland, of the name of Elers, about the year 1700. The use of flint, in the manufacture of white stone ware, was introduced according to Parke, in the following manner: about the year 1720, a potter travelling to London on horseback, had occasion, at Dunstable, to seek a remedy for a disorder in his horse's eyes; and the ostler of the inn, by burning a flint stone, reduced it to a fine powder, which he blew into them. The potter, observing the beautiful white colour of the flint, after calcination, instantly conceived the uses to which it might be applied in his art, and then introducing into use the *white pipe clay*, instead of the iron clays, he readily produced a *white stone ware*.

Enamel is nothing more than an opaque glass, melted over the surface of the biscuit. It consists essentially of various proportions of oxyd of lead, mixed with sand and glass. Wedgwood's enamel consists of a mixture of the oxyd of lead and tin, silica, talc and muriate of soda. The yellow glaze is composed of white lead, ground flint, and flint glass. The whiteness of an enamel depends on the proportion of tin; its fusibility upon the lead.

Porcelain, or china, is a finer kind of stone ware, and is a semi-vitrified earthen ware, of an intermediate nature, between common wares and glass. Porcelain is more capable of resisting the action of chemical agents, on account of the purity of the substances of which it is

composed, and the nature of the enamel with which it is covered. It was known in the east at an early period, but the discovery of the art of making it in Europe is of a much later date. Specimens were brought to modern Europe, and were much admired.\*

Accident led to the discovery, in Germany, about the beginning of the 18th century. A chemist in Saxony, during a set of experiments in order to ascertain the best mixtures for making crucibles, stumbled upon a compound which yielded a porcelain similar to the Eastern.

A number of experiments have been made on the mixture of different earths, in order to obtain porcelain by exposure to heat. Reaumur published his dissertations on the subject of making porcelain in 1727 and 1729. Father Entrecolles, a missionary to China, had sent an account of the Chinese mode of making porcelain, which coincided exactly with this ingenious thought of Reaumur. The ingredients, according to him, are a hard stone called *petuntze*, which they grind to powder, and a white earth called *kaolin*, which is intimately mixed with it. Reaumur found the petuntze fusible, and the kaolin infusible, when exposed separately to a violent heat.

\* Porcelain vessels were known to the Romans. They were first brought to Rome by Pompey, after the defeat of Mithridates, as we are informed by Pliny, (xxxvii. 2.) The Romans were ignorant of the mode of manufacturing them, but imported them from Pontus and Porthia. After the taking of Alexandria, a vessel of Porcelain was the only part of the spoil retained by Augustus. That the *vasa murchina* of the Romans, were the same as our porcelain vessels, has been ascertained, as Whitaker informs us, by the porcelain found in the ruins of the ancient Lyons. The name porcelain, if we believe Whitaker, came by the French name of the plant *portulaca oleracea* or purslain, which has a purple coloured flower. It got that name because the porcelain of the ancients, was always of a purple colour. See Whitaker's Course of Hannibal over the Alps, i. 55.

For the description of the most superb specimen of ancient pottery, which modern art has not yet equalled, the Portland vase, see Darwin's Botanic Garden.

The porcelain clay of Limoges, according to the analysis of Hassenfratz, is composed of

62 silica  
19 alumina  
12 magnesia  
7 barytes

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100

The porcelain clay of Cornwall, which does not acquire transparency without addition, yielded to Mr. Wedgwood,

60 alumina  
20 silica  
12 moisture  
8 loss

---

100

The *kaolin* of the Chinese very much resembles what is called the earthy or disintegrated feldspar. This is found in many places in the United States, and is derived from the disintegration of granite rocks. The petuntze of China, according to Rozen, is a feldspar which has lost a portion of potash naturally belonging to it; but, not having been reduced to a completely earthy state, still retains traces of a laminated structure: and that the kaolin of China differs from the petuntze in having undergone decomposition to a greater extent; and having been in consequence almost entirely deprived of the potash originally contained in it: that in the composition of China these two ingredients are mixed; the proportion of potash present in the mixed mass giving that degree of fusibility which is just sufficient to cement the particles together without vitrifying the porcelain: that the petuntze by itself would be too fusible for the purpose intended; and that the kaolin is too refractory to acquire a sufficient degree of cohesion between its particles. Equal parts of grand feldspar and porcelain clay, according to an anonymous German writer, forms the Saxon porcelain.

