CONVERSATIONS

ON

CHEMISTRY.

IN WHICH

THE ELEMENTS OF THAT SCIENCE

ARE

FAMILIARLY EXPLAINED

AND

ILLUSTRATED BY EXPERIMENTS.

IN TWO VOLUMES.

VOL. I.

ON SIMPLE BODIES.

LONDON:

PRINTED FOR LONGMAN, HURST, REES, AND ORME, PATERNOSTER ROW.

1806.

Printed by C. Mercier and Co.
Northumberland-court, Strand, London.

PREFACE.

IN venturing to offer to the public, and more particularly to the female sex, an Introduction to Chemistry, the author, herself a woman, conceives that some explanation may be required; and she feels it the more necessary to apologize for the present undertaking, as her knowledge of the subject is but recent, and as she can have no real claims to the title of chemist.

On attending, for the first time, experimental lectures, the author found it almost impossible to derive any clear or satisfactory information from the rapid demonstrations which are usually, and perhaps necessarily, crowded into popular courses of this kind. But frequent opportunities having afterwards occurred of conversing with a friend on the subject of chemistry, and of repeating a variety of experiments, she became better acquainted with the principles of that science, and began to feel highly interested in its pursuit. It was then that she perceived, in attending the excellent lectures delivered at the Royal Institution, by the present Professor of Chemistry, the great advantage which her previous knowledge of the subject, slight as it was, gave her over others who had not enjoyed the same means of private instruction. Every fact or experiment attracted her attention, and served to explain some theory to which she was not a total stranger; and she had the gratification to find that the numerous and elegant illustrations, for which that school is so much distinguished, seldom failed to produce on her mind the effect for which they were intended.

Hence it was natural to infer, that familiar conversation was, in studies of this kind, a most useful auxiliary source of information; and more especially to the female sex, whose education is seldom calculated to prepare their minds for abstract ideas, or scientific language.

As, however, there are but few women who have access to this mode of instruction; and as the author was not acquainted with any book that could prove a substitute for it, she thought that it might be useful for beginners, as well as satisfactory to herself, to trace the steps by which she had acquired her little stock of chemical knowledge, and to record, in the form of dialogue, those ideas which she had first derived from conversation.

But to do this with sufficient method, and to fix upon a mode of arrangement, was an object of some difficulty. After much hesitation, and a degree of embarrassment, which, probably, the most competent chemical writers have often felt in common with the most superficial, a mode of division was adopted, which, though the most natural, does not always admit of being strictly pursued—it is that of treating first of the simplest bodies, and then gradually rising to the most intricate compounds.

It is not the author's intention to enter into a minute vindication of this plan. But, whatever may be its advantages or inconveniences, the method adopted in this work is such, that a young pupil, who should occasionally recur to it, with a view to procure information on particular subjects, might often find it obscure or unintelligible; for its various parts are so connected with each other as to form an uninterrupted chain of facts and reasonings, which will appear sufficiently clear and consistent to those only who may have patience to go through the whole work, or have previously devoted some attention to the subject.

It will, no doubt, be observed, that in the course of these conversations, remarks are often introduced, which appear much too acute for the young pupils, by whom they are supposed to be made. Of this fault the author is fully aware. But, in order to avoid it, it would have been necessary either to omit a variety of useful illustrations, or to submit to such minute explanations and frequent repetitions, as would have rendered the work much less suited to its purpose.

In writing these pages, the author was more than once checked in her progress by the apprehension that such an attempt might be considered by some, either as unsuited to the ordinary pursuits of her sex, or ill justified by her own recent and imperfect knowledge of the subject. But, on the one hand, she felt encouraged by the establishment of those public institutions, open to both sexes, for the dissemination of philosophical knowledge, which clearly prove that the general opinion no longer excludes women from an acquaintance with the elements of science; and, on the other, she flattered herself that whilst the impressions made upon her mind, by the wonders of Nature studied in this new point of view, were still fresh and strong, she might perhaps succeed the better in communicating to others the sentiments she herself experienced.

It will be observed, that, from the beginning of the work, it is taken for granted that the reader has previously acquired some slight knowledge of natural philosophy, a circumstance, indeed, which appears very desirable. The author's original intention was to commence this work by a small tract, explaining, on a plan analogous to this, the most essential rudiments of that science. This idea she has since abandoned; but the manuscript was ready, and might, perhaps, have been printed at some future period, had not an elementary work of a similar description, under the title of "Scientific Dialogues," been lately pointed out to her, which, on a rapid perusal, she thought very ingenious, and well calculated to answer its intended object.

CONTENTS

OF

THE FIRST VOLUME.

ON SIMPLE BODIES.

CONVERSATION I.

CONVERSATION II.

CONVERSATION V.

CONVERSATION VI.

CONVERSATION VII.

CONVERSATION VIII.

CONVERSATIONS

ON

CHEMISTRY.

CONVERSATION I.

ON THE GENERAL PRINCIPLES OF CHEMISTRY.

MRS. B.

HAVING now acquired some elementary notions of NATURAL PHILOSOPHY, I am going to propose to you another branch of science, to which I am particularly anxious that you should devote a share of your attention. This is CHEMISTRY, which is so closely connected with Natural Philosophy, that the study of the one must be incomplete without some knowledge of the other; for it is obvious that we can derive but a very imperfect idea of bodies from the study of the general laws by which they are governed, if we remain totally ignorant of their intimate nature.

CAROLINE.

To confess the truth, Mrs. B., I am not disposed to form a very favourable idea of chemistry, nor do I expect to derive much entertainment from it. I prefer those sciences that exhibit nature on a grand scale, to those which are confined to the minutiæ of petty details. Can the studies which we have lately pursued, the general properties of matter, or the revolutions of the heavenly bodies, be compared to the mixing up of a few insignificant drugs?

MRS. B.

I rather imagine that your want of taste for chemistry proceeds from the very limited idea you entertain of its object. You confine the chemist's laboratory to the narrow precincts of the apothecary's shop, whilst it is subservient to an immense variety of other useful purposes. Besides, my dear, chemistry is by no means confined to works of art. Nature also has her laboratory, which is the universe, and there she is incessantly employed in chemical operations. You are surprised, Caroline; but I assure you that the most wonderful and the most interesting phenomena of nature are almost all of them produced by chemical powers. Without entering therefore into the minute details of practical chemistry, a woman may obtain such a knowledge of the science, as will not only throw an interest on the common occurrences of life, but will enlarge the sphere of her ideas, and render the contemplation of nature a source of delightful instruction.

CAROLINE.

If this is the case, I have certainly been much mistaken in the notion I had formed of chemistry. I own that I thought it was chiefly confined to the knowledge and preparation of medicines.

MRS. B.

That is only a branch of chemistry, which is called Pharmacy; and though the study of it is certainly of great importance to the world at large, it properly belongs to professional men, and is therefore the last that I should advise you to study.

EMILY.

But did not the chemists formerly employ themselves in search of the philosopher's stone, or the secret of making gold?

MRS. B.

These were a particular set of misguided philosophers, who dignified themselves with the name of Alchemists, to distinguish their pursuits from those of the common chemists, whose studies were confined to the knowledge of medicines.

But, since that period, chemistry has undergone so complete a revolution, that, from an obscure and mysterious art, it is now become a regular and beautiful science, to which art is entirely subservient. It is true, however, that we are indebted to the alchemists for many very useful discoveries, which sprung from their fruitless attempts to make gold, and which undoubtedly have proved of infinitely greater advantage to mankind than all their chimerical pursuits.

The modern chemists, far from directing their ambition to the imitation of one of the least useful productions of inanimate nature, aim at copying almost all her operations, and sometimes even form combinations, the model of which is not to be found in her own productions. They have little reason to regret their inability to make gold (which is often but a false representation of riches), whilst by their innumerable inventions and discoveries, they have so greatly stimulated industry and facilitated labour, as prodigiously to increase the luxuries as well as the necessaries of life.

EMILY.

But I do not understand by what means chemistry can facilitate labour; is not that rather the province of the mechanic?

MRS. B.

There are many ways by which labour may be rendered more easy, independently of mechanics; but even the machine the most wonderful in its effects, the steam engine, cannot be understood without the assistance of chemistry. In agriculture, a chemical knowledge of the nature of soils, and of vegetation, is highly useful; and in those arts which relate to the comforts and conveniences of life, it would be endless to enumerate the advantages which result from the study of this science.

CAROLINE.

But, pray, tell us more precisely in what manner the discoveries of chemists have proved so beneficial to society?

MRS. B.

That would be an unfair anticipation; for you would not comprehend the nature of such discoveries and useful applications, so well as you will do hereafter. Without a due regard to method, we cannot expect to make any progress in chemistry. I wish to direct your observation chiefly to the chemical operations of Nature; but those of Art are certainly of too high importance to pass unnoticed. We shall therefore allow them also some share of our attention.

EMILY.

Well, then, let us now set to work regularly. I am very anxious to begin.

MRS. B.

The object of chemistry is to obtain a knowledge of the intimate nature of bodies, and of their mutual action on each other. You find therefore, Caroline, that this is no narrow or confined science, which comprehends every thing material within our sphere.

CAROLINE.

On the contrary, it must be inexhaustible; and I am at a loss to conceive how any proficiency can be made in a science whose objects are so numerous.

MRS. B.

If every individual substance was formed of different materials, the study of chemistry would indeed be endless; but you must observe that the various bodies in nature are composed of certain elementary principles, which are not very numerous.

CAROLINE.

Yes; I know that all bodies are composed of fire, air, earth, and water; I learnt that many years ago.

MRS. B.

But you must now endeavour to forget it. I have already informed you what a great change chemistry has undergone since it has become a regular science. Within these thirty years especially, it has experienced an entire revolution, and it is now proved that neither fire, air, earth, nor water, can be called elementary bodies. For an elementary body is one that cannot be decomposed, that is to say, separated into other substances; and fire, air, earth, and water, are all of them susceptible of decomposition.

EMILY.

I thought that decomposing a body was dividing it into its minutest parts. And if so, I do not understand why an elementary substance is not capable of being decomposed, as well as any other.

MRS. B.

You have misconceived the idea of *decomposition*; it is very different from mere *division*: the latter simply reduces a body into parts, but the former separates it into the various ingredients, or materials, of which it is composed. If we were to take a loaf of bread, and separate the several ingredients of which it is made, the flour, the yeast, the salt, and the water, it would be very different from cutting the loaf into pieces, or crumbling it to atoms.

EMILY.

I understand you now very well. To decompose a body is to separate from each other the various elementary substances of which it consists.

CAROLINE.

But flour, water, and the other materials of bread, according to your definition, are not elementary substances?

MRS. B.

No, my dear; I mentioned bread rather as a familiar comparison, to illustrate the idea, than as an example.

The elementary substances of which a body is composed, are called the *constituent* parts of that body; in decomposing it, therefore, we separate its constituent parts. If, on the contrary, we divide a body by chopping it to pieces, or even by grinding or pounding it to the finest powder, each of these small particles will still consist of a portion of the several constituent parts of the whole body: these we call the *integrant* parts; do you understand the difference?

EMILY.

Yes, I think, perfectly. We *decompose* a body into its *constituent* parts; and *divide* it into its *integrant* parts.

MRS. B.

Exactly so. If therefore a body consist of only one kind of substance, though we may divide it into its integrant parts, it is not possible to decompose it. Such bodies are therefore called *simple* or *elementary*, as they are the elements of which all other bodies are composed. *Compound bodies* are such as consist of more than one of these elementary principles.

CAROLINE.

But do not fire, air, earth, and water, consist, each of them, but of one kind of substance?

MRS. B.

No, my dear; they are every one of them susceptible of being separated into various simple bodies. Instead of four, chemists now reckon upwards of forty elementary substances. These we shall first examine separately, and afterwards consider in their combinations with each other.

Their names are as follows:

LIGHT,	SILEX,	ZINC,
CALORIC,	ALUMINE,	BISMUTH,
OXYGEN,	YTTRIA,	ANTIMONY,
NITROGEN,	GLUCINA,	ARSENIC,
HYDROGEN,	ZIRCONIA,	COBALT,
SULPHUR,	AGUSTINA.	MANGANESE,
PHOSPHORUS,	(25 *Metals.*)	TUNGSTEN,
CARBONE.	GOLD,	MOLYBDENUM,
(2 *Alkalies.*)	PLATINA,	URANIUM,
POTASH,	SILVER,	TELLURIUM,
SODA.	MERCURY,	TITANIUM,
(10 *Earths.*)	COPPER,	CHROME,
LIME,	IRON,	OSMIUM,
MAGNESIA,	TIN,	IRIDIUM,
STRONTITES,	LEAD,	PALLADIUM,
BARYTES,	NICKEL,	RHODIUM.

CAROLINE.

This is, indeed, a formidable list!

MRS. B.

Not so much so as you imagine; many of the names you are already acquainted with, and the others will soon become familiar to you. But, before we proceed further, it will be necessary to give you some idea of chemical attraction, a power on which the whole science depends.

Chemical Attraction, or the *Attraction of Composition*, consists in the peculiar tendency which bodies of a different nature have to unite with each other. It is by this force that all the compositions, and decompositions, are effected.

EMILY.

What is the difference between chemical attraction, and the attraction of cohesion, or of aggregation, which you often mentioned to us in former conversations?

MRS. B.

The attraction of cohesion exists only between particles of the *same* nature, whether simple or compound; thus it unites the particles of a piece of metal which is a simple substance, and likewise the particles of a loaf of bread which is a compound. The attraction of composition, on the contrary, unites and maintains in a state of combination particles of a *dissimi-*

lar nature; it is this power that forms each of the compound particles of which bread consists; and it is by the attraction of cohesion that all these particles are connected into a single mass.

EMILY.

The attraction of cohesion, then, is the power which unites the integrant particles of a body; the attraction of composition that which combines the constituent particles. Is it not so?

MRS. B.

Precisely: and observe that the attraction of cohesion unites particles of a similar nature, without changing their original properties; the result of such an union, therefore, is a body of the same kind as the particles of which it is formed; whilst the attraction of composition, by combining particles of a dissimilar nature, produces new bodies, quite different from any of their constituent particles. If, for instance, I pour on the piece of copper, contained in this glass, some of this liquid (which is called nitric acid) for which it has a strong attraction, every particle of the copper will combine with a particle of acid, and together they will form a new body, totally different from either the copper or the acid.

Do you observe the internal commotion that already begins to take place? It is produced by the combination of these two substances; and yet the acid has in this case to overcome not only the resistance which the strong cohesion of the particles of copper oppose to its combination with them, but also the weight of the copper, which makes it sink to the bottom of the glass, and prevents the acid from having such free access to it as it would if the metal were suspended in the liquid.

EMILY.

The acid seems, however, to overcome both these obstacles without difficulty, and appears to be very rapidly dissolving the copper.

MRS. B.

By this means it reduces the copper into more minute parts, than could possibly be done by any mechanical power. But as the acid can act only on the surface of the metal, it will be some time before the union of these two bodies will be completed.

You may, however, already see how totally different this compound is from either of its ingredients. It is neither colourless like the acid, nor hard, heavy, and yellow, like the copper. If you tasted it, you would no longer perceive the sourness of the acid. It has at present the appearance of a blue liquid; but when the union is completed, and the water with which the acid is diluted is evaporated, it will assume the form of regular crystals, of a fine blue colour, and perfectly transparent. Of these I can show you a specimen, as I have prepared some for that purpose.

CAROLINE.

How very beautiful they are, in colour, form, and transparency!

EMILY.

Nothing can be more striking than this example of chemical attraction.

MRS. B.

The term *attraction* has been lately introduced into chemistry as a substitute for the word *affinity*, to which some chemists have objected, because it originated in the vague notion that chemical combinations depended upon a certain resemblance, or relationship, between particles that are disposed to unite; and this idea is not only imperfect, but erroneous, as it is generally particles of the most dissimilar nature, that have the greatest tendency to combine.

CAROLINE.

Besides, there seems to be no advantage in using a variety of terms to express the same meaning; on the contrary it creates confusion; and as we are well acquainted with the term attraction in natural philosophy, we had better adopt it in chemistry likewise.

MRS. B.

If you have a clear idea of the meaning, I shall leave you at liberty to express it in the terms you prefer. For myself, I confess that I think the word attraction best suited to the general law that unites the integrant particles of bodies; and affinity better adapted to that which combines the constituent particles, as it may convey an idea of the preference which some bodies have for others, which the term *attraction of composition* does not so well express.

EMILY.

So I think; for though that preference may not result from any relationship, or similitude, between the particles (as you say was once supposed), yet, as it really exists, it ought to be expressed.

MRS. B.

Well, let it be agreed that you may use the terms *affinity*, *chemical attraction*, and *attraction of composition*, indifferently, provided you recollect that they have all the same meaning.

EMILY.

I do not conceive how bodies can be decomposed by chemical attraction. That this power should be the means of composing them, is very obvious; but how it can at the same time produce exactly the contrary effect, appears to me very singular.

MRS. B.

To decompose a body, is, you know, to separate its constituent parts, which, as we have just observed, can never be done by mechanical means.

EMILY.

No; because mechanical means separate only the integrant particles; they act merely against the attraction of cohesion.

MRS. B.

The decomposition of a body, therefore, can only be performed by chemical powers. If you present to a body composed only of two principles, a third, which has a greater affinity for one of them than the two first have for each other, it will be decomposed, that is, its two principles will be separated by means of the third body. Let us call two ingredients, of which a body is composed, A and B. If we present to it another ingredient C, which has a greater affinity for B than that which unites A and B, it necessarily follows that B will quit A to combine with C. The new ingredient, therefore, has effected a decomposition of the original body A B; A has been left alone, and a new compound, B C, has been formed.

EMILY.

We might, I think, use the comparison of two friends, who were very happy in each other's society, till a third disunited them by the preference which one of them gave to the new-comer.

MRS. B.

Very well. I shall now show you how this takes place in chemistry.

Let us suppose that we wish to decompose the compound we have just formed by the combination of the two ingredients, copper and nitric acid: we may do this by presenting to it a piece of iron, for which the acid has a stronger attraction than for copper; the acid will consequently quit the copper to combine with the iron, and the copper will be what the chemists call *precipitated*, that is to say, it will return to its separate ſtate, and reappear in its simple form.

In order to produce this effect, I shall dip the blade of this knife into the fluid, and, when I take it out, you will observe that, instead of being wetted with a blueish liquid like that contained in the glass, it will be covered with a very thin pellicle of copper.

CAROLINE.

So it is, really! But then is it not the copper, instead of the acid, that has combined with the iron blade?

MRS. B.

No; you are deceived by appearances: it is the acid which combines with the iron, and in so doing deposits the copper on the surface of the blade.

EMILY.

But cannot three or more substances combine together, without any of them being precipitated?

MRS. B.

That is sometimes the case; but, in general, the stronger affinity deftroys the weaker; and it seldom happens that the attraction of several substances for each other is so equally balanced as to produce such complicated compounds.

It is now time to conclude our conversation for this morning. But, before we part, I must recommend you to fix in your memory the names of the simple bodies, against our next interview.

CONVERSATION II.

ON LIGHT AND HEAT.

CAROLINE.

We have learned by heart the names of all the simple bodies, which you have enumerated, and we are now ready to enter on the examination of each of them successively. You will begin, I suppose, with LIGHT?

MRS. B.

That will not detain us long: the nature of light, independent of heat, is so imperfectly known, that we have little more than conjectures respecting it.

EMILY.

But is it possible to separate light from heat; I thought that they were only different degrees of the same thing?

MRS. B.

They are certainly very intimately connected; yet it appears that they are distinct substances, as they can, under certain circumstances, be in a great measure separated. The most striking instance of this was pointed out by Dr. Herschell.

This philosopher discovered that heat was less refrangible than light; for in separating the different coloured rays of light by a prism (as we did some time ago), he found that the greatest heat was beyond the spectrum, at a little distance from the red rays, which you may recollect are the least refrangible.

EMILY.

I should like to try that experiment.

MRS. B.

It is by no means an easy one: the heat of a ray of light, refracted by a prism, is so small, that it requires a very delicate thermometer to distinguish the difference of the degree of heat within and without the spectrum. For in this experiment the heat is not totally separated from the light, each coloured ray retaining a certain portion of it, though the greatest part is not sufficiently refracted to fall within the spectrum.

EMILY.

I suppose, then, that those coloured rays which are the least refrangible, retain the greatest quantity of heat?

MRS. B.

They do so.

CAROLINE.

Perhaps the different degrees of heat which the seven rays possess, may in some unknown manner occasion their variety of colour. I have heard that melted metals change colour according to the different degrees of heat to which they are exposed; might not the colours of the spectrum be produced by a cause of the same kind? Do let us try if we cannot ascertain this, Mrs. B—? I should like extremely to make some discovery in chemistry.

MRS. B.

Had we not better learn first what is already known? Surely you cannot seriously imagine that, before you have acquired a single clear idea on chemistry, you can have any chance of discovering secrets that have eluded the penetration of those who have spent their whole lives in the study of that science.

CAROLINE.

Not much, to be sure, in the regular course of events; but a lucky chance sometimes happens. Did not a child lead the way to the discovery of telescopes?

MRS. B.

There are certainly a few instances of this kind. But, believe me, it is infinitely wiser to follow up a pursuit regularly, than to trust to chance for your success.

EMILY.

But to return to our subject. Though I no longer doubt that light and heat can be separated, Dr. Herschel's experiment does not appear to me to afford sufficient proof that they are essentially different; for light, which you call a simple body, may likewise be divided into the various coloured rays; is it not therefore possible that heat may only be a modification of light?

MRS. B.

That is a supposition which, in the present state of natural philosophy, can neither be positively affirmed nor denied: it is generally thought that light and heat are connected with each other as cause and effect; but which is the cause, and which the effect, it is extremely difficult to determine. But it would be useless to detain you any longer on this intricate subject. Let us now pass on to that of HEAT, with which we are much better acquainted.

CAROLINE.

Heat is not, I believe, amongst the number of the simple bodies?

MRS. B.

Yes, it is; but under another name—that of CALORIC, which is nothing more than the principle, or matter of heat.—We suppose caloric to be a very subtle fluid, originally derived from the sun, and composed of very minute particles, constantly in agitation and moving in a manner similar to light, as long as they meet with no obstacle. But when these rays come in contact with the earth, and the various bodies belonging to it, part of them are reflected from their surfaces according to certain laws, and part enters into them.

CAROLINE.

These rays of heat, or caloric, proceeding from the same source, and following the same direction, as the rays of light, bear a very strong resemblance to them.

MRS. B.

So much so that it often requires great attention not to confound them.

EMILY.

I think there is no danger of that, if we recollect one great distinction—light is visible, and caloric is not.

MRS. B.

Very right. *Light* affects the sense of *Sight*; *Caloric* that of *Feeling*: the one produces *Vision*, the other the peculiar sensation of *Heat*.

Caloric is found to exist in a variety of forms, and to be susceptible of certain modifications, all of which may be comprehended under the four following heads:

1. FREE CALORIC,
2. SPECIFIC HEAT,
3. LATENT HEAT,
4. CHEMICAL HEAT.

The first, or FREE CALORIC, is also called HEAT OF TEMPERATURE; it comprehends all heat which is perceptible to the senses, and affects the thermometer.

EMILY.

You mean such as the heat of the sun, of fire, of candles, of stoves; in short, of every thing that burns?

MRS. B.

And likewise of things that do not burn, as, for instance, the warmth of the body; in a word, all heat that is *sensible*, whatever may be its degree, or the source from which it is derived.

CAROLINE.

What then are the other modifications of caloric? It must be a strange kind of heat that cannot be perceived by our senses?

MRS. B.

None of the modifications of caloric should properly be called *heat*; for heat, strictly speaking, is the sensation produced by caloric, on animated bodies, and this word therefore should be confined to express the sensation. But custom has adapted it likewise to inanimate matter, and we say *the heat of an oven, the heat of the sun,* without any reference to the sensation which they are capable of exciting.

It was in order to avoid the confusion which arose from thus confounding the cause and effect, that modern chemists adopted the new word *Caloric,* to express the principle which produces heat; but they do not yet limit the word *heat* (as they should do) to the expression of the sensation, since they still retain the habit of connecting this word with the three other modifications of caloric.

CAROLINE.

But you have not yet explained to us what these other modifications of caloric are.

MRS. B.

Because you are not yet acquainted with the properties of free caloric, and you know that we have agreed to proceed with regularity.

One of the most remarkable properties of free caloric is its power of *dilating* bodies. This fluid is so extremely subtle, that it enters and pervades all bodies whatever, forces itself between their particles, and not only separates them, but, by its repulsive power, drives them asunder, frequently to a considerable distance from each other. It is thus that caloric dilates or expands a body so as to make it occupy a greater space than it did before.

EMILY.

The effect of caloric on bodies therefore, is directly contrary to that of the attraction of cohesion; the one draws the particles together, the other drives them asunder.

MRS. B.

Precisely. There is a kind of continual warfare between the attraction of aggregation and the repulsive power of caloric; and from the action of these two opposite forces, result all the various forms of matter, or degrees of consistence, from the solid, to the liquid and aeriform state. And accordingly we find that most bodies are capable of passing from one of these forms to the other, merely in consequence of their receiving different quantities of caloric.

CAROLINE.

That is very curious; but I think I understand the reason of it. If a great quantity of caloric is added to a solid body, it introduces itself between the particles in such a manner as to overcome, in a considerable degree, the attraction of cohesion; and the body, from a solid, is then converted into a fluid.

MRS. B.

This is the case whenever a body is melted; but if you add caloric to a liquid, can you tell me what is the consequence?

CAROLINE.

The caloric forces itself in greater abundance between the particles of the fluid, and drives them to such a distance from each other, that their attraction of aggregation is wholly destroyed; the liquid is then transformed into vapour.

MRS. B.

Very well; and this is precisely the case with boiling water, when it is converted into steam or vapour.

But each of these various states, solid, liquid, and aeriform, admit of many different degrees of density, or consistence, still arising (partly at least) from the different quantities of caloric the bodies contain. Solids are of various degrees of density, from that of gold, to that of a thin jelly. Liquids, from the consistence of melted glue, or melted metals, to that of ether, which is the lightest of all liquids. The different elastic fluids (with which you are not yet acquainted) admit of no less variety in their degrees of density.

EMILY.

But does not every individual body also admit of different degrees of consistence, without changing its state?

MRS. B.