The *glaze* used for porcelain is merely feldspar, which is composed essentially of silica and alumina united to some potash, to which the fusibility is to be ascribed. This is the glaze used in Saxony, and at the manufactory of Sevres, near Paris.

The method of colouring porcelain, may be found in the Philosophical Magazine, vol. xiii, page 342. The flux, for the colour, is sometimes feldspar. The *purple* colour is given by means of the purple oxyd of gold; the *red* by oxyd of iron; the *yellow* by the oxyd of silver, lead, or antimony, with sand; *green* by the oxyd of copper; *blue*, by the oxyd of cobalt, and *violet*, by the oxyd of manganese. For the gilding on porcelain, which is performed nearly in the same manner as that of painting, see Nicholson's Journal, vii. 286.

## PART XIII.

### OF GLASS.

We have before noticed, that glass is made by mixing silica with a proper proportion of some flux, as potash, or soda, and exposing this mixture to a violent heat.

The method of making glass is of ancient date. Pliny informs us, that some merchants, with a ship load of soda from Egypt, had cast anchor at the mouth of the river Belus in Phœnicia, and were dressing their dinner on the sand. They made use of large lumps of soda to support their kettles, and lighted fires under them. The heat melted the soda and siliceous earth together, and the result was glass. For some time the manufacture of glass was confined to the river Belus. The ancients carried this manufacture to much perfection. They mention drinking glasses, glass prisms, and coloured glasses. Nero gave 50,000*l.* for two glass cups with handles; as white glass, of which they were made, was considered very valuable. The materials of glass was melted into a black mass, called *ammonitrum*, which was purified by refiners. Glass panes were introduced about the third century, but it was some time after before they came into common use.

There are several kinds of glass in use, as the plate glass, of which looking glasses are made, crown glass, bottle glass, &c. which are composed of different proportions of silica and alkali, with occasionally other ingredients.

The following facts and observations respecting glass are given by Accum. When silica and alkali are completely fused and have acquired a certain degree of heat, which is known by the fluidity of the mass, part of the melted matter is taken out at the end of a long hollow tube, which is dipped into it, and turned about

until a sufficient quantity is taken up; the workman at each turn rolling it gently upon a piece of iron, to unite it more intimately. He then blows through the tube, till the melted mass at the extremity swells like a bubble; after which he rolls it again on a smooth surface to polish it, and repeats the blowing until the glass is brought as near the size and form of the vessel required, as he thinks necessary.

If it be a common bottle, the melted matter at the end of the tube is put into a mould of the exact size and shape of its body, and the neck is formed on the outside by drawing out the ductile glass.

If it be a vessel with a large or wide orifice, the glass in its melted state is opened and widened with an iron tool; after which being again heated, it is whirled about with a circular motion, and by means of the centrifugal force thus produced is extended to the size required. Should a handle, foot, or any thing else of the kind be required, these are made separately, and stuck on in its melted state.

Window-glass is made in a similar manner, except that the mass at the end of the tube is formed into a cylindrical shape, which being cut longitudinally, by scissors or shears, is gradually bent back until it becomes a flat plate.

Large plate-glass for looking glasses, &c. is made by suffering the mass in a state of complete fusion to flow upon a casting table, with iron ledges to confine the melted matter, and as it cools a metallic roller is passed over it to reduce it to a uniform thickness. There are different kinds of glass manufactured for different purposes; the principal of these are *flint-glass*, *crown-glass*, and *bottle-glass*.

*Flint-glass* is the densest, most transparent, colourless, and beautiful. It is often called *crystal*. The best kind is said to be manufactured in this capital from 120 parts of white siliceous sand, 40 parts of pearl-ash, 35 of red oxyd of lead, 13 of nitrate of potash, and 25 of black oxyd of manganese.

This is the most fusible glass. It is used for bottles and other utensils intended to be cut and polished, and for various ornamental purposes.

*Crown-glass* differs from the preceding in containing no lead. It is manufactured of soda and fine sand. This kind is used for panes of windows, &c.

*Bottle-glass* is the coarsest of all. It is made of soda and common sand. Its green colour is owing to iron. It is the least fusible.