Undoubtedly; and this I can immediately show

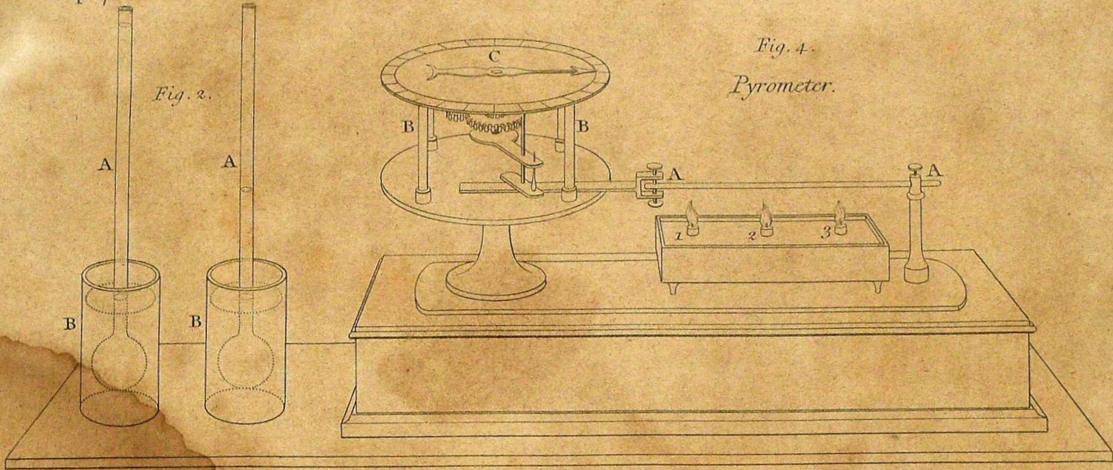


Fig. 1 A.A *Bar of Metal*. 1.2.3 *Lamps burning*. B.B *Wheel work*. C *Index*. *Fig. 2* A.A *Glass tubes with bulbs*. B.B *Glasses of water in which they are immersed.*

Drawn by the Author.

Engraved by Lowry

Published by Longman & C^o. Dec^r. 2^nd 1806.

you by a very simple experiment. This piece of iron now exactly fits the frame, or ring, made to receive it; but if heated red hot, it will no longer do so, for its dimensions will be so much increased by the caloric that has penetrated into it, that it will be much too large for the frame.

The iron is now red hot; by applying it to the frame, we shall see how much it is dilated.

EMILY.

Considerably so indeed! I knew that heat had this effect on bodies, but I did not imagine that it could be made so conspicuous.

MRS. B.

By means of this instrument (called a Pyrometer) we may estimate, in the most exact manner, the various dilatations of any solid body by heat. The body we are now going to submit to trial is this small iron bar; I fix it to this apparatus, (PLATE I. Fig. 1.) and then heat it by lighting the three lamps beneath it: when the bar dilates, it increases in length as well as thickness; and, as one end communicates with this wheel-work, whilst the other end is fixed and immovable, no sooner does it begin to dilate than it presses against the wheel-work, and sets in motion the index, which points out the degrees of dilatation on the dial-plate.

EMILY.

This is indeed a very curious instrument; but I do not underftand the use of the wheels: would it not be more simple, and answer the purpose equally well, if the bar pressed against the index, and put it in motion without the intervention of the wheels?

MRS. B.

The use of the wheels is merely to multiply the motion, and therefore render the effect of the caloric more obvious: for if the index moved no more than the bar increased in length, its motion would scarcely be perceptible; but by means of the wheels it moves in a much greater proportion, which therefore renders the variations much more conspicuous.

By submitting different bodies to the test of the pyrometer, it is found that they are far from dilating in the same proportion. Different metals expand in different degrees, and other kinds of solid bodies vary still more in this respect. But this different susceptibility of dilatation is still more remarkable in fluids than in solid bodies, as I shall show you. I have here two glass tubes, terminated at one end by large bulbs. We shall fill the bulbs, the one with spirit of wine, the other with water. I have coloured both liquids, that the effect may be more conspicuous. The spirit of wine, you see, dilates merely by the warmth of my hand as I hold the bulb.

EMILY.

It certainly dilates, for I see it is rising into the tube. But water, it seems, is not so easily affected by heat; for no apparent change is produced on it by the warmth of the hand.

MRS. B.

True; we shall now plunge the bulbs into hot water, (PLATE I. Fig. 2.) and you will see both liquids rise in the tubes; but the spirit of wine will begin to ascend first.

CAROLINE.

How rapidly it dilates! Now it has nearly reached the top of the tube, though the water has not yet begun to rise.

EMILY.

The water now begins to dilate. Are not these glass tubes, with liquids rising within them, very like thermometers?

MRS. B.

A Thermometer is constructed exactly on the same principle, and these tubes require only a scale to answer the purpose of thermometers: but they would be rather awkward in their dimensions. The tubes and bulbs of thermometers, though of various sizes, are in general much smaller than these; the tube too is hermetically closed, and the air excluded from it. The fluid most generally used in thermometers is mercury, commonly called quicksilver, the dilatations and contractions of which correspond more exactly to the additions, and subtractions, of caloric, than those of any other fluid.

CAROLINE.

Yet I have often seen coloured spirit of wine used in thermometers.

MRS. B.

The dilatations and contractions of that liquid are not quite so uniform as those of mercury; but in cases in which it is not requisite to ascertain the temperature with great precision, spirit of wine will answer the purpose equally well, and indeed in some respects better, as the expansion of the latter is greater and therefore more conspicuous. This fluid is used likewise in situations and experiments in which mercury would be frozen; for mercury becomes a solid body, like a piece of lead or any other metal, at a certain degree of cold: but no degree of cold has ever been known to freeze spirit of wine.

A thermometer therefore consists of a tube with a bulb, such as you see here, containing a fluid whose degrees of dilatation and contraction are indicated by a scale to which the tube is fixed. The degree which indicates the boiling point, simply means that, when the fluid is sufficiently dilated to rise to this point, the heat is such, that water exposed to the same temperature will boil. When, on the other hand, the fluid is so much condensed as to sink to the freezing point, we know that water will freeze at that temperature. The extreme points of the scales are not the same in all thermometers, nor are the degrees always divided in the same manner. In different countries philosophers have chosen to adopt different scales and divisions. The two thermometers most used are those of Fahrenheit, and of Reaumur; the first is generally preferred by the English, the latter by the French.

EMILY.

The variety of scale must be very inconvenient, and I should think liable to occasion confusion, when French and English experiments are compared.

MRS. B.

This inconvenience is but very trifling, because the different graduations of the scales do not affect the principle upon which thermometers are constructed. When we know, for instance, that Fahrenheit's scale is divided into 212 degrees, in which 32° corresponds with the freezing point, and 212° with the point of boiling water; and that Reaumur's is divided only into 80 degrees, in which 0° denotes the freezing point, and 80° that of boiling water, it is easy to compare the two scales together, and reduce the one into the other. But, for greater convenience, thermometers are sometimes constructed with both these scales, one on either side of the tube; so that the correspondence of the different degrees of the two scales, is thus instantly seen. Here is one of these scales, (PLATE II. Fig. 3.) by which you can at once perceive that each degree of Reaumur's corresponds to $2\frac{1}{4}$ of Fahrenheit's division.

EMILY.

Are spirit of wine, and mercury, the only fluids used in the construction of thermometers?

MRS. B.

I believe they are the only liquids now in use, though some others, such as linseed oil, would make tolerable thermometers: but for experiments in which a very quick and delicate test of the changes of temperature is required, air thermometers are sometimes employed. The bulb, in these, instead of containing a liquid, is filled only with common air, and its dilatations and contractions are made sensible, by a small drop of any coloured fluid, which is suspended within the tube, and moves up and down, according as the air within the bulb and tube expands or contracts. But air thermometers, however sensible to changes of temperature, are by no means accurate in their indications.

THERMOMETER.

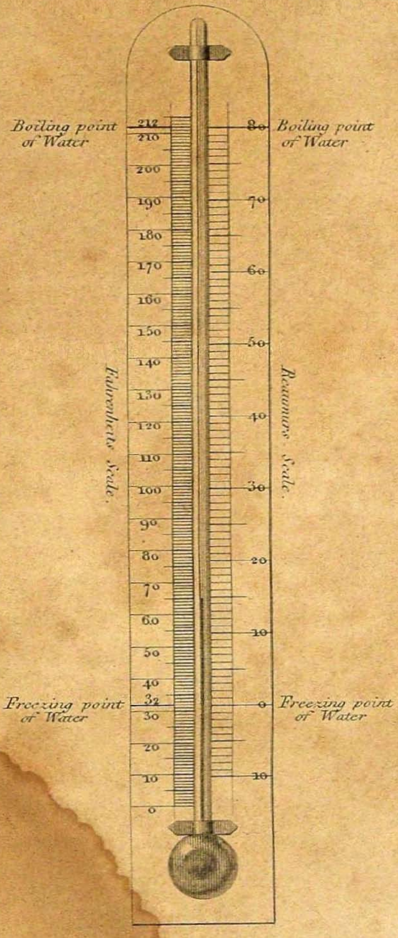


Fig. 3.

EMILY.

A thermometer, then, indicates the exact quantity of caloric contained either in the atmosphere, or in any body with which it is in contact?

MRS. B.

No: first, because there are other modifications of caloric which do not affect the thermometer; and, secondly, because the temperature of a body, as indicated by the thermometer, is only relative. When, for instance, the thermometer remains stationary at the freezing point, we know that the atmosphere (or medium in which it is placed, whatever it may be) is as cold as freezing water; and when it stands at the boiling point, we know that this medium is as hot as boiling water; but we do not know the positive quantity of heat contained either in freezing or boiling water, any more than we know the real extremes of heat and cold; and consequently we cannot determine that of the body in which the thermometer is placed.

CAROLINE.

I do not quite understand this explanation.

MRS. B.

Let us compare a thermometer to a well, in which the water rises to different heights, according as it is more or less supplied by the spring which feeds it: if the depth of this well be unfathomable, it must be impossible to know the absolute quantity of water it contains; yet we can with the greatest accuracy measure the number of feet the water has risen or fallen in the well at any time, and consequently know the precise quantity of its increase or diminution, without having the least knowledge of the whole quantity of water it contains.

CAROLINE.

Now I comprehend it very well; nothing explains a thing so clearly as a comparison.

EMILY.

But will thermometers bear any degree of heat?

MRS. B.

No; for if the temperature be much above the highest degree marked on the scale of the thermometer, the mercury would burst the tube in an attempt to ascend. And at any rate no thermometer can be applied to temperatures higher than the boiling point of the liquid used in its construction. In furnaces, or whenever any very high temperature is to be measured, a pyrometer, invented by Wedgewood, is used for that purpose. It is made of a certain composition of baked clay, which has the peculiar property of contracting by heat, so that the degree of contraction of this substance indicates the temperature to which it has been exposed.

EMILY.

But is it possible for a body to contract by heat? I thought that heat dilated all bodies whatever.

MRS. B.

That is, I believe, true. Yet heat frequently diminishes the bulk of a body by evaporating some of its particles; thus, if you dry a wet sponge before the fire, the heat, though it must, according to the general law of nature, dilate the particles of the sponge, will very considerably contract its bulk by evaporating its moisture.

CAROLINE.

And how do you ascertain the degrees of contraction of this pyrometer?

MRS. B.

The dimensions of a piece of clay are measured by the bore of a graduated conical tube in which it is placed; the more it is contracted by the heat, the lower it descends into the narrow part of the tube.

Let us now proceed to examine the other properties of free caloric.

Free caloric always tends to an equilibrium;

that is to say, when two bodies are of different temperatures, the warmer gradually parts with its heat to the colder, till they are both brought to the same temperature.

EMILY.

Is cold then nothing but a negative quality, simply implying the absence of heat?

MRS. B.

Not the total absence, but a diminution of heat; for we know of no body in which some caloric may not be discovered.

CAROLINE.

But when I lay my hand on this marble table, I feel it *positively* cold, and cannot conceive that there is any caloric in it.

MRS. B.

The cold you experience consists in the loss of caloric that your hand sustains in an attempt to bring its temperature to an equilibrium with the marble. If you lay a piece of ice upon it, you will find that the contrary effect will take place; the ice will be melted by the heat which it abstracts from the marble.

CAROLINE.

Is it not in this case the air of the room, which being warmer than the marble, melts the ice?

MRS. B.

The air certainly acts on the surface exposed to it, but the table melts that part which is in contact with it.

CAROLINE.

But why does caloric tend to an equilibrium? It cannot be on the same principle as other fluids, since it has no weight?

MRS. B.

Very true, Caroline, that is an excellent remark. The tendency of caloric to an equilibrium is best explained by a supposed repulsive force of its particles, which having a constant tendency to fly from each other, diffuse themselves wherever there is a deficiency of that fluid, and thus gradually restore an equilibrium of temperature. But it is not only bodies which contain a greater proportion of caloric that part with it to those that contain less: in order to explain all the phenomena of heat and cold, we must suppose that a mutual exchange of caloric takes place between all bodies, of whatever temperature, and that the rays of caloric, in passing from one body to another, are subject to all the laws of reflection and refraction, the same as those of light. This theory was first suggesed by Professor Prevost, of Geneva, and is now, I believe, pretty generally adopted. Thus you may suppose all bodies whatever constantly radiating caloric: those that are of the same temperature give out and receive equal quantities, so that no change of temperature is produced in them; but when one body contains more free caloric than another, the exchange is always in favour of the colder body, until an equilibrium is effected; this you found to be the case when the marble table cooled your hand, and again when it melted the ice.

CAROLINE.

This surprises me extremely: I thought, from what you first said, that the hotter bodies alone emitted rays of caloric which were absorbed by the colder; for it seems unfair that a hot body should receive any caloric from a cold one, even though it should return a greater quantity.

MRS. B.

It may at first appear so, but it is no more extraordinary than that a candle should send forth rays of light to the sun, or that a stone, in falling, should attract the earth, as you know it does from the law of gravitation.

CAROLINE.

Well, Mrs. B—, since you have all nature to oppose to me, I believe that I must give up the point. But I wish I could *see* these rays of caloric, I should then have greater faith in them.

MRS. B.

Will you give no credit to any sense but that of sight? You may feel the rays of caloric which you receive from any body of a temperature higher than your own; the loss of the caloric you part with in return, it is true, is not perceptible; for as you gain more than you lose, instead of suffering a diminution, you are really making an acquisition of caloric. It is therefore only when you are parting with it to a body of a lower temperature, that you are sensible of the sensation of cold, because you then sustain an absolute loss of caloric.

EMILY.

And in this case we cannot be sensible of the small quantity of heat we receive in exchange from the colder body, because it serves only to diminish the loss.

MRS. B.

Very well, indeed, Emily. Professor Pictet, of Geneva, has made some very interesting experiments to prove that caloric radiates from all bodies whatever, and that these rays may be reflected, according to the laws of optics, in the same manner as light. I wish I could repeat these experiments before you, but the difficulty of procuring mirrors fit for the purpose puts it out of my power; you must therefore be satisfied with an account of them, illustrated by this diagram: (PLATE III. Fig. 4.)—

He placed an iron bullet, about two inches in diameter, and heated to a degree not sufficient to render it luminous, in the focus of a large metallic concave mirror. The rays of heat which fell on this mirror were reflected, agreeably to the property of concave mirrors, in a parallel direction, so as to fall on a similar mirror, which was placed opposite to the first, at the distance of about twelve feet; thence they converged to the focus of the second mirror, in which the bulb of a thermometer was placed, the consequence of which was, that the thermometer immediately rose several degrees.

EMILY.

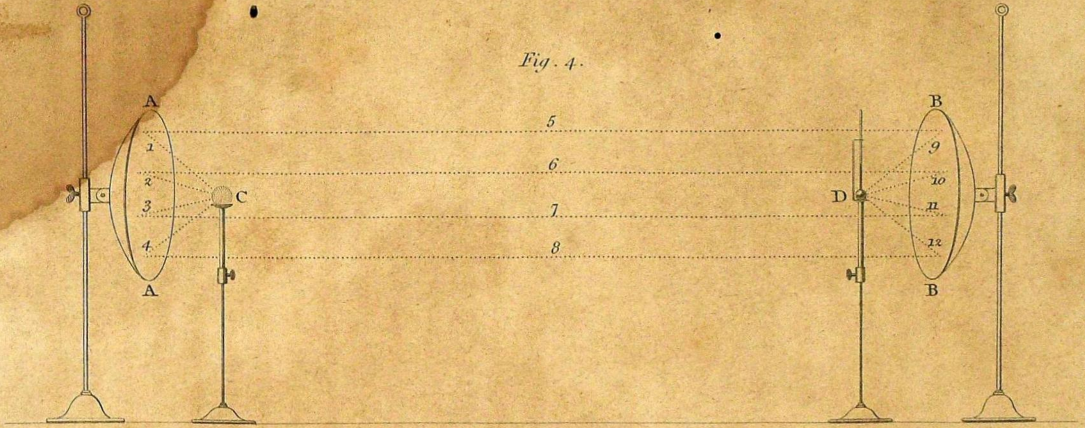
But would not the same effect have taken place, if the rays of caloric from the heated bullet had fallen directly on the thermometer, without the assistance of the mirrors?

MRS. B.

The effect would in that case have been so trifling, at the distance at which the bullet and the thermometer were from each other, as would probably have rendered it imperceptible. The mirrors, you know, greatly increase the effect, by collecting a large quantity of rays into a focus; but their principal use was to prove that the calorific emanation was reflected in the same manner as light.

M^r. PICTET'S APPARATUS FOR THE REFLECTION OF HEAT.

Fig. 4.



A.A & B.B *Concave mirrors fixed on stands.*_C *Heated Bullet placed in the focus of the mirror* A._D *Thermometer, with its bulb placed in the focus of the mirror* B._ 1. 2. 3. 4 *Rays of Caloric radiating from the bullet & falling on the mirror* A._ 5. 6. 7. 8 *The same rays reflected from the mirror* A *to the mirror* B._ 9. 10. 11. 12 *The same rays reflected by the mirror* B *to the Thermometer.*

Drawn by the Author. *Engraved by Lowry.*

Published by Longman & C^o. Dec^r. 2^nd. 1805.

CAROLINE.

And the result, I think, was very conclusive.

MRS. B.

The experiment was afterwards repeated with a wax taper instead of the bullet, with a view of separating the light from the caloric. For this purpose a transparent plate of glass was interposed between the mirrors; for light, you know, passes with great facility through glass, whilst the transmission of caloric is considerably impeded by it. It was found however, in this experiment, that some of the calorific rays passed through the glass together with the light, as the thermometer rose a few degrees; but as soon as the glass was removed, and a free passage left to the caloric, it rose immediately double the number of degrees.

EMILY.

This experiment, as well as that of Dr. Herschell's, proves that light and heat may be separated; for in the latter experiment the separation was not perfect, any more than in that of Mr. Pictet.

CAROLINE.

I should like to repeat Mr. Pictet's experiments, with the difference of substituting a cold body instead of the hot one, to see whether cold would not be reflected as well as heat.

MRS. B.

That experiment was proposed to Mr. Pictet by an incredulous philosopher like yourself, and he immediately tried it by substituting a piece of ice in the place of the heated bullet.

CAROLINE.

Well, Mrs. B—, and what was the result?

MRS. B.

The thermometer fell considerably.

CAROLINE.

And does not that prove that cold is not merely a *negative* quality, implying simply an inferior degree of heat? The cold must be *positive*, since it is capable of reflection.

MRS. B.

So it at first appeared; but upon a little consideration it was found that it afforded only an additional proof of the reflection of heat: this I shall endeavour to explain to you.

We suppose that all bodies whatever radiate caloric; the thermometer used in these experiments therefore emits calorific rays in the same manner as any other substance. When its temperature is in equilibrium with that of the surrounding bodies, it receives as much caloric as it parts with, and no change of temperature is produced. But when we introduce a body of a lower temperature, such as a piece of ice, which parts with less caloric than it receives, the consequence is, that its temperature is raised, whilst that of the surrounding bodies is proportionally lowered; and as, from the effect of the mirrors, a more considerable exchange of rays takes place between the ice and the thermometer, than between these and any of the surrounding bodies, the temperature of the thermometer must be more lowered than that of any other adjacent object.

CAROLINE.

I do not perfectly understand your explanation.

MRS. B.

This experiment is exactly similar to that made with the heated bullet: for, if we consider the thermometer as the hot body (which it certainly is in comparison to the ice), you may then easily understand that it is by the loss of the calorific rays which the thermometer sends to the ice, and not by any cold rays received from it, that the fall of the mercury is occasioned; for the ice, far from emitting rays of cold, sends forth rays of caloric, which diminish the loss sustained by the thermometer.

Let us say, for instance, that the radiation of the thermometer towards the ice is equal to 20, and that of the ice towards the thermometer to 10; the exchange in favour of the ice is as 20 is to 10, or the thermometer absolutely loses 10, whilst the ice gains 10.

CAROLINE.

But if the ice actually sends rays of caloric to the thermometer, must not the latter fall still lower when the ice is removed?

MRS. B.

No; for the air which will fill the space that the ice occupied, being of the same temperature as the thermometer, will emit and receive an equal quantity of caloric, so that no alteration of temperature will be produced.

CAROLINE.

I must confess that you have explained this in so satisfactory a manner, that I cannot help being convinced that cold has no real claim to the rank of a positive being. So now we may proceed to the other modifications of caloric.

MRS. B.

We have not yet concluded our observations on free caloric. But I shall defer, till our next meeting, what I have further to say on this subject, as I believe it will afford us ample conversation for another interview.

CONVERSATION III.

CONTINUATION OF THE SUBJECT.

MRS. B.

In our last conversation, we began to examine the constant tendency of free caloric to restore an equilibrium of temperature. This property, when once well understood, affords the explanation of a great variety of facts which appeared formerly unaccountable. You must observe, in the first place, that the effect of this tendency is gradually to bring all bodies that are in contact, to the same temperature. Thus, the fire which burns in the grate, communicates its heat from one object to another, till every part of the room has an equal proportion of it.

EMILY.

And yet this book is not so cold as the table on which it lies, though both are at an equal distance from the fire, and actually in contact with each other, so that, according to your theory, they should be exactly of the same temperature?

CAROLINE.

And the hearth, which is much nearer the fire than the carpet, is certainly the colder of the two.

MRS. B.

If you ascertain the temperature of these several bodies by a thermometer (which is a much more accurate test than your feeling), you will find that it is exactly the same.

CAROLINE.

But if they are of the same temperature, why should the one feel colder than the other?

MRS. B.

The hearth and the table feel colder than the carpet or the book, because the latter are not such good *conductors of heat* as the former. Caloric finds a more easy passage through marble and wood, than through leather and worsted; the two former will therefore absorb heat more rapidly from your hand, and consequently give it a stronger sensation of cold than the two latter, although they are all of them really of the same temperature.

CAROLINE.

So, then, the sensation I feel on touching a cold body, is in proportion to the rapidity with which my hand yields its heat to that body?

MRS. B.

Precisely; and, if you lay your hand successively on every object in the room, you will discover which are good, and which are bad conductors of heat, by the different degrees of cold you feel. But, in order to ascertain this point, it is necessary that the several substances should be of the same temperature, which will not be the case with those that are very near the fire, or those that are exposed to a current of cold air from a window or door.

EMILY.

But what is the reason that some bodies are better conductors of heat than others?

MRS. B.

That is a point not well ascertained. It is conjectured that a certain union or adherence takes place between the caloric and the particles of the body through which it passes. If this adherence be strong, the body detains the heat, and parts with it slowly and reluctantly; if slight, it propagates it freely and rapidly. The conducting power of a body is therefore, inversely, as its tendency to unite with caloric.

EMILY.

That is to say, that the best conductors are those that have the least affinity for caloric.

MRS. B.

Yes; but I object to the term affinity in this case, because, as that word is used to express a chemical attraction (which can be destroyed only by decomposition), it cannot be applicable to the slight and transient union that takes place between free caloric and the bodies through which it passes; an union which is so weak, that it constantly yields to the tendency which caloric has to an equilibrium. Now you clearly understand, that the passage of caloric, through bodies that are good conductors, is much more rapid than through those that are bad conductors, and that the former both give and receive it more quickly, and therefore, in a given time, more abundantly, than bad conductors, which makes them feel either hotter or colder, though they may be, in fact, of the same temperature.

CAROLINE.

Yes, I understand it now; the table, and the book lying upon it, being really of the same temperature, would each receive, in the same space of time, the same quantity of heat from my hand, were their conducting powers equal; but as the table is the best conductor of the two, it will absorb the heat from my hand more rapidly, and consequently produce a stronger sensation of cold than the book.

MRS. B.

Very well, my dear; and observe, likewise, that if you were to heat the table and the book an equal number of degrees above the temperature of your body, the table, which before felt the colder, would now feel the hotter of the two; for, as in the first case it took the heat most rapidly from your hand, so it will now impart heat most rapidly to it. Thus the marble table, which seems to us colder than the mahogany one, will prove the hotter of the two to the ice; for, if it takes heat more rapidly from our hands, which are warmer, it will give out heat more rapidly to the ice, which is colder. Do you understand the reason of these apparently opposite effects?

EMILY.

Perfectly. A body that is a good conductor of caloric, affords it a free passage; so that it penetrates through that body more rapidly than through one which is a bad conductor; and, consequently, if it is colder than your hand, you lose more caloric, and if it is hotter, you gain more than with a bad conductor of the same temperature.

MRS. B.

But you must observe that this is the case only when the conductors are either hotter or colder than your hand; for, if you heat different conductors to the temperature of your body, they will all feel equally warm, since the exchange of radiation between bodies of the same temperature is equal. Now, can you tell me why flannel clothing, which is a very bad conductor of heat, prevents our feeling cold?

CAROLINE.

It prevents the cold from penetrating. . . . . .

MRS. B.

But you forget that cold is only a negative quality.

CAROLINE.

True; it only prevents the heat of our bodies from escaping so rapidly as it would otherwise do.

MRS. B.

Now you have explained it right: the flannel rather keeps in the heat, than keeps out the cold. Were the atmosphere of a higher temperature than our bodies, it would be equally efficacious in preserving them of an uniform temperature, as it would prevent the free access of the external heat, by the difficulty with which it conducts it.

EMILY.

This, I think, is very clear. Heat, whether external or internal, cannot easily penetrate flannel;

therefore in cold weather it keeps us warm; and if the weather was hotter than our bodies, it would keep us cool.

MRS. B.

For the same reason, glass windows, which are very bad conductors of heat, keep a room warm in winter and cool in summer, provided the sun does not shine upon them. The most dense bodies are, generally speaking, the best conductors of heat. At the temperature of the atmosphere a piece of metal will feel much colder than a piece of wood, and the latter than a piece of woollen cloth: this again will feel colder than flannel; and down, which is one of the lightest, is at the same time one of the warmest bodies.

CAROLINE.

This is, I suppose, the reason that the plumage of birds preserves them so effectually from the influence of cold in winter?

MRS. B.

Yes; but though feathers in general are an excellent preservative against cold, down is a kind of plumage peculiar to aquatic birds, and covers their chest, which is the part exposed to the water; for though the surface of the water is not of a lower temperature than the atmosphere, yet, as it is a better conductor of heat, it feels much colder, consequently the chest of the bird requires a warmer covering than any other part of its body.

Most animal substances, especially those which Providence has assigned as a covering for animals, such as fur, wool, hair, skin, &c. are bad conductors of heat, and are, on that account, such excellent preservatives against the inclemency of winter, that our warmest apparel is made of these materials.

In fluids of different densities, the power of conducting heat varies no less remarkably; if you dip your hand into this vessel full of mercury, you will scarcely conceive that its temperature is not lower than that of the atmosphere.

CAROLINE.

Indeed I can hardly believe it, it feels so extremely cold.—But we may easily ascertain its true temperature by the thermometer.—It is really not colder than the air;—the apparent difference then is produced merely by the difference of the conducting power in mercury and in air?

MRS. B.

Yes; hence you may judge how little the sense of feeling is to be relied on as a test of the temperature of bodies, and how necessary a thermometer is for that purpose.

But I must not forget to tell you that it has been doubted whether fluids have the power of conducting caloric in the same manner as solid bodies. Count Rumford, a very few years since, attempted to prove, by a variety of experiments, that fluids, when at rest, were not at all endowed with this property.

CAROLINE.

How is that possible, since they are capable of imparting cold or heat to us; for if they did not conduct heat, they would neither take it from, nor give it to us?

MRS. B.

Count Rumford did not mean to say that fluids do not communicate their heat to solid bodies; but only that heat does not pervade fluids, that is to say, is not transmitted from one particle of a fluid to another, in the same manner as in solid bodies.

EMILY.

But when you heat a vessel of water over the fire, if the particles of water do not communicate heat to each other, how does the water become hot throughout?

MRS. B.

By constant agitation. Water, as you have seen, expands by heat in the same manner as solid bodies; the heated particles of water therefore, at the bottom of the vessel, become specifically lighter than the rest of the liquid, and consequently ascend to the surface, where, parting with some of their heat to the colder atmosphere, they are condensed, and give way to a fresh succession of heated particles ascending from the bottom, which having thrown off their heat at the surface, are in their turn displaced. Thus every particle is successively heated at the bottom, and cooled at the surface of the liquid; but as the fire communicates heat more rapidly than the atmosphere cools the succession of surfaces, the whole of the liquid in time becomes heated.

CAROLINE.

This accounts most ingeniously for the propagation of heat upwards. But suppose you were to heat the upper surface of a liquid, the particles being specifically lighter than those below, could not descend: how therefore would the heat be communicated downwards?

MRS. B.

Count Rumford assures us that if there was no agitation to force the heated surface downwards, the heat would not descend. In proof of this he succeeded in making the upper surface of a vessel of water boil and evaporate, while a cake of ice remained frozen at the bottom.

CAROLINE.

That is very extraordinary indeed!

MRS. B.

It appears so, because we are not accustomed to heat liquids by their upper surface; but you will understand this theory better if I show you the internal motion that takes place in liquids when they experience a change of temperature. The motion of the liquid itself is indeed invisible from the extreme minuteness of its particles; but if you mix with it any coloured dust, or powder, of nearly the same specific gravity as the liquid, you may judge of the internal motion of the latter by that of the coloured dust it contains. —Do you see the small pieces of amber moving about in the liquid contained in this phial?

CAROLINE.

Yes, perfectly.

MRS. B.

We shall now immerse the phial in a glass of hot water, and the motion of the liquid will be shown, by that which it communicates to the amber.

EMILY.

I see two currents, the one rising along the sides of the phial, the other descending in the centre; but I do not understand the reason of this.

MRS. B.

The hot water communicates its caloric, through the medium of the phial, to the particles of the fluid nearest to the glass; these dilate and ascend laterally to the surface, where, in parting with their heat, they are condensed, and in descending, form the central current.

CAROLINE.

This is indeed a very clear and satisfactory experiment; but how much slower the currents now move than they did at first?

MRS. B.

It is because the circulation of particles has nearly produced an equilibrium of temperature between the liquid in the glass and that in the phial.

CAROLINE.

But these communicate laterally, and I thought that heat in liquids could be propagated only upwards?

MRS. B.

You do not take notice that the heat is imparted from one liquid to the other, through the medium of the phial itself, the external surface of which receives the heat from the water in the glass, whilst its internal surface transmits it to the liquid it contains. Now take the phial out of the hot water, and observe the effect of its cooling.

EMILY.

The currents are reversed; the external current now descends, and the internal one rises.—I guess the reason of this change:—the phial being in contact with cold air instead of hot water, the external particles are cooled instead of being heated; they therefore descend and force up the central particles, which, being warmer, are consequently lighter.

MRS. B.

It is just so. Count Rumford infers from hence that no alteration of temperature can take place in a fluid, without an internal motion of its particles; and as this motion is produced only by the comparative levity of the heated particles, heat cannot be propagated downwards.

This theory explains the reason of the cold that is found to prevail at the bottom of the lakes in Switzerland, which are fed by rivers issuing from the snowy Alps. The water of these rivers being colder, and therefore more dense than that of the lakes, subsides to the bottom, where it cannot be affected by the warmer temperature of the surface; the motion of the waves may communicate this temperature to some little depth, but it can descend no further than the agitation extends.

EMILY.

But when the atmosphere is colder than the lake, the colder surface of the water will descend for the very reason that the warmer will not?

MRS. B.

Certainly; and it is on this account that neither a lake, nor any body of water whatever, can be frozen until every particle of the water has risen to the surface to give off its caloric to the colder atmosphere; therefore the deeper a body of water is, the longer will be the time it requires to be frozen.

EMILY.

But if the temperature of the whole body of water is brought down to the freezing point, why is only the surface frozen?

MRS. B.

The temperature of the whole body is lowered, but not to the freezing point. The diminution of heat, as you know, produces a contraction in the bulk of fluids, as well as of solids. This effect, however, does not take place in water below the temperature of 40 degrees, which is 8 degrees above the freezing point. At that temperature, therefore, the internal motion, occasioned by the increased specific gravity of the condensed particles, ceases; for when the water at the surface no longer condenses, it will no longer descend, and leave a fresh surface exposed to the atmosphere: this surface alone, therefore, will be further exposed to its severity, and will soon be brought down to the freezing point, when it becomes ice, which being a bad conductor of heat, preserves the water beneath a long time from being affected by the external cold.

CAROLINE.

And the sea does not freeze, I suppose, because its depth is so great, that a frost never lasts long enough to bring down the temperature of such a great body of water to 40 degrees?

MRS. B.

No, that is not the case; for salt water is an exception to this law, as it condenses even many degrees below the freezing point. When the caloric of fresh water therefore is imprisoned by the ice, the ocean still continues throwing off heat into the atmosphere, which is a most signal dispensation of Providence to moderate the intensity of the cold in winter.

EMILY.

I admire this theory extremely *; but allow me to ask you one more question relative to it. You said that when water was heated over the fire, the particles at the bottom of the vessel ascended as soon

* This theory of the non-conducting power of fluids, notwithstanding all its plausibility, has been found, by a variety of subsequent experiments, to have been carried by Count Rumford rather too far; and it is now generally admitted that fluids are not entirely destitute of conductibility, though they propagate heat chiefly by motion, in the manner just explained, and possess the conducting power but in a very imperfect degree.

as heated, in consequence of their specific levity: why does not the same effect continue when the water boils, and is converted into steam? and why does the steam rise from the surface, instead of the bottom of the liquid?

MRS. B.

The steam or vapour does ascend from the bottom, though it seems to arise from the surface of the liquid. We shall boil some water in this Florence flask; (PLATE IV. Fig. 5.) you will then see, through the glass, that the vapour rises in bubbles from the bottom. We shall make it boil by means of a lamp, which is more convenient for this purpose than the chimney fire——

EMILY.

I see some small bubbles ascend, and a great many appear all over the inside of the flask; does the water begin to boil already?

MRS. B.

No; what you now see are bubbles of air, which were either enclosed in the water, or attached to the inner surface of the flask, and which, being rarefied by the heat, ascend in the water.

EMILY.

But the heat which rarefies the air enclosed in the water, must rarefy the water at the same time; there-

Fig. 6.

Pneumatic Pump.

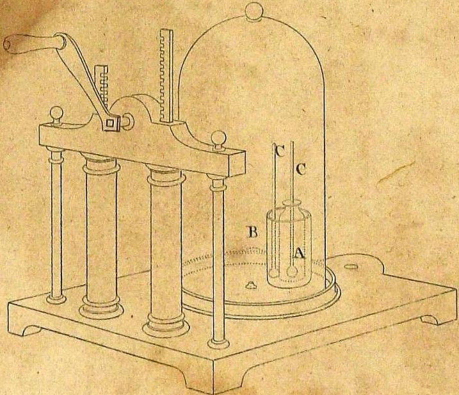


Fig. 5.

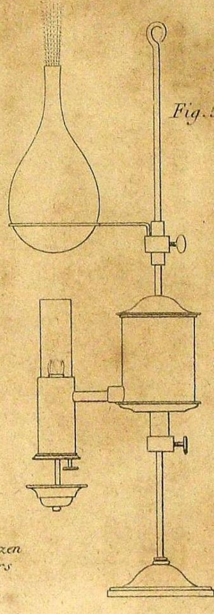


Fig. 5 Boiling water in a flask over a Patent lamp.__Fig. 6 Ether evaporated & water frozen in the air pump.__A Phial of Ether.__B Glass veſsel containing water.__C.C Thermometers one in the Ether, the other in the water.

Drawn by the Author.

Published by Longman & C.^o Dec.^r 2.^nd 1805.

Engraved by Lowry.

fore, if it could remain stationary in the water when both were cold, I do not understand why it should not when both are equally heated?

MRS. B.

Air being much less dense than water, is more easily rarefied; the former therefore expands to a great extent, whilst the latter continues to occupy nearly the same space; for water dilates comparatively but very little without changing its state and becoming vapour. Now that the water in the flask begins to boil, observe what large bubbles rise from the bottom of it.

EMILY.

I see them perfectly; but I wonder that they have sufficient power to force themselves through the water.

CAROLINE.

They *must* rise, you know, from their specific levity.

MRS. B.

You are right, Caroline; but vapour has not in all liquids (when brought to the degree of vaporisation) the power of overcoming the pressure of the less heated surface. Metals, for instance, evaporate only from the surface; therefore no vapour will ascend from them till the degree of heat which is necessary to form it has reached the surface; that is to say, till the whole of the liquid is brought to the boiling point. This is the case with all metals, mercury alone excepted.

EMILY.

I have observed that steam, immediately issuing from the spout of a tea-kettle, is less visible than at a further distance from it; yet it must be more dense when it first evaporates than when it begins to diffuse itself in the air.

MRS. B.

Your objection is a very natural one; and in order to answer it, it will be necessary for me to enter into some explanation respecting the nature of SOLUTION. Solution takes place whenever a body is melted in a fluid. In this operation the body is reduced to such a minute state of division by the fluid, as to become invisible in it, and to partake of its fluidity: but this happens without any decomposition, the body being only divided into its integrant particles by the fluid in which it is melted.

CAROLINE.

It is then a mode of destroying the attraction of aggregation.

MRS. B.

Undoubtedly.—The two principal solvent fluids are *water*, and *caloric*. You may have observed that if you melt salt in water, it totally disappears, and the water remains clear, and transparent as before; yet though the union of these two bodies appears so perfect, it is not produced by any chemical combination; both the salt and the water remain unchanged; and if you were to separate them by evaporating the latter, you would find the salt in the same state as before.

EMILY.

I suppose that water is a solvent for solid bodies, and caloric for liquids?

MRS. B.

Liquids of course can only be converted into vapour by caloric. But the solvent power of this agent is not at all confined to that class of bodies; a great variety of solid substances are dissolved by heat: thus metals, which are insoluble in water, can be dissolved by intense heat, being first fused or converted into a liquid, and then rarefied into an invisible vapour. Many other bodies, such as salts, gums, &c. yield to either of these solvents.

CAROLINE.

And that, no doubt, is the reason why hot water will melt them so much better than cold water?

MRS. B.

It is so. Caloric may indeed be considered as having, in every instance, some share in the solution of a body by water, since all water, however low its temperature may be, always contains more or less caloric.

EMILY.

Then perhaps water owes its solvent power merely to the caloric it contains?

MRS. B.

That probably would be carrying the speculation too far; I should rather think that water and caloric unite their efforts to dissolve a body, and that the difficulty or facility of effecting this, depend both on the degree of attraction of aggregation to be overcome, and on the arrangement of the particles which are more or less disposed to be divided and penetrated by the solvent.

EMILY.

But have not all liquids the same solvent power as water?

MRS. B.

The solvent power of other liquids varies according to their nature, and that of the substance submitted to their action. Most of these solvents, indeed, differ essentially from water, as they do not merely separate the integrant particles of the bodies which they dissolve, but attack their constituent principles by the power of chemical attraction, thus producing a true decomposition. These more complicated operations, which may be distinguished by the name of *chemical solutions*, we must consider in another place, and confine our attention at present to the simple solutions by water and caloric.

CAROLINE.

But there are a variety of substances which, when dissolved in water, make it thick and muddy, and destroy its transparency.

MRS. B.

In this case it is not a solution, but simply a mixture. I shall show you the difference between a solution and a mixture, by putting some common salt into one glass of water, and some powder of chalk into another; both these substances are white, but their effect on the water will be very different.

CAROLINE.

Very different indeed! The salt entirely disappears and leaves the water transparent, whilst the chalk changes it into an opake liquid like milk.

EMILY.

And would lumps of chalk and salt produce similar effects on water?

MRS. B.

Yes, but not so rapidly; salt is indeed soon melted though in a lump; but chalk, which does not mix so readily with water, would require a much greater length of time; I therefore preferred showing you the experiment with both substances reduced to powder, which does not in any respect alter their nature, but facilitates the operation merely by presenting a greater quantity of surface to the water.

I must not forget to mention a very curious circumstance respecting solutions, which is, that a fluid is not increased in bulk by holding a body in solution.

CAROLINE.

That seems impossible; for two bodies cannot exist together in the same space.

MRS. B.

That is true, my dear; but two bodies may, by condensation, occupy the same space which one of them filled before. It is supposed that there are pores or interstices, in which the salt lodges, between the minute particles of the water. And these spaces are so small, that the body to be dissolved must be divided into very minute particles in order to be contained in them; and it is this state of very great division that renders them invisible.

CAROLINE.

I can try this experiment immediately.—It is exactly so—the water in this glass, which I filled to the brim, is melting a considerable quantity of salt without overflowing. I shall try to add a little more.—But now, you see, Mrs. B., the water runs over.

MRS. B.

Yes; but observe that the last quantity of salt you put in remains solid at the bottom, and displaces the water; for it has already melted all the salt it is capable of holding in solution. This is called the point of *saturation*; and the water is now said to be *saturated* with salt.

EMILY.

This happens, I suppose, when the interstices between the particles of the liquid are completely filled?

MRS. B.

Probably. But these remarks, you must observe, do not apply to a mixture; for any substance which does not dissolve, increases the bulk of the liquid.

EMILY.

I think I now understand the solution of a solid body by water perfectly: but I have not so clear an idea of the solution of a liquid by caloric.

MRS. B.

It is precisely of the same nature; but as caloric is an invisible fluid, its action as a solvent is not so obvious as that of water. Caloric dissolves water, and converts it into vapour by the same process as water dissolves salt; that is to say, the particles of water are so minutely divided by the caloric as to become invisible. Thus, you are now enabled to understand why the vapour of boiling water, when it first issues from the spout of a kettle, is invisible; it is so, because it is then completely dissolved by caloric. But the air with which it comes in contact, being much colder than the vapour, the latter yields to it a quantity of its caloric. The particles of vapour being thus in a great measure deprived of their solvent, gradually collect and become visible in the form of steam, which is water in a state of imperfect solution; and if you were further to deprive it of its caloric, it would return to its original liquid state.

CAROLINE.

That I understand very well; but in what state is the steam, when it again becomes invisible by being diffused in the air.

MRS. B.

It is carried off and again dissolved by the air.

EMILY.

The air then has a solvent power, like water and caloric?

MRS. B.

Its solvent power proceeds chiefly, if not entirely, from the caloric contained in it, the atmosphere acting only as a vehicle. Sometimes the watery vapour diffused in the atmosphere is but imperfectly dissolved, as is the case in the formation of clouds and fogs; but if it gets into a region of air sufficiently warm, it becomes perfectly invisible.

EMILY.

Does the air ever dissolve water, without its being previously converted into vapour by boiling?

MRS. B.

Yes, it does. Water, when heated to the boiling point, can no longer exist in the form of water, and must necessarily be converted into vapour, whatever may be the state and temperature of the surrounding medium; but the air (by means probably of the caloric it contains) can take up a certain portion of water at any temperature, and hold it in a state of solution. Thus the atmosphere is continually carrying off moisture from the earth, until it is saturated with it.

The tendency of free caloric to an equilibrium, together with its solvent power, are likewise connected with the phenomena of rain, of dew, &c. When a cloud of a certain temperature happens to pass through a colder region of the atmosphere, it parts with a portion of its heat to the surrounding air; the quantity of caloric therefore, which served to keep the cloud in a state of vapour, being diminished, the watery particles approach each other, and form themselves into drops of water, which being heavier than the atmosphere, descend to the earth. There are also other circumstances, and particularly the variation in the weight of the atmosphere, which may contibute to the formation of rain. This, however, is an intricate subject, into which we cannot more fully enter at present.

EMILY.

But in what manner do you account for the formation of dew?

MRS. B.

During the heat of the day the air is able to retain a greater quantity of vapour in a state of solution, than either in the morning or evening. As soon, therefore, as a diminution of heat takes place towards sun-set, a quantity of vapour is condensed, and falls to the ground in the form of dew. The morning dew, on the contrary, rises from the earth; but when the sun has emitted a sufficient quantity of caloric to dissolve it, it becomes invisible in the atmosphere. When once the dew, or any liquid whatever, is perfectly dissolved by the air, it occasions no humidity; it is only when in a state of imperfect solution, and floating in the form of watery vapour in the atmosphere, that it produces dampness.

CAROLINE.

I have often observed, Mrs. B., that when I walk out in frosty weather, with a veil over my face, my breath freezes upon it. Pray what is the reason of that?

MRS. B.

It is because the cold air immediately seizes on the caloric of your breath, and reduces it, by robbing it of its solvent, to a denser fluid, which is the watery vapour that settles on your veil, and there it continues parting with its caloric till it is brought down to the temperature of the atmosphere, and assumes the form of ice.

You may, perhaps, have observed that the breath of animals, or rather the moisture contained in it, is visible during a frost, but not in warm weather*. In the latter case, the air is capable of retaining it in a state of solution, whilst in the former, the cold condenses it into visible vapour; and for the same reason, the steam arising from water that is warmer than the atmosphere, is visible. Have you never taken notice of the vapour rising from your hands after having dipped them into warm water?

CAROLINE.

Often, especially in frosty weather.

* Unless in very damp weather, when the atmosphere is already saturated with moisture.

MRS. B.

When a bottle of wine is taken fresh from the cellar (in summer particularly), it will soon be covered with dew; and even the glasses into which the wine is poured will be moistened with a similar vapour. Let me hear if you can account for this?

EMILY.

The bottle is colder than the surrounding air, therefore it must absorb caloric from it; and the moisture which that air held in solution must become visible, and form the dew which is deposited on the bottle.

MRS. B.

Very well, Emily. Now, Caroline, can you tell me why, in a warm room, or close carriage, the contrary effect takes place; that is to say, that the inside of the windows are covered with vapour?

CAROLINE.

I have heard that it proceeds from the breath of those within the carriage; and I suppose it is occasioned by the windows which, being colder than the breath, deprive it of part of its caloric, and by this means convert it into watery vapour.

MRS. B.

Very well, my dear: I am extremely glad to find that you both understand the subject so well.

We have already observed that pressure is an obstacle to evaporation: there are liquids that contain so great a quantity of caloric, and whose particles consequently adhere so slightly together, that they may be converted into vapour without any elevation of temperature, merely by taking off the weight of the atmosphere. In such liquids, you perceive, it is the pressure of the atmosphere alone that connects their particles and keeps them in a liquid state.

CAROLINE.

I do not well understand why the particles of such fluids should be disunited and converted into vapour, without any addition of heat, in spite of the attraction of cohesion?

MRS. B.

It is because the quantity of caloric which enters into the formation of these fluids is sufficient to overcome their attraction of cohesion. Ether is of this description; it will boil and be converted into vapour, without any application of heat, if the pressure of the atmosphere be taken off.

EMILY.

I thought that ether would evaporate without either taking away the pressure of the atmosphere, or applying heat, and that it was for that reason so necessary to keep it carefully corked up.

MRS. B.

That is true; but in this case it will evaporate but very slowly. I am going to show you how suddenly the ether in this phial will be converted into vapour, by means of the air-pump.—Observe with what rapidity the bubbles ascend, as I take off the pressure of the atmosphere.

CAROLINE.

It positively boils: how singular to see a liquid boil without heat!

MRS. B.

Now I shall place the phial of ether in this glass, which it nearly fits, so as to leave only a small space, which I fill with water; and in this state I put it again under the receiver. (PLATE IV. Fig. 6.)*—You will observe, as I exhaust the air from it, that whilst the ether boils, the water freezes.

CAROLINE.

It is indeed wonderful to see water freeze by means of a boiling fluid!

* Two pieces of thin glass tubes, sealed at one end, might answer this purpose better. The experiment, however, as here described, is difficult, and requires a very nice apparatus. But if, instead of phials or tubes, two watch-glasses be used, water may be frozen almost instantly in the same manner. The two glasses are placed over one another, with a few drops of water interposed between them, and the uppermost glass is filled with ether. After working the pump for a minute or two, the glasses are found to adhere strongly together, and a thin layer of ice is seen between them.

EMILY.

There is another circumstance which I am unable to account for. How can the ether change to a state of vapour without an addition of caloric; for it must contain more caloric in a state of vapour, than in a state of liquidity; and though you say that it is the pressure of the atmosphere which condenses it into a liquid, it must be, I suppose, by forcing out part of the caloric that belongs to it when in an aeriform state?

MRS. B.

You are right. Ether, in a liquid state, does not contain a sufficient quantity of caloric to become vapour. I have, therefore, two difficulties to explain; first, from whence the ether obtains the caloric necessary to convert it into vapour when it is relieved from the pressure of the atmosphere; and, secondly, what is the reason that the water, in which the bottle of ether stands, is frozen?

CAROLINE.

Now, I think, I can answer both these questions. The ether obtains the addition of caloric required from the water in the glass; and the loss of caloric, which the latter sustains, is the occasion of its freezing.

MRS. B.

You are perfectly right; and if you look at the thermometer which I have placed in the water, whilst I am working the pump, you will see that every time bubbles of vapour are produced, the mercury descends; which proves that the heat of the water diminishes in proportion as the ether boils.

EMILY.

This I understand now very well; but if the water freezes in consequence of yielding its caloric to the ether, the equilibrium of heat must, in this case, be totally destroyed. Yet you have told us, that bodies of a different temperature are always communicating their heat to each other, till it becomes every where equal; and besides, I do not see why the water, though originally of the same temperature as the ether, gives out caloric to it, till the water is frozen, and the ether made to boil.

MRS. B.

I suspected that you would make these objections; and, in order to remove them, I enclosed two thermometers in the air-pump; one which stands in the glass of water, the other in the phial of ether: and you may see that the equilibrium of temperature is not destroyed; for as the thermometer descends in the water, that in the ether sinks in the same manner; so that both thermometers indicate the same temperature, though one of them is in a boiling, the other in a freezing liquid.

EMILY.

The ether then becomes colder as it boils? This is so contrary to common experience, that I confess it astonishes me exceedingly.

CAROLINE.

It is, indeed, a most extraordinary circumstance. But pray how do you account for it?

MRS. B.

I cannot satisfy your curiosity at present; for before we can attempt to explain this apparent paradox, we must become acquainted with the subject of LATENT HEAT; and that, I think, we must defer till our next interview.

CAROLINE.

I believe, Mrs. B., that you are glad to put off the explanation; for it must be a very difficult point to account for.

MRS. B.

I hope, however, that I shall do it to your complete satisfaction.

EMILY.

But before we part, give me leave to ask you one question. Would not water, as well as ether, boil with less heat, if the pressure of the atmosphere were taken off?

MRS. B.

Undoubtedly. You must always recollect that there are two forces to overcome, in order to make a liquid boil, or evaporate; the attraction of aggregation, and the weight of the atmosphere. On the summit of a high mountain (as Mr. De Saussure ascertained on Mount Blanc) less heat is required to make water boil than in the plain, where the weight of the atmosphere is greater.—But I can show you a very pretty experiment, which proves the effect of the pressure of the atmosphere in this respect.

Observe, that this Florence flask is about half full of water, and the upper half of invisible vapour, the water being in the act of boiling.—I take it from the lamp and cork it carefully—the water, you see, immediately ceases boiling.—I shall now wrap a cold wet cloth round the upper part of the flask*——

CAROLINE.

But look, Mrs. B., the water begins to boil again, although the wet cloth must rob it more and more of its caloric! What can be the reason of that?

MRS. B.

Let us examine its temperature. You see the thermometer immersed in it remains stationary at

* Or the whole flask may be dipped into a bason of cold water. In order to show how much the water cools whilst it is boiling, a thermometer, graduated on the tube itself, may be introduced into the bottle through the cork.

180 degrees, which is about 30 degrees below the boiling point. When I took the flask from the lamp, I observed to you that the upper part of it was filled with vapour; this being compelled to yield its caloric to the wet cloth, was again converted into water—What then filled the upper part of the flask?

EMILY.

Nothing; for it was too well corked for the air to gain admittance, and therefore the upper part of the flask must be a vacuum.

MRS. B.

If the upper part of the flask be a vacuum, the water below no longer sustains the pressure of the atmosphere, and will therefore boil at a much lower temperature. Thus, you see, though it had lost many degrees of heat, it began boiling again the instant the vacuum was formed above it. The boiling has now ceased: if it had been ether, instead of water, it would have continued boiling much longer; but water being a more dense fluid, requires a more considerable quantity of caloric to make it evaporate, even when the pressure of the atmosphere is removed.

EMILY.

But if the pressure of the atmosphere keeps the particles of ether together, why does it evaporate when exposed to the air? Nay, does not even water, the particles of which adhere so strongly together, slowly evaporate in the atmosphere?

MRS. B.

I have already told you that air has the power of keeping a certain quantity of vapour in solution at any known temperature; and being constantly in a state of motion, and incessantly renewing itself on the surface of the liquid, it skims off, and gradually dissolves, new quantities of vapour. Water also has the power of absorbing a certain quantity of air, so that their action on each other is reciprocal; the air thus enclosed in water is that which you see evaporate in bubbles when water is heated previous to its boiling.

EMILY.

What proportion of vapour can air contain in a state of solution?

MRS. B.

I do not know whether it has been exactly ascertained by experiment; but at any rate this proportion must vary, both according to the temperature and the weight of the atmosphere; for the lower the temperature, and the greater the pressure, the smaller must be the proportion of vapour that air can contain in a state of solution. But we have dwelt so long on the subject of free caloric, that we must reserve the other modifications of that fluid to our next meeting, when we shall endeavour to proceed more rapidly.

CONVERSATION IV.

ON SPECIFIC HEAT, LATENT HEAT, AND CHEMICAL HEAT.

MRS. B.

We are now to examine the three other modifications of caloric.

CAROLINE.

I am very curious to know of what nature they can be; for I have no notion of any kind of heat that is not perceptible to the senses.