Glass is often coloured by mixing with it, while in a fluid state, various metallic oxyds. It is coloured *blue* by the oxyd of cobalt; *red* by the oxyd of gold; *green* by the oxyd of copper or iron; *yellow* by the oxyd of silver or antimony; and *violet* by the oxyd of manganese.

The properties of glass are well known. Its hardness is very considerable; its gravity varies from 2.3 to 4, according to the quantity of metallic oxyd which entered into its composition. Though glass when cold is brittle, it is one of the most ductile bodies known. If a thread of melted glass be drawn out and fastened to a reel, the whole of the glass can be spun off on the reel, and by cutting the threads at a certain length, there is obtained a sort of silver feather of glass. A thread of glass, when red hot, may be drawn or spun so fine as to be scarcely visible to the naked eye. It is almost perfectly elastic, and of course is one of the most sonorous bodies. Fluoric acid dissolves it at common temperatures, and alkalis at high degrees of heat. These are the only agents known which act upon it.

*Glass* utensils, unless very small and thin, require to be gradually cooled in an oven. This operation is called *annealing*, and is necessary to prevent their cracking by change of temperature, wiping, or slight accidental scratches.

There are two toys made of unannealed glass, which, though commonly used for the amusement of children, exhibit phenomena which justly interest the curiosity

of the philosopher, we mean prince Rupert's drop, and the Bologna flask, or philosophical phial.

*Prince Rupert's drop* is made by letting drops of melted glass fall into water; the drop assumes by that means an oval form, with a tail or neck resembling a retort. These drops are said to have been invented by prince Rupert, and are therefore called by his name. They possess the singular property, that if a small portion of the tail is broken off, the whole bursts into powder, with a kind of explosion, and a considerable shock is communicated to the hand that grasps it. Their explosion in the dark is said to be attended with a flash of light; this, however, is a mistake: a flash of light indeed is produced if the drop be broken in a glass receiver, but in that case the flash proceeds from the action of the projected particles, forcibly striking against the body of the glass; but no such phenomenon takes place if the drop be broken in free space.

*The Bologna, or philosophical phial*, is a small cylindrical vessel of glass which has been suddenly cooled, open at the upper end, and rounded at the bottom. It is generally made so thick at the bottom, that it will bear a smart blow against a hard body without breaking; but if a little pebble or piece of flint is let fall into it, it immediately cracks, and the bottom falls into pieces.

Concerning the cause of the phenomena of both these bodies, different opinions have been advanced. The most general is founded on the assumption, that the dimensions of bodies, which are suddenly cooled, remain shorter than if the cooling had been more gradual. The dimensions, therefore, of the smooth external surface of these glasses, which are suddenly cooled, are supposed to be shorter than is adapted to the accurate envelopement of the internal part, which is necessarily cooled in a more gradual manner; if, therefore, by a crack or fissure, a solution of the continuity takes place in the external coat, the sudden action of the parts which remained in a state of tension

to recover that of perfect expansion, is supposed to effect the destruction of the mass.

Other philosophers again have been inclined to suspect that the phenomenon arises from a quantity of air being included in the substance of the glass which rushes suddenly out, if the surface which incarcerates it becomes broken. Mr. Lambert, on the contrary, maintains an opinion diametrically opposite to this : he supposes, that during the sudden cooling of the glass, vacuities are formed between its particles, and that they are sealed up by the smooth surface of the external covering, so that on the continuity of that surface being interrupted, the air suddenly rushing in occasions the bursting of the drop.

## PART XIV.

### OF HYDROSULPHURETS.

*Experiment 1.* If potash be saturated with sulphuretted hydrogen, which may be accomplished by passing that gas through the solution of the alkali, a compound will be formed, called *hydrosulphuret of potash*. Or,

*Experiment 2.* If sulphuret of potash be dissolved in water, and the solution evaporated, *hydrosulphuret of potash* will be produced, on standing, in large prismatic crystals.

*Rationale* In the first experiment a direct combination of the gas and alkali ensues: in the second that compound is formed by the decomposition of the water, for the oxygen unites with a portion of the sulphuret, converting it into sulphate of potash, whilst the hydrogen unites with another portion, forming hydrosulphuret of potash.

*Remark.* Vauquelin has lately described the properties of this substance. It is transparent and colourless, and may be obtained in the form of crystals. Its taste is alkaline. On exposure to the air it deliquesces. The crystals have no smell, but either by their deliquescence, or the addition of acids, they emit sulphuretted hydrogen gas.