MRS. B.

In order to enable you to understand them, it will be necessary to enter into some previous explanations.

It has been discovered by modern chemists, that bodies of a different nature, heated to the same temperature, do not contain the same quantity of caloric.

CAROLINE.

How could that be ascertained?

MRS. B.

It was found that, in order to raise the temperature of different bodies the same number of degrees, different quantities of caloric were required for each of them. If, for instance, you place a pound of lead, a pound of chalk, and a pound of milk, in a hot oven, they will be gradually heated to the temperature of the oven; but the lead will attain it first, the chalk next, and the milk last.

EMILY.

As they were all of the same weight, and exposed to the same heat, I should have thought that they would have attained the temperature of the oven at the same time.

CAROLINE.

And how is it that they do not?

MRS. B.

It is supposed to be on account of the different capacity of these bodies for caloric.

CAROLINE.

What do you mean by the *capacity* of a body for caloric?

MRS. B.

I mean a certain disposition of bodies to admit more or less caloric between their minute particles.

Let us put as many marbles into this glass as it will contain, and pour some sand over them—observe how the sand penetrates and lodges between them. We shall now fill another glass with pebbles of various forms—you see that they arrange themselves in a more compact manner than the marbles, which, being globular, can touch each other by a single point only. The pebbles, therefore, will not admit so much sand between them; and consequently one of these glasses will necessarily contain more sand than the other, though both of them be equally full.

CAROLINE.

This I understand perfectly. The marbles and the pebbles represent two bodies of different kinds, and the sand the caloric contained in them; and it appears very plain, from this comparison, that one body may admit of more caloric between its particles than another.

MRS. B.

If you understand this, you can no longer be surprised that bodies of a different capacity for caloric should require different proportions of that fluid to raise their temperatures equally.

EMILY.

But I do not understand why the body that contains the most caloric should not be of the highest temperature; that is to say, feel hot in proportion to the quantity of caloric it contains?

MRS. B.

The caloric that is employed in filling the capacity of a body, is not free caloric; but it is imprisoned as it were in the body, and is therefore imperceptible: for we can feel only the free radiating caloric which the body parts with, and not that which it retains.

CAROLINE.

It appears to me very extraordinary that heat should be confined in a body in such a manner as to be imperceptible.

MRS. B.

If you lay your hand on a hot body, you feel only the caloric which leaves it, and enters your hand; for it is impossible that you should be sensible of that which remains in the body. The thermometer, in the same manner, is affected only by the free caloric which a body transmits to it, and not at all by that which it does not part with. You see, therefore, that the temperature of bodies can be raised only by free radiating caloric.

CAROLINE.

I begin to understand it; but I confess that the idea of insensible heat is so new and strange to me, that it requires some time to render it familiar.

MRS. B.

Call it insensible caloric, and the difficulty will appear much less formidable. It is indeed a sort of contradiction to call it heat, when it is so situated as to be incapable of producing that sensation.

EMILY.

Yet is it not this modification of caloric which is called SPECIFIC HEAT?

MRS. B.

It is so; but it certainly would have been more correct to have called it *specific caloric*.

EMILY.

I do not understand how the term *specific* applies to this modification of caloric?

MRS. B.

It expresses the relative quantity of caloric which different bodies of the same weight and temperature are capable of containing. This modification is also frequently called *heat of capacity*, a term perhaps preferable, as it explains better its own meaning.

You now understand, I suppose, why the milk and chalk required a longer time than the lead to raise their temperature to that of the oven?

EMILY.

Yes: the milk and chalk having a greater capacity for caloric than the lead, a greater proportion of that fluid became insensible in those bodies; and the more slowly therefore, their temperature was raised.

MRS. B.

You are quite right. And could we measure the heat communicated by the oven to these three bodies, we should find, that though they have all ultimately reached the same temperature, yet they have absorbed different quantities of heat according to their respective capacities for caloric; that is to say, the milk most, the chalk next, and the lead least.

EMILY.

But supposing that these three bodies were made much hotter, would heat continue to become insensible in them, or is there any point beyond which the capacity of bodies for caloric is so completely filled, that their heat of temperature can alone be increased?

MRS. B.

No: there is no such point; for the capacity of bodies for caloric always increases or diminishes in proportion to their temperature; so that whenever a body is exposed to an elevation of temperature, part of the caloric it receives is detained in an insensible state, in order to fill up its increased capacity.

EMILY.

The more dense a body is, I suppose, the less is its capacity for caloric?

MRS. B.

That is the case with every individual body; its capacity is least when solid, greater when melted, and most considerable when converted into vapour. But this does not always hold good with respect to bodies of different nature; iron, for instance, contains more specific heat than ashes, though it is certainly much more dense. This seems to show that specific heat does not merely depend upon the interstices between the particles; but, probably, also upon some peculiar power of attraction for caloric. The word capacity, therefore, which is generally used, is not perhaps strictly correct; but until we are better acquainted with the nature and cause of specific heat, we cannot adopt a more appropriate term.

EMILY.

But, Mrs. B—, it would appear to me more proper to compare bodies by *measure*, rather than by *weight*, in order to estimate their specific heat. Why, for instance, should we not compare *pints* of milk, of chalk, and of lead, rather than *pounds* of those substances; for equal weights may be composed of very different quantities?

MRS. B.

You are mistaken, my dear; equal weights must contain equal quantities of matter; and when we wish to know what is the relative quantity of caloric, which substances of various kinds are capable of containing, under the same temperature, we must compare equal weights, and not equal bulks of those substances. Bodies of the same weight may undoubtedly be of very different dimensions; but that does not change the real quantity of matter. A pound of feathers does not contain one atom more than a pound of lead.

CAROLINE.

I have another difficulty to propose. It appears to me, that if the temperature of the three bodies in the oven did not rise equally, they would never reach the same degree; the lead would always keep its advantage over the chalk, and milk, and would perhaps be boiling before the others had attained the temperature of the oven. I think you might as well say that, in the course of time, you and I should be of the same age?

MRS. B.

Your comparison is not correct, my dear. As soon as the lead reached the temperature of the oven, it would remain stationary; for it would then give out as much heat as it would receive. You should recollect that the exchange of radiating heat, between two bodies of equal temperature, is equal; it would be impossible, therefore, for the lead to accumulate heat after having attained the temperature of the oven; and that of the chalk and milk therefore would ultimately arrive at the same standard. Now I fear that this will not hold good with respect to our ages, and that, as long as I live, I shall never cease to keep my advantage over you.

EMILY.

I think that I have found a comparison for specific heat, which is very applicable. Suppose that two men of equal weight and bulk, but who required different quantities of food to satisfy their appetites, sit down to dinner, both equally hungry; the one would consume a much greater quantity of provisions than the other, in order to be equally satisfied.

MRS. B.

Yes, that is very fair; for the quantity of food necessary to satisfy their respective appetites, varies in the same manner as the quantity of caloric requisite to raise equally the temperature of different bodies.

EMILY.

The thermometer, then, affords no indication of the specific heat of bodies?

MRS. B.

None at all; no more than satiety is a test of the quantity of food eaten. The thermometer, as I have repeatedly said, can be affected only by free or radiating caloric, which alone raises the temperature of bodies.

EMILY.

And is there no method of measuring the comparative quantities of caloric absorbed in the oven by the lead, the chalk, and the milk?

MRS. B.

It may be done by cooling them to the same degree in an apparatus adapted to receive and measure the caloric which they give out. Thus, if you plunge them into three equal quantities of water, each at the same temperature, you will be able to judge of the relative quantity of caloric which the three bodies contained, by that, which, in cooling, they communicated to their respective portions of water; for the same quantity of caloric which they each absorbed to raise their temperature, will abandon them in lowering it; and on examining the three vessels of water, you will find the one in which you immersed the lead to be the least heated; that which contained the chalk will be the next; and that which contained the milk will be heated the most of all. The celebrated Lavoisier has invented a machine to estimate, upon this principle, the specific heat of bodies in a more perfect manner; but I cannot explain it to you, till you are acquainted with the next modification of caloric, which is called LATENT HEAT.

CAROLINE.

And pray what kind of heat is that?

MRS. B.

It is so analogous to specific heat, that most chemists make no distinction between them; but Mr. Pictet, in his Essay on Fire, has so judiciously discriminated them, that I think his view of the subject may contribute to render it clearer. We therefore call *latent heat* (a name that was first used by Dr. Black) that portion of insensible caloric which is employed in changing the state of bodies; that is to say, in converting solids into liquids, or liquids into vapour. The heat which performs these changes becomes fixed in the body which it has transformed, and, as it is perfectly concealed from our senses, it has obtained the name of *latent* heat.

CAROLINE.

I think it would be much more correct to call this modification latent caloric, instead of latent heat, since it does not excite the sensation of heat.

MRS. B.

That remark is equally applicable to both the modifications of specific and latent heat; but we must not presume (unless amongst ourselves in order to explain the subject) to alter terms which are still used by much better chemists than ourselves. And, besides, you must not suppose that the nature of heat is altered by being variously modified: for if latent heat, and specific heat, do not excite the same sensations as free caloric, it is owing to their being in a state of confinement, which prevents them from acting upon our organs; and, consequently, as soon as they are extricated from the body in which they are imprisoned, they return to their state of free caloric.

EMILY.

But I do not yet clearly see in what respect latent heat differs from specific heat; for they are both of them imprisoned and concealed in bodies?

MRS. B.

Specific heat is that which is employed in filling the capacity of a body for caloric, in the state in which this body actually exists; while latent heat is that which is employed only in effecting a change of state, that is, in converting bodies from a solid to a liquid, or from a liquid to an aeriform state. But I think that, in a general point of view, both these modifications might be comprehended under the name of *heat of capacity*, as in both cases the caloric is equally engaged in filling the capacities of bodies.

I shall now show you an experiment which I hope will give you a clear idea of what is understood by latent heat.

The snow, which you see in this phial, has been cooled by certain chemical means (which I cannot well explain to you at present), to 5 degrees below the freezing point, as you will find indicated by the thermometer, which is placed in it. We shall expose it to the heat of a lamp, and you will see the thermometer gradually rise, till it reaches the freezing point——

EMILY.

But there the thermometer stops, Mrs. B—, and yet the lamp burns just as well as before. Why is not its heat communicated to the thermometer?

CAROLINE.

And the snow begins to melt, therefore it must be rising above the freezing point?

MRS. B.

The heat no longer affects the thermometer, because it is wholly employed in converting the ice into water. As the ice melts, the caloric becomes *latent* in the new-formed liquid, and therefore cannot raise its temperature; and the thermometer will consequently remain stationary, till the whole of the ice is melted.

CAROLINE.

Now it is all melted, and the thermometer begins to rise again.

MRS. B.

Because the conversion of the ice into water being completed, the caloric is no longer converted into latent heat; and therefore the heat which the water now receives raises its temperature, as you find the thermometer indicates.

EMILY.

But I do not think that the thermometer rises so quickly in the water, as it did in the ice, previous to its beginning to melt, though the lamp burns equally well?

MRS. B.

That is owing to the different specific heat of ice and water. The capacity of water for caloric being greater than that of ice, more heat is required to raise its temperature, and therefore the thermometer rises slower in the water than in the ice.

EMILY.

True; you said the other day, that a solid body always increased its capacity for heat by becoming fluid; and this is an instance of it.

MRS. B.

But be careful not to confound this with latent heat.

EMILY.

On the contrary, I think that this example distinguishes them extremely well; for though they both go into an insensible state, yet they differ in this respect, that the specific heat fills the capacity of the body in the state in which it exists, while latent heat changes that state, and is afterwards employed in maintaining the body in its new form.

CAROLINE.

Now, Mrs. B—, the water begins to boil, and the thermometer is again stationary.

MRS. B.

Well, Caroline, it is your turn to explain the phenomenon.

CAROLINE.

It is wonderfully curious! The caloric is now busy in changing the water into steam, in which it hides itself, and becomes insensible.

MRS. B.

You see, my dear, how easily you have become acquainted with these modifications of insensible heat, which at first appeared so unintelligible. If, now, we were to reverse these changes, and condense the vapour into water, and the water into ice, the latent heat would reappear entirely, in the form of free caloric.

EMILY.

Pray do let us see the effect of latent heat returning to its natural state.

MRS. B.

For the purpose of showing this, we need simply conduct the vapour through this tube, into this vessel of cold water, where it will part with its latent heat and return to its liquid state——

EMILY.

How rapidly the steam heats the water!

MRS. B.

That is because it does not merely impart its free caloric to the water, but likewise its latent heat. There is a large dye-house at Leeds, in which a great number of coppers are kept boiling by means of a single one which is heated by fire; the steam of this last, instead of being allowed to escape and be wasted, is conveyed through pipes into each of the other coppers, which are thus heated without any additional fuel.

CAROLINE.

That is an admirable contrivance, and I wonder that it is not in common use.

MRS. B.

The steam kitchens, which are getting into such general use, are upon the same principle. The steam is conveyed through a pipe in a similar manner, into the several vessels which contain the provisions to be dressed, where it communicates to them its latent caloric, and returns to the state of water. Count Rumford makes great use of this principle in many of his fire-places: his grand maxim is to avoid all unnecessary waste of caloric, for which purpose he confines the heat in such a manner, that not a particle of it shall unnecessarily escape; and while he economises the free caloric, he takes care also to turn the latent heat to advantage. It is thus that he is enabled to produce a degree of heat superior to that which is obtained in common fire-places, though he employs but half the quantity of fuel.

EMILY.

When the advantages of such contrivances are so clear and plain, I cannot understand why they are not universally used.

MRS. B.

A long time is always required before innovations, however useful, can be reconciled with the prejudices of the vulgar.

EMILY.

What a pity it is that there should be a prejudice against new inventions; how much more rapidly the world would improve, if such useful discoveries were immediately, and universally adopted!

MRS. B.

I believe, my dear, that there are as many novelties attempted to be introduced, the adoption of which would be prejudicial to society, as there are of those which would be beneficial to it. The well-informed, though by no means exempt from error, have an unquestionable advantage over the illiterate, in judging what is likely or not to prove serviceable; and therefore we find the former more ready to adopt such discoveries as promise to be really advantageous, than the latter, who, having no other test of the value of a novelty but time and experience, at first oppose its introduction. The well-informed are, however, frequently disappointed in their most sanguine expectations, and the prejudices of the vulgar, though they often retard the progress of knowledge, yet sometimes, it must be admitted, prevent the propagation of error.—But we are deviating from our subject.

We have converted steam into water, and are now to change water into ice, in orde. to render the latent heat sensible, as it escapes from the water on its becoming solid. For this purpose we must produce a degree of cold that will make water freeze.

CAROLINE.

That must be very difficult in this warm room.

MRS. B.

Not so much so as you think. There are certain chemical mixtures which produce a rapid change from the solid to the fluid state, or the reverse, in the substances combined, in consequence of which latent heat is either extricated or absorbed.

EMILY.

I do not quite understand you.

MRS. B.

This snow and salt, which you see me mix together, are melting rapidly; heat therefore must be absorbed by the mixture, and cold produced.

CAROLINE.

It feels even colder than ice, and yet the snow is melted. This is very extraordinary.

MRS. B.

The cause of the intense cold of the mixture is to be attributed to the change from a solid to a fluid state. The union of the snow and salt produces a new arrangement of their particles, in consequence of which they become liquid, and the quantity of caloric required to effect this change is seized upon by the mixture wherever it can be obtained. This eagerness of the mixture for caloric, during its liquefaction, is such, that it converts part of its own free caloric into latent heat, and it is thus that its temperature is lowered.

EMILY.

Whatever you put into this mixture therefore, would freeze?

MRS. B.

Yes; at least any fluid that is susceptible of freezing at that temperature; for the exchange of radiant heat would always be in favour of the cold mixture, until an equilibrium of temperature was established; therefore, unless the body immersed contained more free caloric than would become latent in the mixture during its conversion into a liquid, the former must ultimately give out its latent heat till it cools down to the temperature of the latter. I have prepared this mixture of salt and snow for the purpose of freezing the water from which you are desirous of seeing the latent heat escape. I have put a thermometer in the glass of water that is to be frozen, in order that you may observe how it cools——

CAROLINE.

The thermometer descends, but the heat which the water is now losing, is its *free*, not its *latent* heat?

MRS. B.

Certainly; it does not part with its latent heat till it changes its state and is converted into ice.

EMILY.

But here is a very extraordinary circumstance! The thermometer is fallen below the freezing point, and yet the water is not frozen.

MRS. B.

That is always the case previous to the freezing of water when it is in a state of rest. Now it begins to congeal, and you may observe that the thermometer again rises to the freezing point.

CAROLINE.

It appears to me very strange that the thermometer should rise the very moment that the water freezes; for it seems to imply that the water was colder before it froze than when in the act of freezing.

MRS. B.

It is so; and after our long dissertation on this circumstance, I did not think that it would appear so strange to you. Reflect a little, and I think you will discover the reason of it.

CAROLINE.

It must be, no doubt, the extrication of latent heat, at the instant the water freezes, that raises the temperature.

MRS. B.

Certainly; and if you now examine the thermometer, you will find that its rise was but temporary, and lasted only during the disengagement of the latent heat; it has now fallen, and will continue to fall till the ice and mixture are of an equal temperature.

EMILY.

And can you show us any experiments in which liquids, by being mixed, become solid, and disengage latent heat?

MRS. B.

I could show you several; but you are not yet sufficiently advanced to understand them well. I shall, however, try one which will afford you a striking instance of the fact. The fluid which you see in this phial consists of a quantity of a certain salt called *muriat of lime*, dissolved in water. Now, if I pour into it a few drops of this other fluid, called *sulphuric acid*, the whole, or very nearly the whole, will be instantaneously converted into a solid mass.

EMILY.

How white it turns! I feel the latent heat escaping, for the bottle is warm, and the fluid is changed to a solid white substance like chalk!

CAROLINE.

This is indeed the most curious experiment we have seen yet. But pray what is that white vapour that ascends from the mixture?

MRS. B.

You are not yet enough of a chemist to understand that. But take care, Caroline, do not approach too near it, for it smells extremely strong.

The mixture of spirit of wine and water affords another striking example of the extrication of latent heat. The particles of these liquids, by penetrating each other, change their arrangement, so as to become more dense, and (if I may use the expression), less fluid, in consequence of which they part with a quantity of latent heat.

Sulphuric acid and water produce the same effect, and even in a much greater degree. We shall try both these experiments, and you will feel how much heat, which was in a latent state, is set at liberty— Now each of you take hold of one of these glasses——

CAROLINE.

I cannot hold mine; I am sure it is as hot as boiling water.

MRS. B.

Your glass, which contains the sulphuric acid and water, is, indeed, of as high a temperature as boiling water; but you do not find yours so hot, Emily?

EMILY.

Not quite. But why are not these liquids converted into solids by the extrication of their latent heat?

MRS. B.

Because they part only with a portion of that heat, and therefore they suffer only a diminution of their liquidity.

EMILY.

Yet they appear as perfectly liquid as they did before they were mixed.

MRS. B.

They are however considerably condensed. I shall repeat the experiment in a graduated tube, and you will see that the two liquids, when mixed, occupy less space than they did separately. This tube is graduated by cubic inches, and this little measure contains exactly one cubic inch; therefore, if I fill it twice, and pour its contents into the tube, they should fill it up to the second mark.

CAROLINE.

And so they do, exactly.

MRS. B.

Because I put two measures of the same liquid into the tube; but we shall now try it with one of water and one of sulphuric acid; observe the difference——

EMILY.

The two measures, this time, evidently take up less space, though the fluid does not appear to have suffered any change in its liquidity.

MRS. B.

The two liquids, however, have undergone some degree of condensation from the new arrangement of their particles; they have penetrated each other, so as to form a closer substance, and have thus, as it were, squeezed out a portion of their latent heat. But this change of state is certainly much less striking, and less complete, than when liquids are converted into solids.

The slakeing of lime is another curious instance of the extrication of latent heat. Have you never observed how quick-lime smokes when water is poured upon it, and how much heat it produces?

CAROLINE.

Yes; but I do not understand what change of state takes place in the lime that occasions its giving out latent heat; for the quick-lime, which is solid, is (if I recollect right) reduced to powder by this operation, and is therefore rather expanded than condensed.

MRS. B.

It is from the water, not the lime, that the latent heat is set free. The water incorporates with, and becomes solid in the lime; in consequence of which the heat, which kept it in a liquid state, is disengaged and escapes in a sensible form.

CAROLINE.

I always thought that the heat originated in the lime. It seems very strange that water, and cold water too, should contain so much heat.

EMILY.

After this extrication of caloric, the water must exist in a state of ice in the lime, since it parts with the heat which kept it liquid?

MRS. B.

It cannot properly be called ice, since ice implies a degree of cold, at least equal to the freezing point. Yet as water, in combining with lime, gives out more heat than in freezing, it must be in a state of still greater solidity in the lime, than it is in the form of ice; and you may have observed that it does not moisten or liquefy the lime in the smallest degree.

EMILY.

But, Mrs. B., the smoke that rises is white; if it was only pure caloric which escaped, we might feel, but could not see it.

MRS. B.

This white vapour is formed by some of the particles of lime, in a state of fine dust, which are carried off by the caloric.

EMILY.

In all changes of state, then, a body either absorbs or disengages latent heat?

MRS. B.

You cannot exactly say *absorbs* latent heat, as the heat becomes latent only on being confined in the body; but you may say that all bodies, in passing from a solid to a liquid form, or from the liquid state to that of vapour, absorb heat; and that when the reverse take place heat is disengaged. We have seen likewise that a body may part with some of its latent heat without completely changing its form, as was the case with the mixtures of sulphuric acid and water, and spirit of wine and water; but here you must observe that the condensation which forces out a portion of their latent heat, is occasioned by a new arrangement of the particles, produced by mixing the liquids, they therefore really undergo a change of state, though no very sensible difference takes place in their form.

CAROLINE.

All solid bodies, I suppose, must have parted with the whole of their latent heat?

MRS. B.

We cannot precisely say that; for solid bodies are in general susceptible of being brought to different degrees of density, during which operation a quantity of heat is disengaged; as it happens in the hammering of metals, the boring of cannon, and in general whenever bodies are exposed to considerable friction or violent pressure.

It has been much disputed, however, to what modification of heat caloric thus extricated belongs, though in general it is considered as latent heat; but it does not seem strictly entitled to that name, as its extrication produces no other change in the body than an increase of density.

EMILY.

And may not the same objection be made to the heat extricated from the mixtures we have just witnessed? for the only alteration that is produced by it is a greater density.

MRS. B.

But I observed to you that the density was produced by a new arrangemnt of the particles, owing to the mixing of two different substances; this cannot be the case, when heat is extricated from solid bodies by mere mechanical force, such as hammering metals; no foreign particles are introduced, and, except a closer union, no change of arrangement can take place. The caloric, thus extricated, seems therefore to have a still more dubious title to the modification of latent heat, than that produced by mixtures. I know no other way of settling this difficulty than by calling them both heat of capacity, a title to which we have agreed that both specific heat, and latent heat, have an equal claim.

EMILY.

We can now, I think, account for the ether boiling, and the water freezing in vacuo, at the same temperature.

MRS. B.

Let me hear how you explain it?

EMILY.

The latent heat, which the water gave out in freezing, was immediately absorbed by the ether, during its conversion into vapour; and therefore, from a latent state in one liquid, it passed into a latent state in the other.

MRS. B.

But this only partly accounts for the experiment;

it remains to be explained why the temperature of the ether, whilst evaporating, is brought down to the freezing temperature of the water.—It is because the ether, during its evaporation, reduces its own temperature, in the same proportion as that of the water, by converting its free caloric into latent heat; so that, though one liquid evaporates, and the other freezes, their temperatures remain in a state of equilibrium.

Having advanced so far on the subject of heat, I may now give you an account of the calorimeter, an instrument invented by Lavoisier, upon the principles just explained, for the purpose of estimating the specific heat of bodies. It consists of a hollow globe of ice, in the midst of which the body, whose specific heat is to be ascertained, is placed. The ice absorbs caloric from this body, till it has brought it down to the freezing point: this caloric converts into water a certain portion of the ice which runs out through an aperture at the bottom of the machine; and the quantity of ice changed to water, is a test of the quantity of caloric which the body has given out in descending from a certain temperature to the freezing point.

CAROLINE.

In this apparatus, I suppose, the milk, chalk, and lead, would melt different quantities of ice, in proportion to their different capacities for caloric?

MRS. B.

Certainly; and thence we are able to ascertain, with precision, their respective capacities for heat. But the calorimeter affords us no more idea of the absolute quantity of heat contained in a body, than the thermometer; for though by means of it we extricate both the free and confined caloric, yet we extricate them only to a certain degree, which is the freezing point; and we know not how much they contain of either below that point.

EMILY.

According to this theory of latent heat, it appears to me that the weather should be warm when it freezes, and cold in a thaw: for latent heat is liberated from every substance that freezes, and such a large supply of heat must warm the atmosphere; whilst, during a thaw, that very quantity of free heat must be taken from the atmosphere, and return to a latent state in the bodies which it thaws.

MRS. B.

Your observation is very natural; but consider that in a frost the atmosphere is so much colder than the earth, that all the caloric which it takes from the freezing bodies is insufficient to raise its temperature above the freezing point; otherwise the frost must cease. But if the quantity of latent heat extricated does not destroy the frost, it serves to moderate the suddenness of the change of temperature of the atmosphere, at the commencement both of a frost, and of a thaw. In the first instance, its extrication diminishes the severity of the cold; and, in the latter, its absorption moderates the warmth occasioned by a thaw: it even sometimes produces a discernible chill, at the breaking up of a frost.

CAROLINE.

But what are the general causes that produce those sudden changes in the weather, especially from hot to cold, which we often experience?

MRS. B.

This question would lead us into meteorological discussions, to which I am by no means competent. One circumstance, however, we can easily understand. When the air has passed over cold countries, it will probably arrive here, at a temperature much below our own, and then it must absorb heat from every object it meets with, which must produce a general fall of temperature.

But I think we have now sufficiently dwelt on the subject of latent heat; we may therefore proceed to the last modification, which is CHEMICAL HEAT. In this state we consider caloric as one of the constituent parts of bodies. Like any other substance, it is subject to the attraction of composition, and is thus capable of being chemically combined.

EMILY.

In this case, then, it neither affects the thermometer, nor the calorimeter, since principles united by the attraction of composition can be separated only by the decomposition of the body.

MRS. B.

You are perfectly right. We may consider *free caloric* as moving constantly through the integrant particles of a body; *specific* and *latent heat*, as lodging between them, and being there detained by a mere mechanical union; but it is *chemical heat* alone that actually *combines*, in consequence of a true chemical affinity, with the constituent particles of bodies; and this union, therefore, cannot be dissolved without a decomposition produced by superior attractions.

CAROLINE.

But if this kind of heat is so perfectly concealed in the body, pray how is it known to exist?

MRS. B.

By being freed from its imprisonment; for when the body in which it exists is decomposed, it then returns to the state of free caloric. This caloric, however, seldom shows itself entirely, as part of it generally enters into new combinations with some of the constituent parts of the decomposed body, and is thus again concealed under the form of latent heat.

But it will be better to defer saying any thing further of this modification of heat at present. When we come to analyse compound bodies, and resolve them into their constituent parts, we shall have many opportunities of becoming better acquainted with it.

CAROLINE.

Caloric appears to me a most wonderful element: but I cannot reconcile myself to the idea of its being a substance; for it seems to be constantly acting in opposition, both to the attraction of aggregation and the laws of gravity; and yet you decidedly class it amongst the simple bodies.

MRS. B.

You are not at all singular in the doubts you entertain, my dear, on this point; for although caloric is now generally believed to be a real substance, yet there are certainly some strong circumstances which seem to militate against this doctrine.

CAROLINE.

But do *you*, Mrs. B., believe it to be a substance?

MRS. B.

Yes, I do; but I am inclined to think, that its levity is, in all probability, only relative, like that of vapour, which ascends through the heavier medium, air.

CAROLINE.

If that be the case, it would not ascend in a vacuum.

MRS. B.

In an absolute vacuum, perhaps, it would not. But as the most complete vacuum we can obtain is never perfect, we may always imagine the existence of some unknown invisible fluid, which, however light and subtle, may be heavier than caloric, and will gravitate in it. The fact has not, I believe, been yet determined by very decisive experiments; but it appears from some made by Professor Pictet, mentioned in his 'Essay on Fire,' that heat has a tendency to ascend in the most complete vacuum which we are able to obtain.

EMILY.

But if there exists such a subtle fluid as you imagine, do you not think that chemists would have discovered it by some of its properties?

MRS. B.

It has been conjectured that light might be such a fluid; but I confess that I do not think it probable: for, as it appears by Dr. Herschell's experiment that heat is less refrangible than light, I should be rather inclined to think it the heavier of the two. But, while you have so many well ascertained facts to learn, I shall not perplex you with conjectures. We have dwelt on the subject of caloric much longer than I intended, and I fear you will find it difficult to remember so long a lesson. At our next meeting we shall examine the nature of oxygen and nitrogen, two substances with which you must now be made acquainted.

CONVERSATION V.

ON OXYGEN AND NITROGEN.

MRS. B.

To-day we shall examine the chemical properties of the ATMOSPHERE.

CAROLINE.

I thought you said that we were to learn the nature of OXYGEN and NITROGEN, which come next in our table of simple bodies ?

MRS. B.

And so you shall: the atmosphere is composed of these two principles; we shall therefore analyse it, and consider its component parts separately.

EMILY.

I always thought that the atmosphere had been a very complicated fluid, composed of all the variety of exhalations from the earth.

MRS. B.

In a general point of view, it may be said to consist of all the substances capable of existing, in an aeriform state, at the common temperature of our globe. But, laying aside these heterogeneous and accidental substances (which rather float in the atmosphere than form any of its component parts), it consists of an elastic fluid called ATMOSPHERICAL AIR, which is composed of two gasses, known by the names of OXYGEN GAS and NITROGEN GAS.

EMILY.

Pray what is a gas?

MRS. B.

The name of *gas* is given to any aeriform fluid, which consists of some substance chemically combined with caloric, and capable of existing constantly in an aeriform state, under the pressure, and at the temperature of the atmosphere. Every individual gas is therefore composed of two parts: 1st, the particular substance that is converted into a gas, by caloric; this is called the *basis* of the gas, as it is from it that the gas derives all its specific and characteristic properties: and, 2dly, the caloric, which, by its chemical combination with the basis, constitutes it a gas, or permanently elastic fluid.

EMILY.

When you speak then of the simple substances, oxygen and nitrogen, you mean to express, those substances which are the bases of the two gasses, independently of caloric?

MRS. B.

Yes, in strict propriety; and they should be called gasses, only when brought, by their combination with caloric, to an aeriform state.

CAROLINE.

Is not water, or any other substance, when evaporated by heat, called also a gas?

MRS. B.

No, my dear; vapour is, indeed, an elastic fluid, and bears so strong a resemblance to a gas, that there is some danger of confounding them; there are, however, several points in which they essentially differ, and by which you may always distinguish them.

Vapour is nothing more than the solution, or mechanical division, of any substance whatever in caloric. The caloric, in this case, becomes *latent* in the vapour; but its union with it is very slight, and, as we have seen in a variety of instances, it is necessary only to lower the temperature in order to separate them. But, to form a gas or *permanently* elastic fluid, a chemical combination must take place between the caloric and the substance, at the time of its being converted into a gaseous state; it is necessary, therefore, that there should be an affinity between them, and hence their combination cannot be destroyed by a mere change of temperature, or by any chemical agents, except such as have a stronger affinity, for either of the constituents of the gas, and by that means effect its decomposition.

CAROLINE.

Indeed, I ought not to have forgotten that caloric, in vapour, is only *latent*, and not chemically combined. But pray, Mrs. B., what kinds of substances are oxygen and nitrogen, when not in a gaseous state?

MRS. B.

We have never been able to obtain these substances in their pure simple state, because we cannot separate them entirely either from caloric or from the other bodies with which we find them united; it is therefore only by their effects in combining with other substances that we are acquainted with them.

CAROLINE.

How much more satisfactory it would be if we could see them!

EMILY.

In what proportions are they combined in the atmosphere?

MRS. B.

The oxygen gas constitutes about one fourth, and the nitrogen gas three fourths. When separated, they are found to possess qualities totally different from each other. Pure oxygen gas is essential both to respiration and combustion, while neither of these processes can be performed in nitrogen gas.

CAROLINE.

But since nitrogen gas is unfit for respiration, how does it happen that the three fourths of this gas, which enter into the composition of the atmosphere, are not a great impediment to breathing?

MRS. B.

We should breathe more freely than our lungs could bear, if we respired oxygen gas alone. The nitrogen is no impediment either to respiration, or combustion: it appears to be merely passive in those functions; but it serves, as it were, to dilute and weaken the oxygen which we breathe, as you would weaken the wine that you drink, by diluting it with water.

EMILY.

And by what means can the two gasses, which compose the atmospheric air, be separated?

MRS. B.

There are many ways of analysing the atmosphere; the two gasses can be separated first by combustion.

EMILY.

How is it possible that combustion should separate them?

MRS. B.

I must first tell you, that all bodies, excepting the earths and alkalies, have so strong an affinity for oxygen, that they will, in certain circumstances, attract and absorb it from the atmosphere; in this case the nitrogen gas remains alone, and we thus obtain it in its simple gaseous state.

CAROLINE.

I do not understand how a gas can be absorbed?

MRS. B.

The gas is not absorbed, but decomposed; and it is oxygen only, that is to say, the basis of the gas, which is absorbed.

CAROLINE.

What then becomes of the caloric of the oxygen gas, when it is deprived of its basis?

MRS. B.

We shall make this piece of dry wood absorb oxygen from the atmosphere, and you will see what becomes of the caloric.

CAROLINE.

You are joking, Mrs. B—; you do not mean to decompose the atmosphere with a piece of stick?

MRS. B.

Not the whole body of the atmosphere, certainly; but if we can make this stick absorb any quantity of oxygen from it, will not a proportional quantity of atmospherical air be decomposed?

CAROLINE.

Undoubtedly; but if wood has so strong an affinity for oxygen, as to attract it from the caloric with which it is combined in the atmosphere, why does it not decompose the atmosphere spontaneously?

MRS. B.

Because the attraction of aggregation of the particles of the wood, is an obstacle to their combination with the oxygen: for you know that the oxygen must penetrate the wood, in order to combine with its particles, and forcibly separate them in direct opposition to the attraction of aggregation.

EMILY.

Just as caloric penetrates bodies?

MRS. B.

Yes; but caloric being a much more subtle fluid than oxygen, can penetrate substances much more easily.

CAROLINE.

But if the attraction of cohesion between the particles of a body, counteracts its affinity for oxygen, I do not see how that body can decompose the atmosphere?

MRS. B.

That is now the difficulty which we have to remove with regard to the piece of wood.—Can you think of no method of diminishing the attraction of cohesion?

CAROLINE.

Heating the wood, I should think, might answer the purpose; for the caloric would separate the particles, and make room for the oxygen.

MRS. B.

Well, we shall try your method; hold the stick close to the fire—closer still, that it may imbibe the caloric plentifully; otherwise the attraction of cohesion between its particles will not be sufficiently overcome—

CAROLINE.

It has actually taken fire, and yet I did not let it touch the coals; but I held it so very close, that I suppose it caught fire merely from the intensity of the heat.

MRS. B.

Or you might say, in other words, that the heat so far overcame the attraction of cohesion of the wood, that it was enabled to absorb oxygen very rapidly from the atmosphere.

EMILY.

Does the wood absorb oxygen while it is burning?

MRS. B.

Yes; and the heat and light are produced by the caloric of the oxygen gas, which being set at liberty by the oxygen uniting with the wood, appears in its sensible form.

CAROLINE.

You astonish me! Is it possible that the heat of a burning body should be produced by the atmosphere, and not by the body itself?

MRS. B.

It is not precisely ascertained whether any portion of the caloric is furnished by the combustible body; but there is no doubt that by far the most considerable part of it is disengaged from the oxygen gas, when its basis combines with the combustible body.

EMILY.

I have not yet met with any thing in chemistry that has surprised or delighted me so much as this explanation of combustion. I was at first wondering what connection there could be between the affinity of a body for oxygen and its combustibility; but I think I understand it now perfectly.

MRS. B.

Combustion then, you see, is nothing more than the rapid absorption of the basis of oxygen gas, by a combustible body, attended by the disengagement of the light and heat, which were combined with the oxygen when in its gaseous state.

EMILY.

But are there no combustible bodies whose attraction for oxygen is so strong, that they will overcome the resistance of the attraction of aggregation, without the application of heat?

CAROLINE.

That cannot be; otherwise we should see bodies burning spontaneously.

MRS. B.

This, indeed, sometimes happens, (and for the very reason which Emily assigns), as I shal show you at some future time. But, in general, all the combustions that could occur spontaneously, at the temperature of the atmosphere, have already taken place; therefore new combustions cannot happen without raising the temperature of the body. Some bodies, however, will burn at a much lower temperature than others.

EMILY.

The elevation of temperature, required to make a body burn, must, I suppose, depend entirely upon the force of aggregation to be overcome?

MRS. B.

That is one point; but you must likewise recollect, that there must be a stronger affinity between the body and oxygen, than between the latter and its caloric; otherwise the oxygen will not quit its gaseous form to combine with the body. It is this degree of affinity for oxygen that constitutes a combustible body. The earths and alkalies have no such affinity for oxygen, and are therefore incombustible. But, in order to make a combustible body burn, you see that it is necessary to give the first impulse to combustion by the approach of a hot or burning body, from which it may obtain a sufficient quantity of caloric to raise its temperature.

CAROLINE.

But the common way of burning a body is not merely to approach it to one already on fire, but rather to put the one in actual contact with the other, as when I burn this piece of paper by holding it in the flame of the fire.

MRS. B.

The closer it is in contact with the source of caloric, the sooner will its temperature be raised to the degree necessary for it to burn. If you hold it near the fire, the same effect will be produced; but more time will be required, as you found to be the case with the piece of stick.

EMILY.

But why is it not necessary to continue applying caloric throughout the process of combustion, in order to prevent the attraction of aggregation from recovering its ground and impeding the absorption of the oxygen?

MRS. B.

The caloric, which is gradually disengaged, by the decomposition of the oxygen gas, during combustion, keeps up the temperature of the burning body; so that when once combustion has begun, no further application of caloric is required.

CAROLINE.

Since I have learnt this wonderful theory of combustion, I cannot take my eyes from the fire; and I can scarcely conceive that the heat and light, which I always supposed to proceed from the coals, are really produced by the atmosphere, and that the coals are only the instruments by which the decomposition of the oxygen gas is effected.

EMILY.

When you blow the fire, you increase the combustion, I suppose, by supplying the coals with a greater quantity of oxygen gas?

MRS. B.

Certainly; but of course no blowing will produce combustion, unless the temperature of the coals be first raised. A single spark, however, is sometimes sufficient to produce that effect; for, as I said before, when once combustion has commenced, the caloric disengaged is sufficient to elevate the temperature of the rest of the body, provided that there be a free access of oxygen. There are, therefore, three things required in order to produce combustion; a combustible body, oxygen, and a temperature at which the one will combine with the other.

EMILY.

You said that combustion was one method of decomposing the atmosphere, and obtaining the nitrogen gas in its simple state; but how do you secure this gas, and prevent it from mixing with the rest of the atmosphere?

MRS. B.

It is necessary for this purpose to burn the body within a close vessel, which is easily done.—We shall introduce a small lighted taper (PLATE V. Fig. 7.) under this glass receiver, which stands in a bason over water, to prevent all communication with the external air.

CAROLINE.

How dim the light burns already!—It is now extinguished.

MRS. B.

Can you tell us why it is extinguished?

CAROLINE.

Let me consider—The receiver was full of atmospherical air; the taper, in burning within it, must have absorbed the oxygen contained in that air, and the caloric that was disengaged produced the light of the taper. But when the whole of the oxygen was absorbed, the whole of its caloric was disengaged; consequently the taper ceased to burn, and the flame was extinguished.

MRS. B.

Your explanation is perfectly correct.

EMILY.

The two constituents of the oxygen gas being thus disposed of, what remains under the receiver must be pure nitrogen gas?

MRS. B.

There are some circumstances which prevent the nitrogen gas, thus obtained, from being perfectly pure; but we may easily try whether the oxygen has disappeared by putting another lighted taper under it.—You see how instantaneously the flame is extinguished for want of oxygen; and were you to put an animal under the receiver, it would immediately be suffocated. But that is an experiment which, I suppose, your curiosity will not tempt you to try.

EMILY.

It must be very cruel indeed!—But look, Mrs. B—, the receiver is full of a thick white smoke. Is that nitrogen gas?

MRS. B.

No, my dear, pure nitrogen gas is perfectly transparent, and invisible, like common air. This cloudiness proceeds from a variety of exhalations, which arise from the burning taper, and the nature of which you cannot yet understand.

CAROLINE.

The water within the receiver has now risen a little above its level in the bason. What is the reason of this?

MRS. B.

With a little reflection, I dare say, you would have explained it yourself. The water rises in consequence of the oxygen gas within it having been destroyed, or rather decomposed, by the combustion of the taper; and the water did not rise immediately, because the heat of the taper, whilst burning, produced a dilatation of the air in the vessel, which counteracted this effect.

Another means of decomposing the atmosphere is the *oxygenation* of certain metals. This process is very analogous to combustion; it is, indeed, only a more general term to express the combination of a body with oxygen.

CAROLINE.

In what respect, then, does it differ from combustion?

MRS. B.

The combination of oxygen in combustion is always accompanied by a disengagement of light and heat; whilst this circumstance is not a necessary consequence of simple oxygenation.

CAROLINE.

But how can a body absorb oxygen without disengaging the caloric of the gas?

MRS. B.

Oxygen does not always present itself in a gaseous state; it is a constituent part of a vast number of bodies, both solid and liquid, in which it exists in a much denser state than in the atmosphere; and from these bodies it may be obtained without any disengagement of caloric. It may likewise, in some cases, be absorbed from the atmosphere without any sensible production of light and heat; for, if the process be slow, the caloric is disengaged in such small quantities, and so gradually, that it is not capable of producing either light or heat. In this case, the absorption of oxygen is called *oxygenation* or *oxydation,* instead of *combustion,* as the disengagement of sensible light and heat is essential to the latter.

EMILY.

I wonder that metals can unite with oxygen; for, as they are very dense, their attraction of aggregation must be very great, and I should have thought that oxygen could never have penetrated such bodies.

MRS. B.

Their strong attraction for oxygen counterbalances this obstacle. Most metals, however, require to be made red hot before they are capable of attracting oxygen in any considerable quantity. By this process they lose most of their metallic properties, and fall into a kind of powder, formerly called *calx,* but now much more properly termed an *oxyd*; thus we have *oxyd of lead*, *oxyd of iron*, &c.

CAROLINE.

The word oxyd, then, simply means a metal combined with oxygen?

MRS. B.

Yes; but the term is not confined to metals, though chiefly applied to them. Any body whatever, that has combined with a certain quantity of oxygen, either by means of oxydation or combustion, is called an *oxyd*, and is said to be *oxydated* or *oxygenated*.

This black powder is an oxyd of manganese, a metal which has so strong an attraction for oxygen, that it absorbs that substance from the atmosphere at any known temperature: it is therefore never found in its metallic form, but always in that of an oxyd, in which state, you see, it has very little of the appearance of a metal. It is now heavier than it was before oxydation, in consequence of the additional weight of the oxygen with which it has combined.

CAROLINE.

I am very glad to hear that; for I confess I could not help having some doubts whether oxygen was really a substance, as it is not to be obtained in a simple and palpable state: but its weight is, I think, a decisive proof of its being really a body.

MRS. B.

It is easy to estimate its weight, by separating it from the manganese, and finding how much the latter has lost.

EMILY.

But if you can take the oxygen from the metal, shall we not then have it in its papable simple state?

MRS. B.

No; for I can only separate the oxygen from the manganese, by presenting to it some other body for which it has a greater affinity than for the manganese. Caloric possesses such a superior affinity for oxygen, provided the temperature of the metal be sufficiently raised; if, therefore, I heat this oxyd of manganese to a certain degree, the caloric will combine with the oxygen, and carry it off in the form of gas.

EMILY.

But you said just now, that manganese would attract oxygen from the atmosphere in which it is combined with caloric; how, therefore, can the oxygen have a superior affinity for caloric, since it abandons the latter to combine with the manganese?

MRS. B.

I give you credit for this objection, Emily; and the only answer I can make to it is, that the mutual affinities of metals for oxygen, and of oxygen for caloric, vary at different temperatures; a certain degree of heat will, therefore, dispose a metal to combine with oxygen, whilst, on the contrary, the former will be compelled to part with the latter when the temperature is further increased. I have put some oxyd of manganese into a retort, which is an earthen vessel with a bent neck, such as you see here (PLATE V. Fig. 9.)—The retort containing the manganese you cannot see, as I have enclosed it in this furnace, where it is now red hot. But, in order to make you sensible of the escape of the gas, which is itself invisible, I have connected the neck of the retort with this bent tube, the extremity of which is immersed in this vessel of water (PLATE V. Fig. 9.)—Do you see the bubbles of air rise through the water?

CAROLINE.

Perfectly. This, then, is pure oxygen gas; what a pity it should be lost! Could we not preserve it?

MRS. B.

We shall collect it in this receiver.—For this purpose, you observe, I first fill it with water, in order to exclude the atmospherical air; and then place it over the bubbles that issue from the retort, so as to make them rise through the water to the upper part of the receiver.

EMILY.

The bubbles of oxygen gas rise, I suppose, from their specific levity?

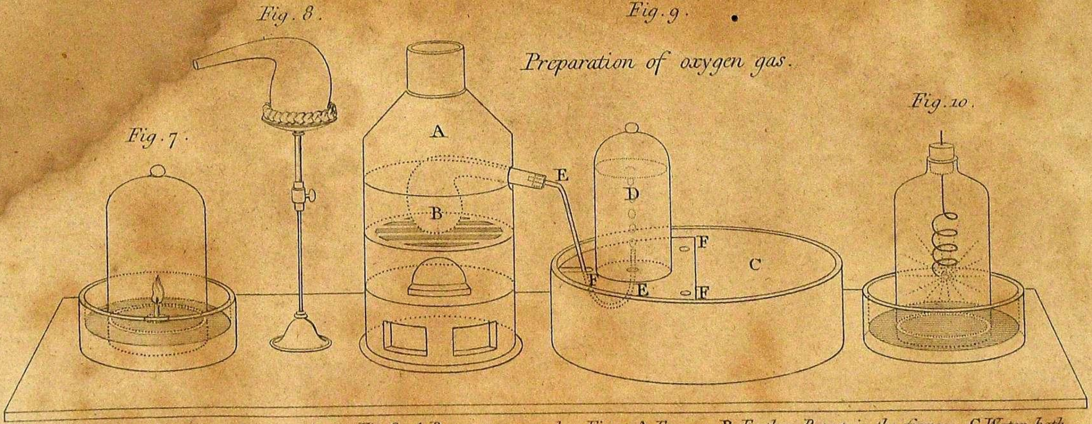


Fig. 7 Combustion of a taper under a receiver. _*Fig. 8* A Retort on a stand._*Fig. 9* A Furnace. B *Earthen Retort in the furnace.* C *Water bath.* D *Receiver.* E.E *Tube conveying the gas from the Retort through the water into the Receiver.* F.F.F *Shelf perforated on which the Receiver stands.* *Fig. 10* Combustion of iron wire in oxygen gas.

Drawn by the Author.

Engraved by Lowry.

Published by Longman & C°. Dec^r. 2^nd. 1805.

MRS. B.

Yes; for though oxygen forms rather a heavy gas, it is light compared to water. You see how it gradually displaces the water from the receiver. It is now full of gas, and I may leave it inverted in water on this shelf, where I can keep the gas as long as I choose, for future experiments. This apparatus (which is indispensable in all experiments in which gasses are concerned) is called a water-bath.

CAROLINE.

It is a very clever contrivance, indeed; it is equally simple and useful. How convenient the shelf is for the receiver to rest upon under water, and the holes in it for the gas to pass into the receiver! I long to make some experiments with this apparatus.

MRS. B.

I shall try your skill that way, when you have a little more experience. I am now going to show you an experiment, which proves, in a very striking manner, how essential oxygen is to combustion. You will see that iron itself will burn in this gas, in the most rapid and brilliant manner.

EMILY.

Really! I did not know that it was possible to burn iron.

MRS. B.

Iron is eminently combustible in pure oxygen gas, and what will surprise you still more, it can be set on fire without any very great rise of temperature. You see this spiral iron wire—I fasten it at one end to this cork, which is made to fit an opening at the top of the glass receiver (PLATE V. Fig. 10.)—

EMILY.

I see the opening in the receiver; but it is carefully closed by a ground glass stopper.

MRS. B.

That is in order to prevent the gas from escaping; but I shall take out the stopper, and put in the cork, to which the wire hangs.—Now I mean to burn this wire in the oxygen gas, but I must fix a small piece of lighted tinder to the extremity of it, in order to give the first impulse to combustion; for however powerful oxygen is in promoting combustion, you must recollect that it cannot take place without a certain elevation of temperature. I shall now introduce the wire into the receiver, by quickly changing the stoppers.

CAROLINE.

Is there no danger of the gas escaping while you change the stoppers?

MRS. B.

Oxygen gas is a little heavier than atmospherical air, therefore it will not mix with it very rapidly; and, if I do not leave the opening uncovered, we shall not lose any——

CAROLINE.

Oh, what a brilliant and beautiful flame!

EMILY.

It is as white, and dazzling as the sun!—Now a piece of the melted wire drops to the bottom: I fear it is extinguished; but no, it burns again as bright as ever.

MRS. B.

It will burn till the wire is entirely consumed, provided the oxygen is not first expended; for you know it can burn only while there is oxygen to combine with it.

CAROLINE.

I never saw a more beautiful light. My eyes can hardly bear it! How astonishing to think that all this caloric was contained in the small quantity of gas that was enclosed in the receiver; and that, without producing any sensible heat!

MRS. B.

The caloric of the oxygen gas could not produce any sensible heat before the combustion took place, because it was not in a free state. You can tell me, I hope, to what modification of heat this caloric is to be referred?

CAROLINE.

Since it is *combined* with the basis of the gas, it must be *chemical* heat.

EMILY.

Chemical heat is then extricated in all combustions?

MRS. B.

Certainly. By the decomposition of the gas, the caloric returns to its free state, and thus produces a quantity of sensible heat, proportional to the rapidity of that decomposition.

CAROLINE.

How wonderfully quick combustion goes on in pure oxygen gas! But pray are these drops of burnt iron as heavy as the wire was before?

MRS. B.

They are even heavier; for the iron, in burning, has acquired exactly the weight of the oxygen which has disappeared, and is now combined with it. It has become an oxyd of iron.

CAROLINE.

I do not know what you mean by saying that the oxygen has *disappeared*, Mrs. B., for it was always invisible.

MRS. B.

True, my dear; the expression was incorrect. But though you could not see the oxygen gas, I believe you had no doubt of its presence, as the effect it produced on the wire was sufficiently evident.

CAROLINE.

Yes, indeed; yet you know it was the caloric of the gas, and not the oxygen gas itself, that dazzled us so much.

MRS. B.

You are not quite correct in your turn, in saying the caloric dazzled you; for caloric is invisible; it affects only the sense of feeling; it was the light which dazzled you.

CAROLINE.

True; but light and caloric are such constant companions, that it is difficult to separate them, even in idea.

MRS. B.

The easier it is to confound them, the more careful you should be in making the distinction.

CAROLINE.

But why has the water now risen, and filled part of the receiver?

MRS. B.

Indeed, Caroline, I did not think you would have asked such a question! I am sure, Emily, you can answer it.

EMILY.

Let me reflect . . . . . . The oxygen has combined with the wire; the caloric has escaped; consequently nothing can remain in the receiver, and the water will rise to fill the vacuum.

CAROLINE.

Indeed I wonder that I did not think of that. I wish that we had weighed the wire and the oxygen gas before combustion; we might then have found whether the weight of the oxyd was equal to that of both.

MRS. B.

You might try the experiment if you particularly wished it; but I can assure you, that, if accurately performed, it never fails to show that the additional weight of the oxyd is precisely equal to that of the oxygen absorbed, whether the process has been a real combustion, or a simple oxygenation.

CAROLINE.

But this cannot be the case with combustions in general, for when any substance is burnt in the common air, so far from increasing in weight, it is evidently diminished, and sometimes entirely consumed.

MRS. B.

But what do you mean by the expression *consumed?* You cannot suppose that the smallest particle of any substance in nature can be actually destroyed. A compound body is decomposed by combustion; some of its constituent parts fly off in a gaseous form, while others remain in a concrete state; the former are called the *volatile*, the latter the *fixed products* of combustion. But if we collect the whole of them, we shall always find that they exceed the weight of the combustible body, by that of the oxygen that has combined with them during combustion.

EMILY.

In the combustion of a coal fire, then, I suppose that the ashes are what would be called the fixed product, and the smoke the volatile product?

MRS. B.

Yet when the fire burns best, and the quantity of volatile products should be the greatest, there is no smoke; how can you account for that?

EMILY.

Indeed I cannot; therefore I suppose that I was not right in my conjecture.

MRS. B.

Not quite: ashes, as you supposed, are a fixed product of combustion; but smoke, properly speaking, is not one of the volatile products, as it consists of some minute undecomposed particles of the coals that are carried off by the caloric without being burnt, and are either deposited in the form of soot, or dispersed by the wind. Smoke, therefore, ultimately becomes one of the *fixed* products of combustion. And you may easily conceive that the stronger the fire is, the less smoke is produced, because the fewer particles escape combustion. On this principle depends the invention of Argand's Patent Lamps; a current of air is made to pass through the cylindrical wick of the lamp, by which means it is so plentifully supplied with oxygen, that not a particle of oil escapes combustion, nor is an atom of smoke produced.