*Experiment 3.* If soda be treated with sulphuretted hydrogen as before, or if the sulphuret be dissolved in water, the *hydrosulphuret of soda* will be formed.

*Rationale.* Analogous to the preceding.

*Remark.* The hydrosulphuret of soda crystallizes in four sided prisms, terminated by quadrangular pyramids. Berthollet and Vauquelin have examined its properties which are similar to the other hydrosulphuret.

*Experiment 4.* When water impregnated with sulphuretted hydrogen is mixed with liquid sulphite of soda, and the fluid then evaporated a *triple salt* is obtained of sulphuretted hydrogen, sulphurous acid, and soda.

*Remark.* Although sulphurous acid and sulphuretted hydrogen mutually decompose each other when both are uncombined, yet if the sulphurous acid be first combined with soda, and then suffered to come in contact with sulphuretted hydrogen, a salt is found, which appears to be a compound of the sulphuretted hydrogen and sulphite.

*Experiment 5.* If sulphuretted hydrogen be passed through liquid ammonia, which is easily accomplished, the liquid will assume a greenish yellow colour, forming *hydrosulphuret of ammonia*.

*Experiment 6.* If equal parts of lime, muriate of ammonia, and sulphur be distilled, the same product will be obtained, or the *fuming liquor* of Boyle.

*Rationale.* The first is a direct combination of sulphuretted hydrogen and ammonia; the second is produced from the decomposition of the muriate of ammonia by means of the lime, and the subsequent union of the sulphur with the ammonia, thus disengaged from the muriate. Some moisture is decomposed; hence the conversion of the sulphuret into an hydrosulphuret. See Sulphur.

*Experiment 7.* If the sulphuret of barytes, which may be formed by decomposing the sulphate by means of charcoal in a crucible, be put into boiling water, the solution filtered while hot, and afterwards evaporated crystals of *hydrosulphuret of barytes* will be formed; Or,

*Experiment 8.* If barytes and sulphur be heated together in a crucible, and the compound dissolved in water, the same product will be obtained.

*Rationale.* Analogous to the former.

*Experiment 8.* If sulphuret of strontian, be treated in the same manner as sulphuret of barytes, *hydrosulphuret of strontian* will be formed.

*Rationale.* Analogous to the preceding.

*Experiment 9.* If a current of sulphuretted hydrogen gas, be passed through lime, *suspended* in water, the lime will be dissolved, and form a *hydrosulphuret of lime*. This solution is colourless, and has an acrid bitter taste.

*Rationale.* The sulphuretted hydrogen gas unites with the lime by direct combination.

*Experiment 10.* If magnesia be dissolved in water, impregnated with sulphuretted hydrogen gas, it will form the hydrosulphuret of magnesia.

*Rationale.* Analogous to the preceding.

*Remark.* It is supposed that glucina and yttria will combine with sulphuretted hydrogen gas; but neither alumina nor zirconia possess this property. Hence the hydrosulphurets precipitate their earth from acids.

When the alkalies or alkaline earths are mixed with sulphur and water, and boiled in a glass vessel, brown coloured solutions are obtained, which have lately been called *hydroguretted sulphurets*, but formerly *liquid livers of sulphur*.

Hydroguretted sulphurets are compounds of a base, with sulphur and sulphuretted hydrogen gas, and are therefore considered as triple compounds. The processes for preparing the hydroguretted sulphurets, are similar to the former. Thus hydroguretted sulphuret of potash, is formed by boiling sulphur with a solution of potash, or by dissolving sulphuret of potash in water; hydroguretted sulphuret of lime, by boiling a mixture of sulphur and lime in water, &c.