EMILY.

But what then are the volatile products of combustion?

MRS. B.

Various new compounds, with which you are not yet acquainted, and which being converted by caloric, either into vapour, or gas, are invisible; but they can be collected, and we shall examine them, at some future period.

CAROLINE.

There are then other gasses, besides the oxygen and nitrogen gasses.

MRS. B.

Yes, several: any substance that has a sufficient affinity for caloric to combine with it, and assume and maintain the form of an elastic fluid at the temperature of the atmosphere, is capable of being converted into a gas. We shall examine the several gasses in their respective places; but we must now confine our attention to those that compose the atmosphere.

I shall show you another method of decomposing the atmosphere, which is very simple. In breathing, we retain a portion of the oxygen, and expire the nitrogen gas; so that if we breathe in a closed vessel, for a certain length of time, we shall fill it with nitrogen gas. Which of you will make the experiment?

CAROLINE.

I should be very glad to try it.

MRS. B.

Very well; breathe several times through this glass tube into the receiver with which it is connected, until you feel that your breath is exhausted—

CAROLINE.

I am quite out of breath already!

MRS. B.

Now let us try the gas with a lighted taper—

EMILY.

It is very pure nitrogen gas, for the taper is immediately extinguished.

MRS. B.

That is not a proof of its being pure, but only of the absence of oxygen, as it is that principle alone that can produce combustion, every other gas being absolutely incapable of it.

EMILY.

In the methods which you have shown us, for decomposing the atmosphere, the oxygen always abandons the nitrogen; but is there no way of taking the nitrogen from the oxygen, so as to obtain the latter pure from the atmosphere?

MRS. B.

You must observe, that whenever oxygen is taken from the atmosphere, it is by decomposing the oxygen gas; we cannot do the same with the nitrogen gas, because nitrogen has a stronger affinity for caloric than for any other known principle: it appears impossible therefore to separate it from the atmosphere by the power of affinities. But if we cannot obtain the oxygen gas, by this means, in its separate state, we have no difficulty (as you have seen) to procure it in its gaseous form, by taking it from those substances that have absorbed it from the atmosphere. This is done by combining the oxygen, at a high temperature, with caloric, as we did with the oxyd of manganese.

EMILY.

Can atmospherical air be recomposed, by mixing due proportions of oxygen and nitrogen gasses?

MRS. B.

Yes: if about one fourth of oxygen gas be mixed with three fourths of nitrogen gas, atmospherical air is produced.

EMILY.

The air then must be an oxyd of nitrogen?

MRS. B.

No, my dear; for there must be a chemical combination between oxygen and nitrogen in order to produce an oxyd; whilst in the atmosphere these two substances are separately combined with caloric, forming two distinct gasses, which are simply mixed in the formation of the atmosphere*.

* This, at least, seems to be the prevailing opinion. Yet it has been questioned by some chemists, particularly of late, whether the union of oxygen and nitrogen in the atmosphere be not a true chemical combination.

I shall say nothing more of oxygen and nitrogen at present, as we shall continually have occasion to refer to them in our future conversations. They are both very abundant in nature; nitrogen is the most plentiful in the atmosphere, and exists also in all animal substances; oxygen forms a constituent part, both of the animal and vegetable kingdoms, from which it may be obtained by a variety of chemical means. But it is now time to conclude our lesson. I am afraid you have learnt more to-day than you will be able to remember.

CAROLINE.

I assure you that I have been too much interested in it, ever to forget it; as for nitrogen there seems to be but little to remember about it; it makes a very insignificant figure in comparison to oxygen, although it composes a much larger portion of the atmosphere.

MRS. B.

It will not appear so insignificant when you are better acquainted with it; for though it seems to perform but a passive part in the atmosphere, and has no very striking properties, when considered in its separate state, yet you will see by and by what a very important agent it becomes, when combined with other bodies. But no more of this at present; we must reserve it for its proper place.

CONVERSATION VI.

ON HYDROGEN.

CAROLINE.

THE next simple body we come to is HYDROGEN. Pray what kind of a substance is that; is it also invisible?

MRS. B.

Yes; we cannot obtain hydrogen in its pure concrete state. We are acquainted with it only in its gaseous form, as we are with oxygen and nitrogen.

CAROLINE.

But in its gaseous state it cannot be called a simple substance, since it is combined with caloric.

MRS. B.

True, my dear; but as we do not know in nature of any substance which is not more or less combined with caloric, we are apt to say (rather incorrectly indeed) that a substance is in its pure state, when combined with caloric only.

Hydrogen is derived from two Greek words, the meaning of which is *to generate water.*

EMILY.

And how does hydrogen generate water?

MRS. B.

Water is composed of 85 parts, by weight, of oxygen, chemically combined with 15 parts of hydrogen gas, or (as it was formerly called) inflammable air.

CAROLINE.

Really! Is it possible that water should be nothing more than a combination of two gasses, and that hydrogen should be the generator of water, and at the same time inflammable air? It must be a most extraordinary gas, that will produce both fire and water!

MRS. B.

Hydrogen, I assure you, though a constituent part of water, is one of the most combustible substances in nature.

EMILY.

But I thought you said that combustion could take place in no gas but oxygen?

MRS. B.

Do you recollect what the process of combustion consists in?

EMILY.

In the combination of a body with oxygen, with disengagement of light and heat.

MRS. B.

Therefore, when I say that hydrogen is combustible, I mean that it has an affinity for oxygen; but, like all other combustible substances, it cannot burn unless supplied with oxygen, and heated to a proper temperature.

CAROLINE.

But I cannot conceive how, by mixing fifteen parts of it, with eighty-five parts of oxygen gas, the two gasses can be converted into water?

MRS. B.

The simply mixing these proportions of oxygen and hydrogen gasses, will not produce water; because the great quantity of caloric to which they owe their gaseous form would prevent their bases from coming into contact, and entering into chemical combination; besides, water is a much denser fluid than gas, and therefore it is necessary, in order to reduce these gasses to a liquid, to diminish the quantity of caloric. Can you think of any means of accomplishing this?

CAROLINE.

By putting a colder body in contact with the gasses, which would take some of their caloric from them.

MRS. B.

That would lower the temperature of the gas; but could not affect the caloric that is chemically combined with the basis.

CAROLINE.

True; I forgot, that in order to separate caloric from a body with which it is chemically combined, a decomposition must take place; but I cannot imagine how this is effected.

MRS. B.

A decomposition can be effected only by superior attractions which produce new combinations. At a certain temperature, oxygen will abandon its caloric, to combine with hydrogen; if, therefore, we raise it to that temperature, the oxygen will combine with the hydrogen, and set its own caloric at liberty; and it is thus that the combustion of hydrogen gas produces water.

CAROLINE.

You love to deal in parodoxes to-day, Mrs. B.—Fire then produces water!

MRS. B.

The combustion of hydrogen gas certainly does; but you do not seem to have remembered the theory of combustion so well as you thought you would. Can you tell me what happens in the combustion of hydrogen gas?

CAROLINE.

The hydrogen gas combines with the basis of the oxygen gas, and the caloric of the latter is disengaged.—Yes, I think, I understand it now: the caloric of the oxygen gas being set at liberty, and the basis of the two gasses coming in contact, they combine, and condense into a liquid.

EMILY.

But does all the caloric, produced by the combustion of hydrogen gas, proceed from the oxygen gas?

MRS. B.

That is a doubtful point; but I rather believe that in this, as probably in every other instance of combustion, some portion of heat and light is disengaged by the combustible itself.

EMILY.

Water then, I suppose, when it evaporates and incorporates with the atmosphere, is decomposed and converted into hydrogen and oxygen gasses?

MRS. B.

No, my dear; there you are quite mistaken: the decomposition of water is totally different from its evaporation; for in the latter case (as you should recollect) water is only in a state of very minute division; and is merely suspended in the atmosphere, without any chemical combination, and without any separation of its constituent parts. As long as these remain combined, they form WATER, whether in a state of liquidity, or in that of an elastic fluid, as vapour, or under the solid form of ice.

In our experiments on latent heat, you may recollect that we caused water successively to pass through these three forms, merely by an increase or diminution of caloric, without employing any power of attraction, or effecting any decomposition.

CAROLINE.

But are there no means of decomposing water?

MRS. B.

Yes, several: charcoal, and metals, when heated red hot, will attract the oxygen from water in the same manner as they will from the atmosphere; but in this process there is no disengagement of caloric, as that which the oxygen abandons, instead of becoming sensible, combines immediately with the hydrogen, which it converts into gas, and carries off in that form.

CAROLINE.

So, then, the quantity of caloric that was employed in maintaining the combined substances in a liquid form, is just sufficient to convert the hydrogen, singly, into a gas.

MRS. B.

That is a very ingenious inference; but I doubt whether it is strictly accurate, as the hot body (whether charcoal or metal) by means of which the water is decomposed, supplies, in cooling, a portion of the caloric which enters into the formation of the gas.

EMILY.

Water, then, may be resolved into a solid substance and a gas; the oxygen being condensed into a solid, by the loss of caloric, and the hydrogen into a gas, by the acquisition of it.

MRS. B.

Very well, my dear; but remember that the base of the oxygen gas, or what you call solid oxygen, can never be obtained alone; it can be separated from the hydrogen only by combining it with some other body for which it has a greater affinity.

CAROLINE.

Hydrogen, I see, is like nitrogen, a poor dependant friend of oxygen, which is continually forsaken for greater favourites.

MRS. B.

The connection, or friendship, as you choose to call it, is much more intimate between oxygen and hydrogen, in the state of water, than between oxygen and nitrogen, in the atmosphere: for, in the first case, there is a chemical union and condensation of the two substances; in the latter, they are simply mixed together in their gaseous state. You will find, however, that, in some cases, nitrogen is quite as intimately connected with oxygen, as hydrogen is.—But this is foreign to our present subject.

EMILY.

Water, then, is an oxyd, though the atmospherical air is not?

MRS. B.

It is not commonly called an oxyd, though it properly belongs to that class of bodies.

CAROLINE.

I should like extremely to see water decomposed.

MRS. B.

I can easily gratify your curiosity by a much more easy process than the oxydation of charcoal or metals: the decomposition of water by these latter means, takes up a great deal of time, and is attended with much trouble; for it is necessary that the charcoal or metal should be made red hot in a furnace, that the water should pass over them in a state of vapour, that the gas formed should be collected over the water-bath, &c. In short, it is a very complicated affair. But the same effect may be produced with the greatest facility, by adding some sulphuric acid (a substance with the nature of which you are not yet acquainted), to the water which the metal is to decompose. The acid disposes the metal to combine with the oxygen of the water so readily and abundantly, that no heat is required to hasten the process. Of this I am going to show you an instance.—I put into this bottle the water that is to be decomposed, the metal that is to effect that decomposition by combining with the oxygen, and the acid which is to facilitate the combination of the metal and the oxygen. You will see with what violence these will act on each other.

CAROLINE.

But what metal is it that you employ for this purpose?

MRS. B.

It is iron; and it is used in the state of filings, as these present a greater surface to the acid than a solid piece of metal. For, as it is the surface of the metal which is acted upon by the acid, and is disposed to receive the oxygen produced by the decomposition of the water, it necessarily follows that the greater is the surface, the more considerable is the effect. The bubbles which are now rising are hydrogen gas—

CAROLINE.

How disagreeably it smells!

MRS. B.

It is indeed unpleasant, but not unwholesome. We shall not, however, suffer any more to escape, as it will be wanted for experiments. I shall therefore collect it in a glass receiver, by making it pass through this bent tube, which will conduct it into the water-bath. (PLATE VI. Fig. 11.)

EMILY.

How very rapidly the gas escapes! it is perfectly transparent, and without any colour whatever.—Now the receiver is full—

MRS. B.

We shall therefore remove it and substitute another in its place. But you must observe, that when the receiver is full, it is necessary to keep it inverted with the mouth under water, otherwise the gas would escape. And in order that it may not be in the way, I introduce within the bath, under the water, a saucer, into which I slide the receiver, so that it can be taken out of the bath and conveyed

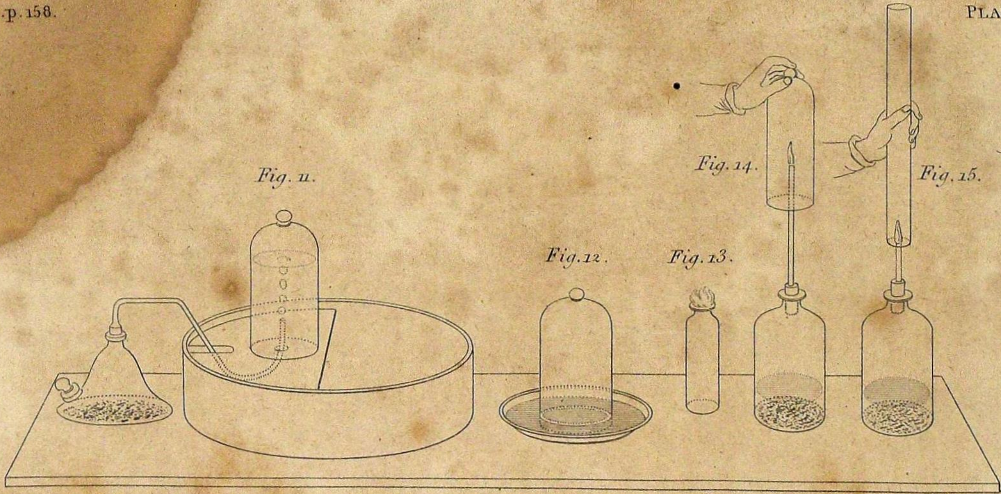


Fig. 11 Apparatus for preparing & collecting hydrogen gas.— Fig. 12 Receiver full of hydrogen gas inverted over water.— Fig. 13 Slow combustion of hydrogen gas.— Fig. 14 Apparatus for illustrating the formation of water by the combustion of hydrogen gas.— Fig. 15 Apparatus for producing harmonic sounds by the combustion of hydrogen gas.

Drawn by the Author. *Engraved by Lowry.*

Published by Longman & C.^o Dec.^r 2.^nd 1805.

any where in the saucer. (PLATE VI. Fig. 12.)

EMILY.

I am quite surprised to see what a large quantity of hydrogen gas can be produced by such a small quantity of water, especially as oxygen is the principal constituent of water.

MRS. B.

In weight, it is; but not in volume. For though the proportion, by weight, is nearly six parts of oxygen to one of hydrogen, yet the proportion of the volume of the gasses, is about one part of oxygen, to two of hydrogen; so much heavier is the former than the latter.

CAROLINE.

But why is the vessel in which the water is decomposed so hot? As the water changes from a liquid to a gaseous form, cold should be produced instead of heat.

MRS. B.

No; for if one of the constituents of water is converted into a gas, the other becomes solid in combining with the metal; and the caloric which the oxygen loses by being thus rendered solid, is just sufficient to transform the hydrogen into a gas.

EMILY.

In this case, neither heat nor cold would be produced; for the caloric disengaged from the oxygen, being immediately combined with the hydrogen, cannot become sensible?

MRS. B.

That is very true; but the sensible heat which is disengaged in this operation is not owing to the decomposition of the water, but to an extrication of latent heat produced by the mixture of water and sulphuric acid, as you saw in a former experiment.

If I now set the hydrogen gas, which is contained in this receiver, at liberty all at once, and kindle it as soon as it comes in contact with the atmosphere, by presenting it to a candle, it will so suddenly and rapidly decompose the oxygen gas, by combining with its basis, that an explosion, or a *detonation* (as chemists commonly call it), will be produced. For this purpose, I need only take up the receiver, and quickly present its open mouth to the candle—so....

CAROLINE.

It produced only a sort of hissing noise, with a vivid flash of light. I had expected a much greater report.

MRS. B.

And so it would have been, had the gasses been closely confined at the moment they were made to explode. If, for instance, we were to put in this bottle a mixture of hydrogen gas and atmospheric air; and if, after corking the bottle, we should kindle the mixture by a very small orifice, from the sudden dilatation of the gasses at the moment of their combination, the bottle must either fly to pieces, or the cork be blown out with considerable violence.

CAROLINE.

But in the experiment which we have just seen, if you did not kindle the hydrogen gas, would it not equally combine with the oxygen?

MRS. B.

Certainly not; have I not just explained to you the necessity of the oxygen and hydrogen gasses being burnt together, in order to combine chemically and produce water?

CAROLINE.

That is true; but I thought this was a different combination, for I see no water produced.

MRS. B.

The water produced by this detonation was so small in quantity, and in such a state of minute division, as to be invisible. But water certainly was produced; for oxygen is incapable of combining with hydrogen in any other proportions than those that form water; therefore water must always be the result of their combination.

If, instead of bringing the hydrogen gas into sudden contact with the atmosphere (as we did just now) so as to make the whole of it explode the moment it is kindled, we allow but a very small surface of gas to burn in contact with the atmosphere, the combustion goes on quietly and gradually at the point of contact, without any detonation, because the surfaces brought together are too small for the immediate union of the gasses. The experiment is a very easy one. This phial with a narrow neck, (PLATE VI. Fig. 13.) is full of hydrogen gas, and is carefully corked. If I take out the cork, without moving the phial, and quickly approach the candle to the orifice, you will see how different the result will be—

EMILY.

How prettily it burns, with a blue flame! The flame is gradually sinking within the phial—now it has entirely disappeared. But does not this combustion likewise produce water?

MRS. B.

Undoubtedly. In order to make the formation of water sensible to you, I shall procure a fresh supply of hydrogen gas, by putting into this bottle (PLATE VI. Fig. 14.) iron filings, water, and sulphuric acid, materials similar to those which we have just used for the same purpose. I shall then cork up the bottle, leaving only a small orifice in the cork, with a piece of glass tube fixed to it, through which the gas will issue in a continued rapid stream.

CAROLINE.

I hear already the hissing of the gas through the tube, and I can feel a strong current against my hand.

MRS. B.

This current I am going to kindle with the candle—see how vividly it burns—

EMILY.

It burns like a candle with a long flame.—But why does this combustion last so much longer than in the former experiment?

MRS. B.

The combustion goes on uninterruptedly as long as the new gas continues to be produced. Now if I invert this receiver over the flame, you will soon perceive its internal surface covered with a very fine dew, which is pure water—

CAROLINE.

Yes, indeed; the glass is now quite dim with moisture! How glad I am that we can *see* the water produced by this combustion.

EMILY.

It is exactly what I was anxious to see; for I confess I was a little incredulous.

MRS. B.

If I had not held the glass-bell over the flame, the water would have escaped in the state of vapour, as it did in the former experiment. We have here, of course, obtained but a very small quantity of water; but the difficulty of procuring a proper apparatus, with sufficient quantities of gasses, prevents my showing it you on a larger scale.

The composition of water was discovered about the same period, both by Mr. Cavendish, in this country, and by the celebrated French chemist Lavoisier. The latter invented a very perfect and ingenious apparatus to perform, with great accuracy, and upon a large scale, the formation of water by the combination of oxygen and hydrogen gasses. Two tubes, conveying due proportions, the one of oxygen, the other of hydrogen gas, are inserted at opposite sides of a large globe of glass, previously exhausted of air; the two streams of gas are kindled within the globe, by the electric spark, at the point where they come in contact; they burn together, that is to say, the hydrogen gas combines with the basis of the oxygen gas, the caloric of which is set at liberty; and a quantity of water is produced, exactly equal in weight to that of the two gasses introduced into the globe.

CAROLINE.

And what was the greatest quantity of water ever formed in this apparatus?

MRS. B.

Several ounces; indeed, very near a pound, if I recollect right; but the operation lasted many days.

EMILY.

This experiment must have convinced all the world of the truth of the discovery. Pray, if improper proportions of the gasses were mixed and set fire to, what would be the result?

MRS. B.

Water would equally be formed, but there would be a residue of either one or other of the gasses, because, as I have already told you, hydrogen and oxygen will combine only in the proportions requisite for the formation of water.

There is another curious effect produced by the combustion of hydrogen gas, which I shall show you, though I must acquaint you first, that I cannot well explain the cause of it. For this purpose, I must put some more materials into our apparatus, in order to obtain a stream of hydrogen gas, just as we have done before. The process is already going on, and the gas is rushing through the tube—I shall now kindle it with the taper—

EMILY.

It burns exactly as it did before—— What is the curious effect which you were mentioning?

MRS. B.

Instead of the receiver, by means of which we have just seen the drops of water form, we shall invert over the flame this piece of tube, which is about two feet in length, and one inch in diameter (Plate VI. Fig. 15.); but you must observe that it is open at both ends.

EMILY.

What a strange noise it makes! something like the Æolian harp, but not so sweet.

CAROLINE.

It is very singular, indeed; but I think rather too powerful to be pleasing. And is not this sound accounted for?

MRS. B.

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*.

CAROLINE.

How very much this flame resembles the burning of a candle.

MRS. B.

The burning of a candle is produced by much the same means. A great deal of hydrogen is contained in candles, whether of tallow or wax. This hydrogen being converted into gas by the heat of the candle, combines with the oxygen of the atmosphere, and flame and water result from this combination. So that, in fact, the flame of a candle is nothing but the combustion of hydrogen gas. An elevation of temperature, such as is produced by a lighted match or taper, is required to give the first impulse to the combustion; but afterwards it goes on of itself, because the candle finds a supply of caloric in the successive quantities of *chemical* heat which become *sensible* by the combination of the two gasses. But there are other accessory circumstances connected with the combustion of candles and lamps, which I cannot explain to you till you

* This ingenious explanation was first suggested by Dr. Delarive.—See Journals of the Royal Institution, vol. i. p. 259.

you are acquainted with *carbone*, which is one of their constituent parts. In general, however, whenever you see flame, you may infer that it is owing to the formation and burning of hydrogen gas; for flame is the peculiar mode of burning of hydrogen gas, which, with only one or two apparent exceptions, does not belongs to any other combustible.

EMILY.

You astonish me! I understood that flame was the caloric abandoned by the basis of the oxygen gas, in all combustions whatever?

MRS. B.

Your error proceeded from your vague and incorrect idea of flame; you have confounded it with light and caloric in general. Flame always implies caloric, since it is produced by the combustion of hydrogen gas; but all caloric does not imply flame. Many bodies burn with intense heat without producing flame. Coals, for instance, burn with flame until all the hydrogen which they contain is evaporated; but when they afterwards become red hot, much more caloric is disengaged than when they produce flame.

CAROLINE.

But the iron wire, which you burnt in oxygen gas, appeared to me to emit flame; yet, as it was a simple metal, it could contain no hydrogen?

MRS. B.

It produced a sparkling dazzling blaze of light, but no real flame.

EMILY.

And what is the cause of the regular shape of the flame of a candle?

MRS. B.

The regular stream of hydrogen gas which exhales from its combustible matter.

CAROLINE.

But the hydrogen gas must, from its great levity, ascend into the upper regions of the atmosphere; why therefore does not the flame continue to accompany it?

MRS. B.

The combustion of the hydrogen gas is completed at the point where the flame terminates; it then ceases to be hydrogen gas, as it is converted by its combustion into watery vapour; but in a state of such minute division as to be invisible.

CAROLINE.

I do not understand what is the use of the wick of a candle; since hydrogen gas burns so well without it?

MRS. B.

The combustible matter of the candle must be decomposed in order to emit the hydrogen gas, and the wick is instrumental in effecting this decomposition. Its combustion first melts the combustible matter, and . . . . .

CAROLINE.

But in lamps the combustible matter is already fluid, and yet they also require wicks?

MRS. B.

I was going to add that, afterwards, the burning wick (by the power of capillary attraction) gradually draws up the fluid to the point where combustion takes place; for you must have observed that the wick does not burn quite to the bottom.

CAROLINE.

Yes; but I do not understand why it does not.

MRS. B.

Because the air has not so free an access to that part of the wick which is immediately in contact with the candle, as to the part just above, so that the heat there is not sufficient to produce its decomposition; the combustion therefore begins a little above this point.—But we dwell too long on a subject which you cannot yet thoroughly understand.—I have another experiment to show you with hydrogen gas, which I think will entertain you. Have you ever blown bubbles with soap and water?

Fig. 16.

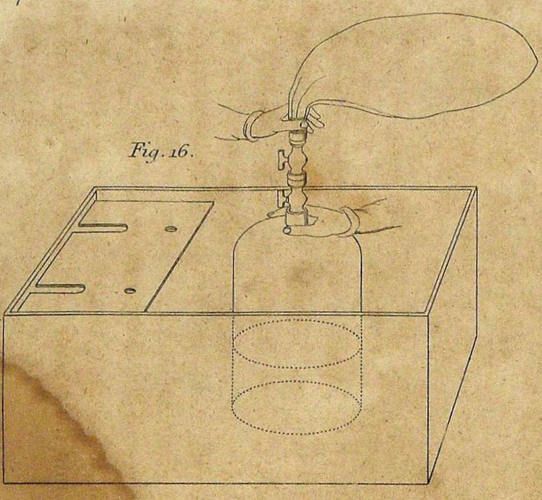


Fig. 17.

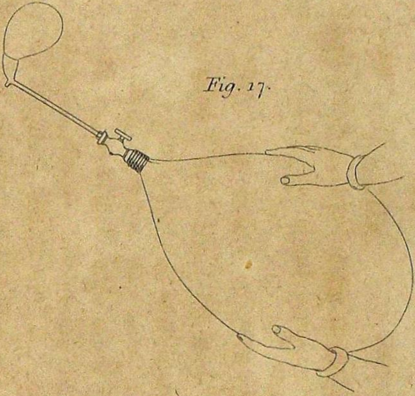


Fig. 16 Apparatus for transferring gases from a Receiver into a bladder. — Fig. 17 Apparatus for blowing Soap bubbles.

Drawn by the Author.
Published by Longman & Co. Decr. 2nd. 1805.
Engraved by Lowry.

EMILY.

Yes, often, when I was a child; and I used to make them float in the air by blowing them upwards.

MRS. B.

We shall fill some such bubbles with hydrogen gas, instead of atmospheric air, and you will see with what ease and rapidity they will ascend, without the assistance of blowing, from the lightness of the gas.—Will you mix some soap and water whilst I fill this bladder with the gas contained in the receiver which stands on the shelf in the water-bath.

CAROLINE.

What is the use of the brass stopper and turn-cock at the top of the receiver?

MRS. B.

It is to afford a passage to the gas when required. There is, you see, a similar stop-cock fastened to this bladder, which is made to fit that on the receiver. I screw them one on the other, and now turn the two cocks, to open a communication between the receiver and the bladder; then, by sliding the receiver off the shelf, and gently sinking it into the bath, the water rises in the receiver and forces the gas into the bladder. (PLATE VII. Fig. 16.)

CAROLINE.

Yes, I see the bladder swell as the water rises in the receiver.

MRS. B.

I think that we have already a sufficient quantity in the bladder for our purpose; we must be careful to stop both the cocks before we separate the bladder from the receiver, lest the gas should escape.—Now I must fix a pipe to the stopper of the bladder, and, by dipping its mouth into the soap and water, take up a few drops—then I again turn the cock, and squeeze the bladder in order to force the gas into the soap and water at the mouth of the pipe. (Plate VII. Fig. 17.)

EMILY.

There is a bubble—but it bursts before it leaves the mouth of the pipe.

MRS. B.

We must have patience and try again; it is not so easy to blow bubbles by means of a bladder, as simply with the breath.

CAROLINE.

Perhaps there is not soap enough in the water; I should have had warm water, it would have dissolved the soap better.

EMILY.

Does not some of the gas escape between the bladder and the pipe?

MRS. B.

No, they are perfectly air-tight; we shall succeed presently, I dare say.

CAROLINE.

Now a bubble ascends; it moves with the rapidity of a balloon. How beautifully it refracts the light!

EMILY.

It has burst against the ceiling—you succeed now wonderfully; but why do they all ascend and burst against the ceiling?

MRS. B.

Hydrogen gas is so much lighter than atmospherical air, that it ascends rapidly with its very light envelope, which is burst by the force with which it strikes the ceiling.

If you are not yet tired of experiments, I have another to show you. It consists in filling soap bubbles with a mixture of hydrogen and oxygen gasses, in the proportions that form water; and afterwards setting fire to them.

EMILY.

They will detonate, I suppose?

MRS. B.

Yes, they will. As you have seen the method of transferring the gas from the receiver into the bladder, it is not necessary to repeat it. I have therefore provided a bladder which contains a due proportion of oxygen and hydrogen gasses, and we have only to blow bubbles with it.

CAROLINE.

Here is a fine large bubble rising—shall I set fire to it with the candle?

MRS. B.

If you please.....

CAROLINE.

Heavens, what an explosion!—It was like the report of a gun: I confess it frightened me much. I never should have imagined it could be so loud.

EMILY.

And the flash was as vivid as lightning.

MRS. B.

The combination of the two gasses takes place during that instant of time that you see the flash, and hear the detonation.

EMILY.

This has a strong resemblance to thunder and lightning.

MRS. B.

It is supposed that thunder and lightning frequently proceed from a similar cause—but this requires some further explanation.—Nature abounds with hydrogen; it constitutes a very considerable portion of the whole mass of water belonging to our globe, and from that source, almost every other body obtains it. It enters into the composition of all animal substances, and of a great number of minerals; but it is most abundant in vegetables. From this immense variety of bodies, it is often spontaneously disengaged; its great levity makes it rise into the superior regions of the atmosphere, and when, either by an electric spark, or any casual elevation of temperature, it takes fire, it may produce thunder, lightning, and such other luminous meteors as are occasionally seen in the atmosphere.

EMILY.

But lightning, I thought, was always produced by the electric fluid?

MRS. B.

The forked lightning is; and in every instance it is perhaps necessary, for the electric spark to give the first impulse to the combustion of the hydrogen gas; but those broad flashes which we frequently see on a summer's evening, the detonation of which is seldom heard, are probably connected with a combustion of hydrogen gas in the higher regions of the atmosphere.

CAROLINE.

Yet, the sudden inflammation of so large a quantity of hydrogen gas, must produce a very loud detonation?

MRS. B.

True; but it is generally too far distant for us to hear it.

EMILY.

Every flash, I suppose, must produce a quantity of water?

CAROLINE.

And this water, naturally, descends in the form of rain?

MRS. B.

That probably is often the case; and, indeed, you may have observed that a loud clap of thunder is commonly followed by an increase of rain; but it is not a necessary consequence; for the water may be dissolved by the atmosphere, as it descends towards the lower regions, and remain there in the form of clouds.—But pray do not question me too closely on this subject, for the phenomena of the atmosphere are not yet well understood; and even with the little that is known I am but imperfectly acquainted.

CONVERSATION VII.

SULPHUR AND PHOSPHORUS.

MRS. B.

SULPHUR is the next simple substance that comes under our consideration. It differs in one essential point from the preceding, as it exists in a solid form at the temperature of the atmosphere.

CAROLINE.

I am glad that we have at last a solid body to examine; one that we can see and touch. Pray, is it not with sulphur that the points of matches are covered to make them easily kindle?

MRS. B.

Yes, it is; and you therefore already know that sulphur is a very combustible substance. It is seldom discovered in nature in a pure unmixed state; so great is its affinity for other substances, that it is almost constantly found combined with some of them. It is most commonly united with metals, under various forms, and is separated from them by a very simple process. It exists likewise in many mineral waters, and some vegetables yield it in various proportions, especially those of the cruciform tribe. It is also found in animal matter; in short, it exists in greater or less quantity, in the mineral, vegetable, and animal kingdoms.

EMILY.

I have heard of *flowers of sulphur*, are they the produce of any plant?

MRS. B.

By no means: they consist of nothing more than common sulphur reduced to a very fine powder by a process called *sublimation.*—You see some of it in this phial; it is exactly the same substance, as this lump of sulphur, only its colour is a paler yellow, owing to its state of very minute division.

EMILY.

Pray what is sublimation?

MRS. B.

It is the evaporation, or, more properly speaking, the volatilization of solid substances, which, in cooling, condense again in a concrete form. The process, in this instance, must be performed in a closed vessel, both to prevent combustion, which would take place if the access of air was not carefully precluded, and likewise in order to collect the substance after the operation. As it is rather a slow process, we shall not try the experiment now; but you will understand it perfectly if I show you the apparatus used for the purpose.—(PLATE VIII. Fig. 18.) Some lumps of sulphur are put into a receiver of this kind, which is called a *cucurbit.* Its shape, you see, somewhat resembles that of a pear, and it is open at the top so as to adapt itself exactly to a kind of conical receiver of this sort called the head. The cucurbit, thus covered with its head, is placed over a sand-bath; this is nothing more than a vessel full of sand, which is kept heated by a furnace, such as you see here, so as to preserve the apparatus in a moderate and uniform temperature. The sulphur then soon begins to melt, and immediately after this, a thick white smoke rises, which is gradually deposited within the head, or upper part of the apparatus, where it condenses against the sides, somewhat in the form of a vegetation, whence it has obtained the name of flowers of sulphur. This apparatus, which is called an *alembic*, is highly useful in all kinds of distillations, as you will see when we come to treat of those operations. Alembics are not commonly made of glass, like this, which is applicable only to distillations upon a very small scale. Those used in manufactures are generally made of copper, and

Fig. 18.

Sublimation of Sulphur.

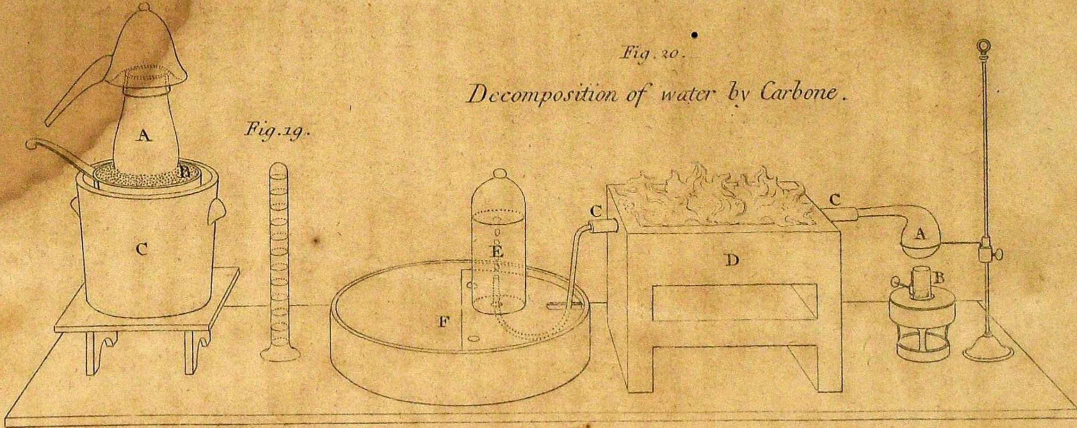


Fig. 18 A Alembic. _ B Sand-bath. _ C Furnace. _ Fig. 19 Eudiometer. _ Fig. 20 A Retort containing water. _ B Lamp to heat the water. _ C.C Porcelain tube containing Carbone. _ D Furnace through which the tube passes. _ E Receiver for the gas produced. _ F Water bath.

Drawn by the Author. Engraved by Lowry.

Published by Longman & Co. Decr. 2nd 1806

are, of course, considerably larger. The principal construction, however, is always the same, although their shape admits of some variation.

CAROLINE.

What is the use of that neck, or tube, which bends down from the upper piece of the apparatus?

MRS. B.

It is of no use in sublimations; but in distillations (the general object of which is to evaporate, by heat, in closed vessels, the volatile parts of a compound body, and to condense them again into a liquid), it serves to carry off the condensed fluid, which otherwise would fall back into the cucurbit. But this is rather foreign to our present subject. Let us return to the sulphur. You now perfectly understand, I suppose, what is meant by sublimation?

EMILY.

I believe I do. Sublimation appears to consist in destroying, by means of heat, the attraction of aggregation of the particles of a solid body, which are thus volatilized; and as soon as they lose the caloric which produced that effect, they are deposited in the form of a fine powder.

CAROLINE.

It seems to me to be somewhat similar to the transformation of water into vapour, which returns to its liquid state when deprived of caloric.

EMILY.

There is this difference, however, that the sulphur does not return to its former state, since, instead of lumps, it changes to a fine powder.

MRS. B.

Chemically speaking, it is exactly the same substance, whether in the form of lump or powder. For if this powder be melted again by heat, and then suffered to cool, it will be restored to the same solid state in which it was before its sublimation.

CAROLINE.

But if there be no real change, produced by the sublimation of the sulphur, what is the use of that operation?

MRS. B.

It divides the sulphur into very minute parts, and thus disposes it to enter more readily into combination with other bodies. It is used also as a means of purification.

CAROLINE.

Sublimation appears to me like the beginning of a combustion, for the completion of which one circumstance only is wanting, the absorption of oxygen.

MRS. B.

But that circumstance is every thing. No essential alteration is produced in sulphur by sublimation; whilst in combustion it combines with the oxygen and forms a new compound totally different in every respect from sulphur in its pure state.—We shall now *burn* some sulphur, and you will see how very different the result will be. For this purpose I put a small quantity of flowers of sulphur into this cup, and place it in a dish, into which I have poured a little water; I now set fire to the sulphur with the point of this hot wire; for its combustion will not begin unless its temperature be considerably raised.—You see it begins to burn with a faint blueish flame; and as I invert over it this receiver, white fumes arise from the sulphur and fill the receiver.—You will soon perceive that the water is rising within the receiver, a little above its level in the plate.—Well, Emily, can you account for this?

EMILY.

I suppose that the sulphur has absorbed the oxygen from the atmospherical air within the receiver; and that we shall find some oxygenated sulphur in the cup. As for the white smoke, I am quite at a loss to guess what it may be.

MRS. B.

Your first conjecture is very right; but you are quite mistaken in the last; for nothing will be left in the cup. The white vapour is the oxygenated sulphur, which assumes the form of an elastic fluid of a pungent and offensive smell, and is a powerful acid. Here you see a chemical combination of oxygen and sulphur, producing a true gas, which would continue such under the pressure and at the temperature of the atmosphere, if it did not unite with the water in the plate, to which it imparts its acid taste and all its acid properties.—You see, now, with what curious effects the combustion of sulphur is attended.

CAROLINE.

This is something quite new; and I confess that I do not perfectly understand why the sulphur turns acid.

MRS. B.

It is because it unites with oxygen, which is the general acidifying principle. And, indeed, the word *oxygen*, is derived from two Greek words signifying *to generate an acid.*

CAROLINE.

Why then is not water, which contains such a quantity of oxygen, acid?

MRS. B.

Because hydrogen, which is the other constituent of water, is not susceptible of acidification.—I believe it will be necessary, before we proceed further, to say a few words of the general nature of acids, though it is rather a deviation from our plan of examining the simple bodies separately, before we consider them in a state of combination.

Acids may be considered as a peculiar class of *burnt* bodies, which, during their combustion, or combination with oxygen, have acquired very characteristic properties. They are chiefly discernible by their sour taste, and by turning red most of the blue vegetable colours. These two properties are common to the whole class of acids; but each of them is distinguished by other peculiar qualities. Every acid consists of some particular substance (which constitutes its basis, and is different in each), and of oxygen, which is common to them all.

EMILY.

But I do not clearly see the difference between acids and oxyds?

MRS. B.

Acids were, in fact, oxyds, which, by the addition of a sufficient quantity of oxygen, have been converted into acids. For acidification, you must observe, always implies previous oxydation, as a body must have combined with the quantity of oxygen requisite to constitute it an oxyd, before it can combine with the greater quantity that is necessary to render it an acid.

CAROLINE.

Are all oxyds capable of being converted into acids?

MRS. B.

Very far from it; it is only certain substances which will enter into that peculiar kind of union with oxygen that produces acids, and the number of these is proportionally very small; but all burnt bodies may be considered as belonging either to the class of oxyds, or to that of acids. At a future period, we shall enter more at large into this subject. At present, I have but one circumstance further to point out to your observation respecting acids: it is, that most of them are susceptible of two degrees of acidification, according to the different quantities of oxygen with which their basis combines.

EMILY.

And how are these two degrees of acidification distinguished?

MRS. B.

By the peculiar properties that result from them. The acid we have just made is the first or weakest degree of acidification, and is called *sulphureous acid*; if it were fully saturated with oxygen, it would be called *sulphuric acid*. You must therefore remember, that in this, as in all acids, the first degree of acidification is expressed by the termination in *ous*; the stronger, by the termination in *ic*.

CAROLINE.

And how is the sulphuric acid made?

MRS. B.

By burning sulphur in pure oxygen gas, and thus rendering its combustion much more complete. I have provided some oxygen gas for this purpose; it is in that bottle, but we must first decant the gas into the glass receiver which stands on the shelf in the bath, and is full of water.

CAROLINE.

Pray, let me try to do it, Mrs. B.?

MRS. B.

It requires some little dexterity—hold the bottle completely under water, and do not turn the mouth upwards, till it is immediately under the aperture in the shelf, through which the gas is to pass into the receiver, and then turn it up gradually.—Very well, you have only let a few bubbles escape, and that must be expected at a first trial.—Now I shall put this piece of sulphur into the receiver, through the opening at the top, and introduce along with it a small piece of lighted tinder to set fire to it.—This requires being done very quickly, lest the atmospherical air should get in, and mix with the pure oxygen gas.

EMILY.

How beautifully it burns!

CAROLINE.

But it is already buried in the thick vapour. This I suppose is sulphuric acid?

EMILY.

Are these acids always in a gaseous state?

MRS. B.

Sulphureous acid, as we have already observed, is a permanent gas, and can be obtained in a liquid form only by condensing it in water. In its pure state, the sulphureous acid is invisible, and it appears in the form of a white smoke, only from its combining with the moisture which it meets with in the atmosphere. But the vapour of sulphuric acid, which you have just seen to rise during the combustion, is not a gas, but only a vapour, which condenses into liquid sulphuric acid, merely by losing its caloric. And this condensation is much hastened and promoted by receiving the vapour into cold water, which may afterwards be separated from the acid by evaporation.

Before we quit the subject of sulphur, I must tell you that it is susceptible of combining with a great variety of substances, and especially with hydrogen, with which you are already acquainted. Hydrogen gas can dissolve a small portion of it.

EMILY.

What; can a gas dissolve a solid substance?

MRS. B.

Yes; a solid substance may be so minutely divided by heat, as to become soluble in a gas; and there are several instances of it. But you must observe that, in this case, a chemical solution, that is to say, a combination of the sulphur with the hydrogen gas, is produced. In order to effect this, the sulphur must be strongly heated in contact with the gas; the heat reduces the sulphur to such a state of extreme division, and diffuses it so thoroughly through the gas, that they combine and incorporate together. And as a proof that there must be a chemical union between the sulphur and the gas, it is sufficient to remark that they are not separated when the sulphur loses the caloric by which it was volatilized. Besides, it is evident, from the peculiar fetid smell of this gas, that it is a new compound totally different from either of its constituents; it is called *sulphurated hydrogen gas*, and is contained in great abundance in sulphureous mineral waters.

CAROLINE.

Are not the Harrogate waters of this nature?

MRS. B.

Yes; they are naturally impregnated with sulphurated hydrogen gas, and there are many other springs of the same kind; which shows that this gas must often be formed in the bowels of the earth by spontaneous processes of nature.

CAROLINE.

And could not such waters be made artificially by impregnating common water with this gas?

MRS. B.

Yes; they can be so well imitated as perfectly to resemble the Harrogate waters.

Sulphur combines likewise with phosphorus, and with the alkalies, and alkaline earths, substances with which you are yet unacquainted. We cannot, therefore, enter into these combinations at present. In our next lesson we shall treat of phosphorus.

EMILY.

May we not begin that subject to-day; this lesson has been so short?

MRS. B.

I have no objection, if you are not tired. What do you say, Caroline?

CAROLINE.

I am as desirous as Emily of prolonging the lesson to-day, especially as we are to enter on a new subject; for I confess that sulphur has not appeared to me so interesting as the other simple bodies.

MRS. B.

Perhaps you may find phosphorus more entertaining. You must not, however, be discouraged when you meet with some parts of a study less amusing than others; it would answer no good purpose to select the most pleasing parts, since, if we did not proceed with some method, in order to acquire a general idea of the whole, we could scarcely expect to take any interest in particular subjects.

PHOSPHORUS.

PHOSPHORUS is a simple substance that was formerly unknown. It was first discovered by Brandt, a chemist of Hamburgh, whilst employed in researches after the philosopher's stone; but the method of obtaining it remained a secret till it was a second time discovered both by Kunckel and Boyle, in the year 1680. You see a specimen of phosphorus in this phial; it is generally moulded into small sticks of a yellowish colour, as you find it here.

CAROLINE.

I do not understand in what the discovery consisted; there may be a secret method of making a composition, but a simple body cannot be *made*, it can only be *found*.

MRS. B.

But a body may exist in nature so closely combined with other substances, as to elude the observation of chemists, or render it extremely difficult to obtain it in its simple state. This is the case with phosphorus, which is always so intimately combined with other substances, that its existence remained unnoticed till Brandt discovered the means of obtaining it free from all combinations. It is found in all animal substances, and is now chiefly extracted from bones, by a chemical process. It exists also in some plants, that bear a strong analogy to animal matter in their chemical composition.

EMILY.

But is it never found in its simple state?

MRS. B.

Never, and this is the reason of its having remained so long undiscovered.

EMILY.

It is possible, then, that in course of time we may discover other new simple bodies?

MRS. B.

Undoubtedly; and we may also learn that some of those, which we now class among the simple bodies, may, in fact, be compound; indeed, you will soon find that discoveries of this kind are by no means unfrequent.

Phosphorus is eminently combustible; it melts and takes fire at the temperature of 100°, and absorbs in its combustion nearly once and a half its own weight of oxygen?

CAROLINE.

What! will a pound of phosphorus consume a pound and a half of oxygen?

MRS. B.

So it appears from accurate experiments. I can show you with what violence it combines with oxygen, by burning some of it in that gas. We must manage the experiment in the same manner as we did the combustion of sulphur.—You see I am obliged to cut this little bit of phosphorus under water, otherwise there would be danger of its taking fire by the heat of my fingers.—I now put it into the receiver, and kindle it by means of a hot wire.

EMILY.

What a blaze! I can hardly look at it. I never saw any thing so brilliant. Does it not hurt your eyes, Caroline?

CAROLINE.

Yes; but still I cannot help looking at it. A prodigious quantity of oxygen must indeed be absorbed, when so much light and caloric are disengaged!

MRS. B.

In the combustion of a pound of phosphorus, a sufficient quantity of caloric is set free to melt upwards of a hundred pounds of ice; this has been computed by direct experiments with the calorimeter.

EMILY.

And is the result of this combustion, like that of sulphur, an acid?

MRS. B.

Yes; phosphoric acid. And had we duly proportioned the phosphorus and the oxygen, they would have been completely converted into phosphoric acid, weighing together, in this new state, exactly the sum of their weights separately. The water would have ascended into the receiver, on account of the vacuum formed, and would have filled it entirely. In this case, as in the combustion of sulphur, the acid vapour formed is absorbed and condensed in the water of the receiver. But when this combustion is performed without any water or moisture being present, the acid then appears in the form of concrete whitish flakes, which are, however, extremely ready to melt upon the least admission of moisture.

EMILY.

Does phosphorus, in burning in atmospherical air, produce, like sulphur, a weaker sort of the same acid?

MRS. B.

No: for it burns in atmospherical air nearly at the same temperature, as in pure oxygen gas; and it is, in both cases, so strongly disposed to combine with the oxygen, that the combustion is perfect, and the product similar; only in atmospherical air, being less rapidly supplied with oxygen, the process is performed in a slower manner.

CAROLINE.

But is there no method of acidifying phosphorus in a slighter manner, so as to form *phosphorous* acid?

MRS. B.

Yes, there is. When simply exposed to the atmosphere, phosphorus undergoes a kind of slow combustion at any temperature above zero.

EMILY.

But is not the process in this case rather an oxydation than a combustion? For if the oxygen is too slowly absorbed for a sensible quantity of light and heat to be disengaged, it is not a true combustion.

MRS. B.

The case is not as you suppose; a faint light is emitted which is very discernible in the dark; but the heat evolved is not sufficiently strong to be sensible; a whitish vapour arises from this combustion, which uniting with water, condenses into liquid phosphorous acid.

CAROLINE.

Is it not very singular that phosphorus should burn at so low a temperature in atmospherical air, whilst it does not burn in pure oxygen without the application of heat?

MRS. B.

So it at first appears. But this circumstance seems to be owing to the nitrogen gas of the atmosphere. This gas dissolves small particles of phosphorus, which being thus minutely divided and diffused in the atmospherical air, combines with the oxygen, and undergoes this slow combustion. But the same effect does not take place in oxygen gas, because it is not capable of dissolving phosphorus; it is therefore necessary, in this case, that heat should be applied to effect that division of particles, which, in the former instance, is produced by the nitrogen.

EMILY.

I have seen letters written with phosphorus, which are invisible by day-light, but may be read in the dark by their own light. They look as if they were written with fire; yet they do not seem to burn.

MRS. B.

But they do really burn; for it is by their slow combustion that the light is emitted; and phosphorous acid is the result of this combustion.

Phosphorus is sometimes used as a test to estimate the purity of atmospherical air. For this purpose, it is burnt in a graduated tube called an *eudiometer* (PLATE VIII. Fig. 19), and from the quantity of air which the phosphorus absorbs, the proportion of oxygen in the air examined, is deduced; for the phosphorus will absorb all the oxygen, and the nitrogen alone will remain.

EMILY.

And the more oxygen is contained in the atmosphere, the purer, I suppose, it is esteemed?

MRS. B.

Certainly. Phosphorus, when melted, combines with a great variety of substances. With sulphur it forms a compound so extremely combustible, that it immediately takes fire on coming in contact with the air. It is with this composition that the phosphoric matches are prepared, which kindle as soon as they are taken out of their case and are exposed to the air.

EMILY.

I have a box of these curious matches; but I have observed, that in very cold weather, they will not take fire without being previously rubbed.

MRS. B.

By rubbing them you raise their temperature; for, you know, friction is one of the means of extricating heat.

EMILY.

Will phosphorus combine with hydrogen gas, as sulphur does?

MRS. B.

Yes; and the compound gas which results from this combination has a smell still more fetid than the sulphurated hydrogen; it resembles that of garlic.

The *phosphorated hydrogen gas* has this remarkable peculiarity, that it takes fire spontaneously in the atmosphere, at any temperature. It is thus that are produced those transient flames, or flashes of light, called by the vulgar *Will-of-the-Wisp*, or more properly *Ignes-fatui*, which are often seen in church-yards, and places where the putrefaction of animal matter exhales phosphorus and hydrogen gas.

CAROLINE.

Country people, who are so much frightened by those appearances, would soon be reconciled to them, if they knew from what a simple cause they proceed.

MRS. B.

There are other combinations of phosphorus that have also very singular properties, particularly that which results from its union with lime.

EMILY.

Is there any name to distinguish the combination of two simple substances, like phosphorus and lime, neither of which are oxygen, and which therefore can produce neither an oxyd nor an acid?

MRS. B.

The names of such combinations are composed from those of their ingredients, merely by a slight change in their termination. Thus we call the combination of sulphur with lime a *sulphuret*, and that of phosphorus, a *phosphoret of lime*. This latter compound, I was going to say, has the singular property of decomposing water, merely by being thrown into it. It effects this by absorbing the oxygen of water, in consequence of which bubbles of hydrogen gas ascend, holding in solution a small quantity of phosphorus.

EMILY.

These bubbles then are *phosphorated hydrogen gas?*

MRS. B.

Yes; and they produce the singular appearance of a flash of fire issuing from water, as the bubbles kindle and detonate on the surface of the water, at the instant that they come in contact with the atmosphere.

CAROLINE.

Is not this effect nearly similar to that produced by the combination of phosphorus and sulphur, or, more properly speaking, the *phosphoret of sulphur?*

MRS. B.

Yes; but the phenomenon appears more extraordinary in this case, from the presence of water and from the gaseous form of the combustible compound. Besides, the experiment surprises by its great simplicity. You only throw a piece of phosphoret of lime into a glass of water, and bubbles of fire will immediately issue from it.

CAROLINE.

Cannot we try the experiment?

MRS. B.

Very easily: but we must do it in the open air; for the smell of the phosphorated hydrogen gas is so extremely fetid, that it would be intolerable in the house. But before we leave the room, we may produce, by another process, some bubbles of phosphorated hydrogen gas, which are much less offensive.

There is in this little glass retort a solution of potash in water; I add to it a small piece of phosphorus. We must now heat the retort over the lamp, after having engaged its neck under water—you see it begins to boil; in a few minutes bubbles will appear, which take fire and detonate as they issue from the water.

CAROLINE.

There is one—and another. How curious it is!—But I do not understand how this is produced?

MRS. B.

It is the consequence of a display of affinities too complicated, I fear, to be made perfectly intelligible to you at present.

In a few words, the reciprocal action of the potash, phosphorus, caloric, and water, are such that some of the water is decomposed, and the hydrogen gas thereby formed carries off some minute particles of phosphorus, with which it forms phosphorated hydrogen gas, a compound which spontaneously takes fire at almost any temperature.

EMILY.

What is that circular ring of smoke which slowly rises from each bubble after its detonation?

MRS. B.

It consists of water and phosphoric acid in vapour, which are produced by the combustion of the hydrogen and phosphorus.

CONVERSATION VIII.

ON CARBONE.

CAROLINE.

To-day, Mrs. B—, I believe we are to learn the nature and properties of CARBONE. This substance is quite new to me; I never heard it mentioned before.

MRS. B.

Not so new as you imagine; for carbone is nothing more than charcoal in a state of perfect purity.

CAROLINE.

But charcoal is made by art, Mrs. B—, and a body consisting of one simple substance cannot be fabricated?

MRS. B.