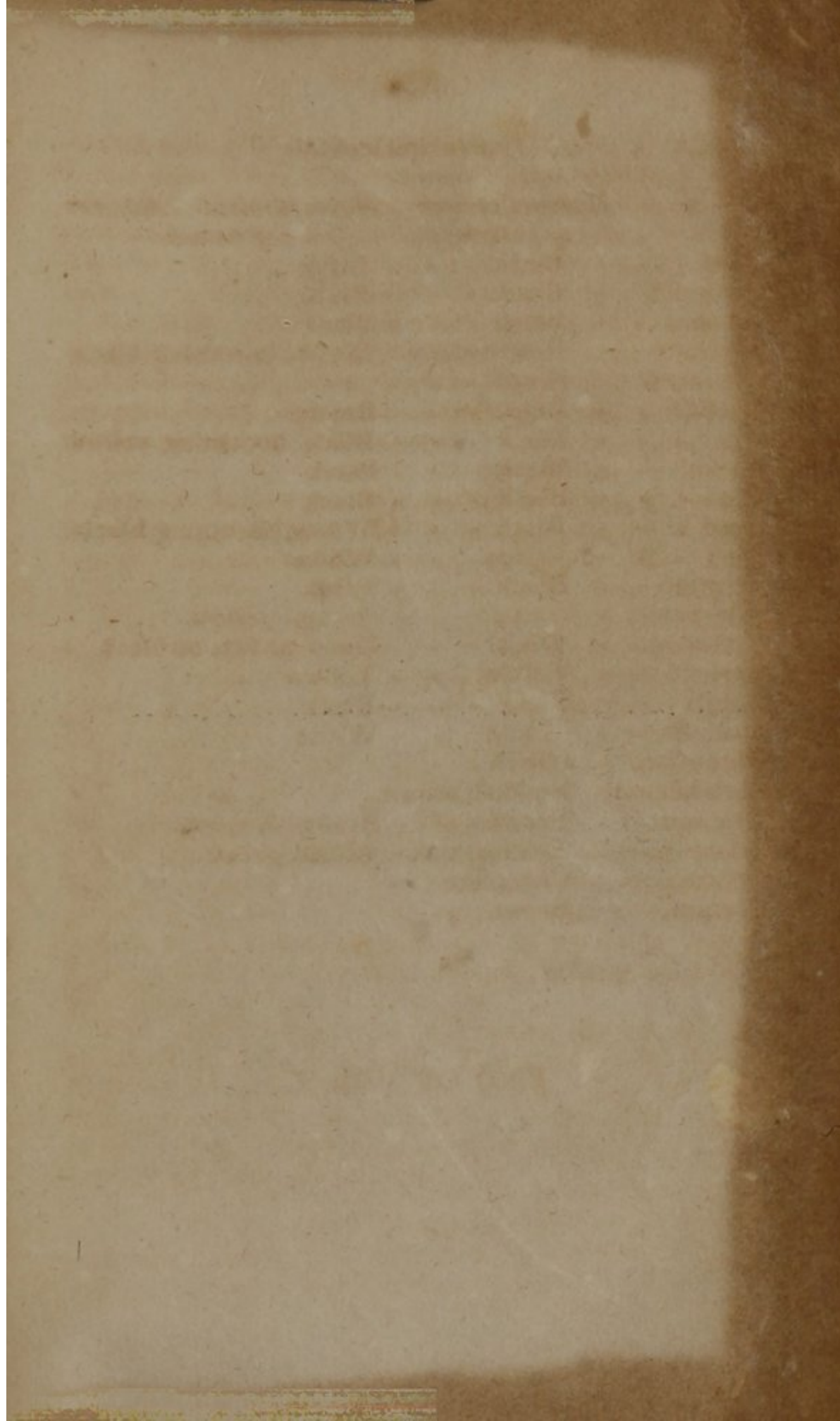
The hydrosulphurets precipitate almost all the metals from their solutions. The precipitates vary in their colour according to the metal. The following table, given by Thomson, exhibits a view of the colours of the various precipitates in these cases, as far as the subject has been investigated.

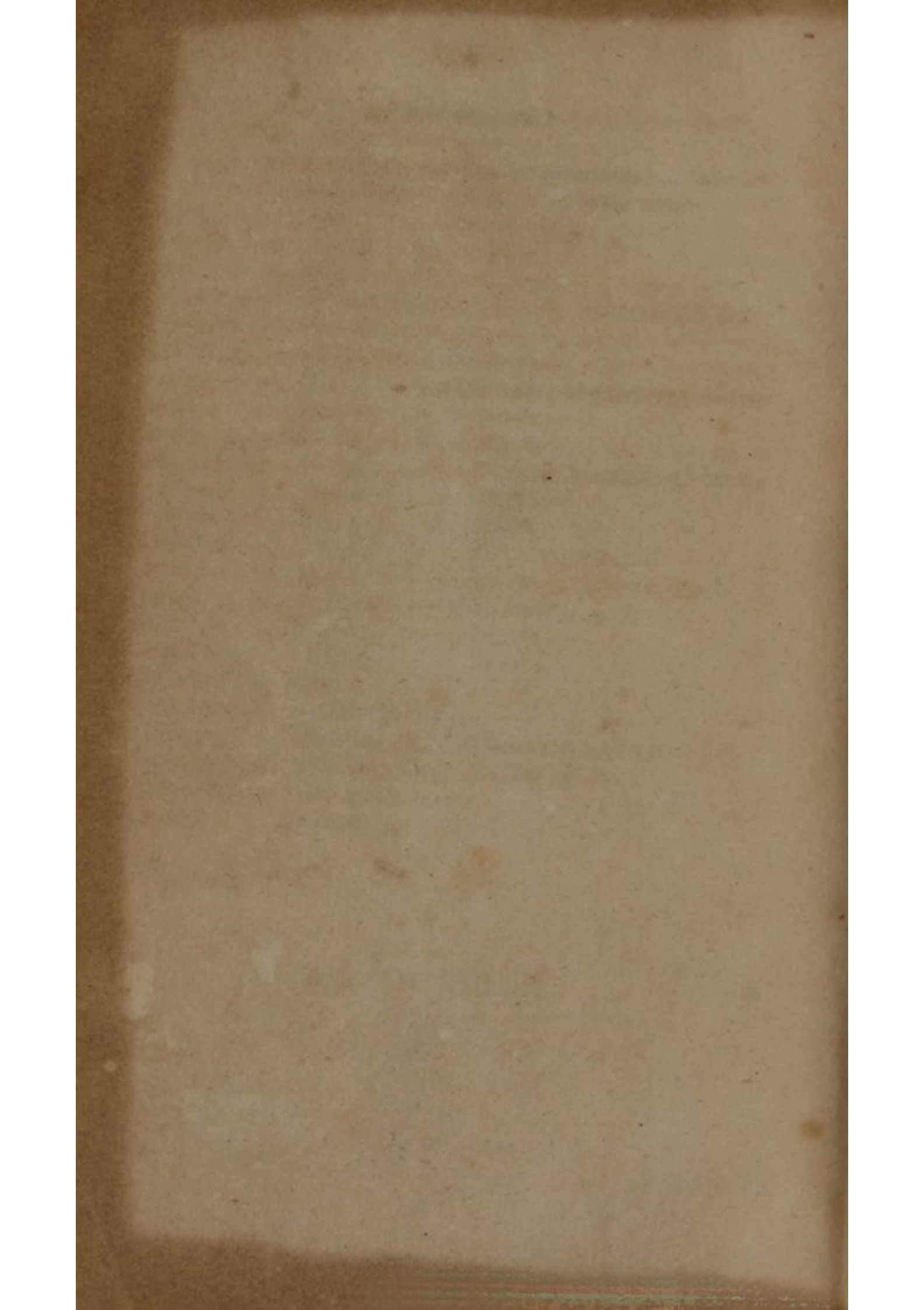
## Metals.

## Precipitated by

	<i>Hydrosulphuret of potash.</i>	<i>Hydroguretted sulphuret of potash.</i>
Gold - - -	Black - - -	Black
Platinum - -	Black - - -	Black
Silver - - -	Black - - -	Black
Mercury - -	Brown black -	Brown, becoming black
Palladium - -	Black - - -	
Copper - - -	Black - - -	Brown
Iron - - -	Black - - -	Black, becoming yellow
Nickel - - -	Black - - -	Black
Tin - - -	Black - - -	Black
Lead - - -	Black - - -	White, becoming black
Zinc - - -	White - - -	White
Bismuth - -	Black - - -	Black
Antimony - -	Orange - - -	Orange yellow
Tellurium - -	Black - - -	Deep brown or black
Arsenic - - -	Yellow - - -	Yellow
Cobalt - - -	Black - - -	Black
Manganese - -	White - - -	White
Chromium - -	Green - - -	
Molybdenum	Reddish brown	
Uranium - -	Brown - - -	Brownish colour
Titanium - -	Bottle green -	Bluish green
Columbium - -	Chocolate - -	
Cerium - - -	Brown - - -	

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