You again confound the idea, of making a simple body, with that of separating it from a compound. The chemical processes by which a simple body is obtained in a state of purity, consist in *unmaking* the compound in which it is contained, in order to separate from it the simple substance in question. The method by which charcoal is usually obtained, is, indeed, commonly called *making* it; but, upon examination, you will find this process to consist in separating it from other substances with which it is found combined in nature.

Charcoal forms a considerable part of the solid matter of all organized bodies; but it is most abundant in the vegetable creation, and it is chiefly obtained from wood. When the oil and water (which are other constituents of vegetable matter) are evaporated, the black, porous, brittle substance that remains, is charcoal.

CAROLINE.

But if heat is applied to the wood in order to evaporate the oil and water, will not the temperature of the charcoal be raised so as to make it burn; and if it combines with oxygen, can we any longer call it pure?

MRS. B.

I was going to say, that, in this operation, the air must be excluded.

CAROLINE.

How then can the vapour of the oil and water fly off?

MRS. B.

In order to produce charcoal in its purest state (which is, even then, but a less imperfect sort of carbone), the operation should be performed in an earthen retort. Heat being applied to the body of the retort, the evaporable parts of the wood will escape through its neck, into which no air can penetrate as long as the heated vapour continues to escape. And if it be wished to collect these volatile products of the wood, this can easily be done by introducing the neck of the retort into the water-bath apparatus, with which you are acquainted. But the preparation of common charcoal, such as is used in kitchens and manufactures, is performed on a much larger scale, and by a much easier and less expensive process.

EMILY.

I have seen the process of making common charcoal. The wood is ranged on the ground in a pile of a pyramidical form, with a fire underneath; the whole is then covered with clay, a few holes only being left for the circulation of air.

MRS. B.

These holes are closed as soon as the wood is fairly lighted, so that the combustion is checked, or at least continues but in a very imperfect manner; but the heat, produced by it, is sufficient to force out and volatilize, through the earthy cover, most part of the oily and watery principles of the wood, although it cannot reduce it to ashes.

EMILY.

Is pure carbone as black as charcoal?

MRS. B.

The more charcoal is purified, that is to say, the nearer it approaches to the state of simple carbone, the deeper its black colour appears; but the utmost efforts of chemical art, are not able to bring it to its perfect elementary state; for in that state it is both colourless and transparent, and as different in appearance from charcoal as any substance can possibly be. This ring, which I wear on my finger, owes its brilliancy to a small piece of carbone.

CAROLINE.

Surely, you are jesting, Mrs. B.?

EMILY.

I thought that your ring was diamond?

MRS. B.

It is so. But diamond is nothing more than carbone in its purest and most perfect state.

EMILY.

That is astonishing! Is it possible to see two things apparently more different than diamond and charcoal?

CAROLINE.

It is, indeed, curious to think that we adorn ourselves with jewels of charcoal!

MRS. B.

When you are better acquainted with the nature of crystallization, in which state bodies are generally the purest, you will more readily conceive the possibility of carbone assuming the transparency and brilliancy of diamond.

There are many other substances, consisting chiefly of carbone, that are remarkably white. Cotton, for instance, is almost wholly carbone.

CAROLINE.

That, I own, I could never have imagined!—But pray, Mrs. B—, since it is known of what substance diamond and cotton are composed, why should they not be manufactured, or imitated, by some chemical process, which would render them much cheaper and more plentiful than the present mode of obtaining them?

MRS. B.

With your system, Caroline, you might as well propose that we should make flowers and fruit, nay, perhaps even animals, by a chemical process; for it is known of what these bodies consist, since every thing which we are acquainted with in nature, is formed from the various simple substances that we have enumerated. But, my dear, you must not suppose that a knowledge of the component parts of a body will in every case enable us to imitate it. It is much less difficult to decompose bodies, and discover of what materials they consist, than it is to recompose them. The first of these processes is called *analysis*, the last *synthesis*. When we are able to ascertain the nature of a substance by both these methods, so that the result of one confirms that of the other, we obtain the most complete knowledge of it that we are capable of acquiring. This is the case with water, with the atmosphere, with most of the oxyds, acids, and neutral salts, and with many other compounds. But the more complicated combinations of nature, even in the mineral kingdom, are in general beyond our reach, and any attempt to imitate organized bodies must probably ever prove fruitless; their formation is a secret that rests in the bosom of the Creator. You see, therefore, how vain it would be to attempt the formation of cotton by chemical means. But, surely, we have no reason to regret our inability in this instance, when nature has so clearly pointed out a method of obtaining it in perfection and abundance.

CAROLINE.

I did not imagine that the principle of life could be imitated by the aid of chemistry; but it did not appear to me ridiculous to suppose that chemists might attain a perfect imitation of inanimate nature.

MRS. B.

They have succeeded in this point in a variety of instances; but, as you justly observe, the principle of life, or even the minute and intimate organization of the vegetable kingdom, are secrets that have almost entirely eluded the researches of philosophers; nor do I imagine that human art will ever be capable of investigating them with complete success.

EMILY.

But diamond, since it consists merely of one simple unorganized substance, might be, one would think, perfectly imitable by art?

MRS. B.

It is sometimes as much beyond our power to obtain a simple body in a state of perfect purity, as it is to imitate a complicated combination; for the operations by which nature decomposes bodies are frequently as inimitable as those which she uses for their combination. This is the case with carbone; all the efforts of chemists to separate it entirely from other substances, have been fruitless, and in the purest state in which it can be obtained by art, it still retains a portion of oxygen, and probably of some other foreign ingredients. It is in the diamond alone, as I have observed before, that carbone exists in its perfect form: we are ignorant of the means which nature employs to bring it to that state; it may probably be the work of ages, to purify, arrange, and unite the particles of carbone in the form of diamond. And with regard to our artificial carbone, which we call charcoal, we must consider it as an oxyd of carbone; since, whatever may be the means employed for obtaining it, it always retains a small portion of oxygen. Here is some charcoal in the purest state we can procure it: you see that it is a very black, brittle, light, porous substance, entirely destitute of either taste or smell. Heat, without air, produces no alteration in it, as it is not volatile; but, on the contrary, it invariably remains at the bottom of the vessel after all the other parts are evaporated.

EMILY.

Carbone is, no doubt, combustible, since you say that charcoal would absorb oxygen if air was admitted during its preparation?

CAROLINE.

Unquestionably. Besides, you know, Emily, how much it is used in cooking. But pray what is the reason that charcoal burns without smoke, whilst a wood fire smokes so much?

MRS. B.

Because, in the conversion of wood into charcoal, the volatile particles of the former have been evaporated.

CAROLINE.

Yet I have frequently seen charcoal burn with flame; therefore it must, in that case, contain some hydrogen.

MRS. B.

Very true; but you must recollect that charcoal, especially that which is used for common purposes, is very far from being pure. It generally retains, as we have seen, not only a small quantity of oxygen, but also some remains of the various other component parts of vegetables, and hydrogen particularly, which accounts for the flame in question.

CAROLINE.

But what becomes of the carbone itself during its combustion?

MRS. B.

It gradually combines with the oxygen of the atmosphere, in the same way as sulphur and phosphorus, and, like those substances, it is converted into a peculiar acid, which flies off in a gaseous form. There is this difference, however, that the acid is not, in this instance, as in the two cases just mentioned, a mere condensable vapour, but a permanent elastic fluid, which always remains in the state of gas, under any pressure and at any temperature. The nature of this acid was first ascertained by Dr. Black, of Edinburgh; and, before the introduction of the new nomenclature, it was called *fixed air*. It is now distinguished by the more appropriate name of *carbonic acid gas*.

EMILY.

Carbone, then, can be volatilized by burning, though, by heat alone, no such effect is produced?

MRS. B.

Yes; but then it is no longer simple carbone, but an acid of which carbone forms the basis. In this state, carbone retains no more appearance of solidity or corporeal form, than the basis of any other gas. And you may, I think, from this instance, derive a more clear idea of the basis of the oxygen, hydrogen, and nitrogen gasses, the existence of which, as real bodies, you seemed to doubt, because they were not to be obtained simply in a solid form.

EMILY.

That is true; we may conceive the basis of the oxygen, and of the other gasses, to be solid, heavy substances, like carbone; but so much expanded by caloric, as to become invisible.

CAROLINE.

But does not the carbonic acid gas partake of the blackness of charcoal?

MRS. B.

Not in the least. Blackness, you know, does not appear to be essential to carbone, and it is pure carbone, and not charcoal, that we must consider as the basis of carbonic acid. We shall make some carbonic acid, and, in order to has en the process, we shall burn the carbone in oxygen gas.

EMILY.

But how can you make carbonic acid, unless you can burn diamond; since that alone is pure carbone?

MRS. B.

Charcoal will answer the purpose still better; for the carbone being, in that state, already combined with some oxygen, it will require less of that principle to complete its oxygenation.

CAROLINE.

But is it possible to burn diamond?

MRS. B.

Yes, it is; and, in order to effect this combustion, nothing more is required than to apply a sufficient degree of heat by means of the blow-pipe, and of a stream of oxygen gas. Indeed it is by burning diamond that its chemical nature has been ascertained. It is long since it has been known as a combustible substance, but it is within these few years only that the product of its combustion has been proved to be pure carbonic acid. This discovery is due to Mr. Tennant. But still more recent experiments have shown that diamond requires a greater proportion of oxygen than charcoal to be converted into carbonic acid. It appears that 15 parts of diamond require 85 parts of oxygen to form 100 parts of carbonic acid; whilst 28 parts of charcoal take up only 72 parts of oxygen to produce 100 parts of carbonic acid; from which it is naturally inferred that carbone, in the state of charcoal, is already combined with a portion of oxygen.

Now let us try to make some carbonic acid— Will you, Emily, decant some oxygen gas from this large jar into the receiver in which we are to burn the carbone; and I shall introduce this small piece of charcoal, with a little lighted tinder, which will be necessary to give the first impulse to the combustion.

EMILY.

I cannot conceive how so small a piece of tinder, and that but just lighted, can raise the temperature of the carbone sufficiently to set fire to it; for it can produce scarcely any sensible heat, and it hardly touches the carbone.

MRS. B.

The tinder thus kindled has only heat enough to begin its own combustion, which, however, soon becomes so rapid in the oxygen gas, as to raise the temperature of the charcoal sufficiently for this to burn likewise, as you see is now the case.

EMILY.

I am surprised that the combustion of carbone is not more brilliant; it does not disengage near so much light or caloric as phosphorus, or sulphur. Yet, since it combines with so much oxygen, why is not a proportional quantity of light and heat disengaged from the decomposition of the oxygen gas?

MRS. B.

It is not surprising that less light and heat should be disengaged in this than in almost any other combustion, since the oxygen, instead of entering into a solid or a liquid combination, as it does in the phosphoric and sulphuric acids, is employed in forming another elastic fluid.

EMILY.

True; and, on second consideration, it appears, on the contrary, surprising that the oxygen should, in its combination with carbone, retain a sufficient portion of caloric to maintain both substances in a gaseous state.

CAROLINE.

We may then judge of the degree of solidity in which oxygen is combined in a burnt body, by the quantity of caloric liberated during its combustion?

MRS. B.

Yes; provided that you take into the account the quantity of oxygen absorbed by the combustible body, and observe the proportion which the caloric bears to it.

CAROLINE.

But why should the water, after the combustion of carbone, rise in the receiver above its level, since the oxygen retains a gaseous state?

MRS. B.

Because carbonic acid gas is more dense, and consequently occupies less space than oxygen gas; the water therefore rises to fill the vacuum formed by the diminution of volume of the gas.

CAROLINE.

That is very clear; and the condensation of the new gas depends, I suppose, on the quantity of caloric that has been disengaged.

MRS. B.

The gas must be decreased in volume, from that circumstance, in a certain proportion; but its density is still further increased by the addition of the carbone. But besides this condensation, there is in our experiment another cause of the diminution of volume, which is, that carbonic acid gas, by standing over water, is gradually absorbed by it, an effect which is much promoted by shaking the receiver.

EMILY.

The charcoal is now extinguished, though it is not nearly consumed; it has such an extraordinary avidity for oxygen, I suppose, that the receiver did not contain enough to satisfy the whole.

MRS. B.

That is certainly the case; for if the combustion was performed in the exact proportions of 28 parts of carbone to 72 of oxygen, both these ingredients would disappear, and 100 parts of carbonic acid would be produced.

CAROLINE.

Carbonic acid must be a very strong acid, since it contains so great a proportion of oxygen?

MRS. B.

That is a very natural inference; yet it is erroneous. For the carbonic is the weakest of all the acids. The strength of an acid seems to depend upon the nature of its basis and its mode of combination, as well as upon the proportion of the acidifying principle. The same quantity of oxygen that will convert some bodies into strong acids, will only be sufficient simply to oxydate others.

CAROLINE.

Since this acid is so weak, I think chemists should have called it the *carbonous*, instead of the *carbonic* acid.

EMILY.

But, I suppose, the carbonous acid is still weaker, and is formed by burning carbone in atmospherical air.

MRS. B.

No, my dear. Carbone does not appear to be susceptible of more than one degree of acidification, whether burnt in oxygen gas, or atmospherical air. There is therefore no carbonous acid.

It has indeed been lately discovered, that carbone may be converted into a gas, by uniting with a smaller proportion of oxygen; but as this gas does not possess any acid properties, it is no more than an oxyd; and in order to distinguish it from charcoal, which contains a still smaller proportion of oxygen, it is called *gaseous oxyd of carbone.*

CAROLINE.

Pray is not carbonic acid a very wholesome gas to breathe, as it contains so much oxygen?

MRS. B.

On the contrary, it is extremely pernicious. Oxygen, when in a state of combination with other substances, loses, in almost every instance, its respirable properties, and the salubrious effects which it has on the animal economy when in its uncombined state. Carbonic acid is not only unfit for respiration, but extremely deleterious if taken into the lungs.

EMILY.

You know, Caroline, how very unwholesome the fumes of burning charcoal are reckoned.

CAROLINE.

Yes; but, to confess the truth, I did not consider that a charcoal fire produced carbonic acid gas.—Pray, can this gas be condensed into a liquid?

MRS. B.

No: for, as I told you before, it is a permanent elastic fluid. But water can absorb a certain quantity of this gas, and can even be impregnated with it, in a very strong degree, by the assistance of agitation and pressure, as I am going to show you. I shall decant some carbonic acid gas into this bottle, which I fill first with water, in order to exclude the atmospherical air; the gas is then introduced through the water, which you see it displaces, for it will not mix with it in any quantity unless strongly agitated, or allowed to stand over it for some time. The bottle is now about half full of carbonic acid gas, and the other half is still occupied by the water. By corking the bottle, and then violently shaking it, in this way, I can mix the gas and water together.—Now will you taste it?

EMILY.

It has a distinct acid taste.

CAROLINE.

Yes, it is sensibly sour, and appears full of little bubbles.

MRS. B.

It possesses likewise all the other properties of acids, but of course in a less degree than the pure carbonic acid gas, as it is so much diluted by water.

This is a kind of artificial Seltzer water. By analysing that which is produced by nature, it was found to contain scarcely any thing more than common water impregnated with a certain proportion of carbonic acid gas. We are, therefore, able to imitate it, by mixing those proportions of water, and carbonic acid. Here, my dear, is an instance, in which, by a chemical process, we can exactly copy the operations of nature; for the artificial Seltzer waters can be made in every respect similar to those of nature: in one point, indeed, the former have an advantage, as they may be prepared stronger, or weaker, as occasion requires.

CAROLINE.

I thought I had tasted such water before. But what renders it so brisk and sparkling?

MRS. B.

This sparkling, or effervescence, as it is called, is always occasioned by the action of an elastic fluid escaping from a liquid; in the artificial Seltzer water it is produced by the carbonic acid, which being lighter than the water in which it was strongly condensed, flies off with great rapidity the instant the bottle is uncorked; this makes it necessary to drink it immediately. The bubbling that took place in this bottle was but trifling, as the water was but very slightly impregnated with carbonic acid. It requires a particular apparatus to prepare the gaseous artificial mineral waters.

EMILY.

If, then, a bottle of Seltzer water remains for any length of time uncorked, I suppose it returns to the state of common water?

MRS. B.

The whole of the carbonic acid gas, or very nearly so, will soon disappear; but there is likewise in Seltzer water a very small quantity of soda, and of a few other saline or earthy ingredients, which will remain in the water, though it should be kept uncorked for any length of time.

CAROLINE.

I have often heard of people drinking soda-water. Pray what sort of water is that?

MRS. B.

It is a kind of artificial Seltzer water, holding in solution, besides the gaseous acid, a particular saline substance, called soda, which imparts to the water certain medicinal qualities.

CAROLINE.

But how can these waters be so wholesome, since carbonic acid is so pernicious?

MRS. B.

What may be very prejudicial to breathe, may be very beneficial to the stomach.—But it would be of no use to attempt explaining this more fully at present.

CAROLINE.

Are waters never impregnated with other gasses?

MRS. B.

Yes; there are several kinds of gaseous waters. I forgot to tell you that waters have for some years past been prepared, impregnated both with oxygen and with hydrogen gasses. These are not an imitation of nature, but are altogether obtained by artificial means. They have been lately used medicinally, particularly abroad, where, I understand, they have acquired some reputation.

EMILY.

If I recollect right, Mrs. B., you told us that carbone was capable of decomposing water; the affinity between oxygen and carbone must therefore be greater than between oxygen and hydrogen?

MRS. B.

Yes; but this is not the case unless their temperature be raised to a certain degree. It is only when carbone is red hot, that it is capable of separating the oxygen from the hydrogen. Thus, if a small quantity of water be thrown on a red hot fire, it will increase, rather than extinguish the combustion; for the coals or wood (both of which contain a great quantity of carbone) decompose the water, and thus supply the fire both with oxygen and hydrogen gasses. If, on the contrary, a large mass of water be thrown over the fire, the diminution of heat thus produced is such that the combustible matter loses the power of decomposing the water, and the fire is extinguished.

EMILY.

I have heard that fire-engines sometimes do more harm than good, and that they actually increase the fire when they cannot throw water enough to extinguish it. It must be owing, no doubt, to the decomposition of the water by the carbone during the conflagration.

MRS. B.

Certainly.—The apparatus which you see here (PLATE VIII. Fig. 20.) may be used to exemplify what we have just said. It consists in a kind of open furnace, through which a porcelain tube, containing charcoal, passes. To one end of the tube is adapted a glass retort with water in it; and the other end communicates with a receiver placed on the water-bath.—A lamp being applied to the retort, and the water made to boil, the vapour is gradually conveyed through the red hot charcoal, by which it is decomposed; and the hydrogen gas which results from this decomposition is collected in the receiver. But the hydrogen thus obtained is far from being pure; it retains in solution a minute portion of carbone, and contains also a quantity of carbonic acid. This renders it heavier than pure hydrogen gas, and gives it some peculiar properties: it is distinguished by the name of *carbonated hydrogen gas.*

CAROLINE.

And whence does it obtain the carbonic acid that is mixed with it?

EMILY.

I believe I can answer that question, Caroline.—From the union of the oxygen (proceeding from the decomposed water) with the carbone, which, you know, makes carbonic acid.

CAROLINE.

True; I should have recollected that.—The product of the decomposition of water by red hot charcoal, therefore, is carbonated hydrogen gas and carbonic acid gas.

MRS. B.

You are perfectly right now.

Carbone is frequently found combined with hydrogen in a state of solidity, especially in coals, which owe their combustible nature to these two principles.

EMILY.

Is it the hydrogen, then, that produces the flame of coals?

MRS. B.

It is so; and when all the hydrogen is consumed, the carbone continues to burn without flame. But again, the hydrogen gas produced by the combustion of coals is not pure; for, during the combustion, particles of carbone are successively volatilized with the hydrogen, with which they form what is called a *hydro-carbonate*, which is the essential combustible part of coals.

Carbone is a very bad conductor of heat; for this reason, it is employed (in conjunction with other ingredients) for coating furnaces and other chemical apparatus.

EMILY.

Pray what is the use of coating furnaces?

MRS. B.

In most cases, in which a furnace is used, it is necessary to produce and preserve a great degree of heat, for which purpose every possible means are used to prevent the heat from escaping by communicating with other bodies, and this object is attained by coating over the inside of the furnace with a kind of plaister, composed of materials that are bad conductors of heat.

Carbone, combined with a small quantity of iron, forms a compound called plumbago, or black lead, of which pencils are made. This substance, agreeably to the new nomenclature, is *a carburet of iron.*

CAROLINE.

Why, then, is it called black lead?

MRS. B.

I really cannot say; but it is certainly a most improper name for it, as there is not a particle of lead in the composition. There is another carburet of iron, in which the iron, though united only to an extremely small proportion of carbone, acquires very remarkable properties; this is steel.

CAROLINE.

Really; and yet steel is much harder than iron?

MRS. B.

But carbone is not ductile, like iron, and therefore may render the steel more brittle, and prevent its bending so easily. Whether it is that the carbone, by introducing itself into the pores of the iron, and, by filling them, renders the metal both harder and heavier; or whether this change depends upon some chemical cause, I cannot pretend to decide. But there is a subsequent operation, by which the hardness of steel is very much increased, which simply consists in heating the steel till it is red hot, and then plunging it into cold water; this is called *tempering*.

Carbone, besides the combination just mentioned, enters into the composition of a vast number of natural productions, such, for instance, as all the various kinds of oils, which result from the combination of carbone, hydrogen, and caloric, in various proportions.

EMILY.

I thought that carbone, hydrogen, and caloric, formed carbonated hydrogen gas?

MRS. B.

That is the case when a small portion of carbonic acid gas is held in solution by hydrogen gas. Different proportions of the same principles, together with the circumstances of their union, produce very different combinations; of this you will see innumerable examples. Besides, we are not now talking of gasses, but of carbone and hydrogen, combined only with a quantity of caloric sufficient to bring them to the consistency of oil or fat.

CAROLINE.

But oil and fat are not of the same consistence?

MRS. B.

Fat is only congealed oil; or oil, melted fat. The one requires a little more heat to maintain it in a fluid state, than the other. Have you never observed the fat of meat turned to oil by the caloric it has imbibed from the fire?

EMILY.

Yet oils in general, as sallad oil, and lamp oil, do not turn to fat when cold?

MRS. B.

Not at the common temperature of the atmosphere, because they retain too much caloric to congeal at that temperature; but if exposed to a sufficient degree of cold, their latent heat is extricated, and they become solid fat substances. Have you never seen sallad oil frozen in winter?

EMILY.

Yes; but it appears to me in that state very different from animal fat.

MRS. B.

The essential constituent parts of either vegetable or animal oils are the same, carbone and hydrogen; their variety arises from the different proportions of these substances, and from other accessory ingredients that may be mixed with them. The oil of a whale, and the oil of roses, are, in their essential constituent parts, the same; but the one is impregnated with the offensive particles of animal matter, the other with the delicate perfume of a flower.

The difference of *fixed oils*, and *volatile* or *essential oils*, consists also in the various proportions of carbone and hydrogen. Fixed oils are those which will not evaporate without being decomposed; this is the case with all the common oils, which contain a greater proportion of carbone than the essential oils. The essential oils (which comprehend the whole class of essences and perfumes) are lighter; they contain more equal proportions of carbone and hydrogen, and are volatilized or evaporated without being decomposed.

EMILY.

When you say that one kind of oil will evaporate, and the other be decomposed, you mean, I suppose, by the application of heat?

MRS. B.

Not necessarily; for there are oils that will evaporate slowly at the common temperature of the atmosphere; but for a more rapid volatilization, or for their decomposition, the assistance of heat is required.

CAROLINE.

I shall now remember, I think, that fat and oil are really the same substances, consisting both of carbone and hydrogen; that in fixed oils the carbone preponderates, and heat produces a decomposition; while, in essential oils, the proportion of hydrogen is greater, and heat produces a volatilization only.

EMILY.

I suppose the reason why oil burns so well in lamps, is because its two constituents are so combustible?

MRS. B.

Certainly; the combustion of oil is just the same as that of a candle; if tallow, it is only oil in a concrete state; if wax, or spermaceti, its chief chemical ingredients are still hydrogen and carbone.

EMILY.

I wonder, then, there should be so great a difference between tallow and wax?

MRS. B.

I must again repeat that the same substances, in different proportions, produce results that have sometimes scarcely any resemblance to each other. But this is rather a general remark that I wish to impress upon your minds, than one which is applicable to the present case; for tallow and wax are far from being very dissimilar; the chief difference consists in the wax being a more pure compound of carbone and hydrogen than the tallow, which retains more of the gross particles of animal matter. The combustion of a candle, and that of a lamp, both produce water and carbonic acid gas. Can you tell me how these are formed?

EMILY.

Let me think .... Both the candle and lamp burn by means of fixed oil—this is decomposed as the combustion goes on; and the constituent parts of the oil being thus separated, the carbone unites to a portion of oxygen from the atmosphere to form carbonic acid gas, whilst the hydrogen combines with another portion of oxygen, and forms with it water. —The products, therefore, of the combustion of oils, are water and carbonic acid gas.

CAROLINE.

But we see neither water nor carbonic acid produced by the combustion of a candle?

MRS. B.

The carbonic acid gas, you know, is invisible, and the water being in a state of vapour, is so likewise. Emily is perfectly correct in her explanation, and I am very much pleased with it.

All the vegetable acids consist of various proportions of carbone and hydrogen, acidified by oxygen. Gums, sugar, and starch, are likewise composed of these ingredients; but, as the oxygen which they contain is not sufficient to convert them into acids, they are classed with the oxyds, and called vegetable oxyds.

EMILY.

I am very much delighted with all these new ideas; but, at the same time, I cannot help being apprehensive that I may forget many of them.

MRS. B.

I would advise you to take notes, or, what would answer better still, to write down, after every lecture, as much of it as you can recollect. And, in order to give you a little assistance, I shall lend you the heads or index, which I occasionally consult for the sake of preserving some method and arrangement in these conversations. Unless you follow some such plan, you cannot expect to retain nearly all that you learn, how great soever be the impression it may make on you at first.

EMILY.

I will certainly follow your advice.—Hitherto I have found that I recollected pretty well what you have taught us; but the history of carbone is a more extensive subject than any of the simple bodies we have yet examined.

MRS. B.

I have little more to say on carbone at present, but hereafter you will see that it performs a considerable part in most chemical operations.

CAROLINE.

That is, I suppose, owing to its entering into the composition of so great a variety of substances?

MRS. B.

Certainly; it is the basis, you have seen, of all vegetable matter; and you will find that it is very essential to the process of animalization. But in the mineral kingdom also, particularly in its form of carbonic acid, we shall often discover it combined with a great variety of substances.

In chemical operations, carbone is particularly useful, from its very great attraction for oxygen, as it will absorb this substance from many oxygenated or burnt bodies, and thus deoxygenate, or *unburn*, them, and restore them to their original combustible state.

CAROLINE.

I do not understand how a body can be *unburnt*, and restored to its original state. This piece of tinder, for instance, that has been burnt, if by any means the oxygen was extracted from it, would not be restored to its former state of linen; for its texture is destroyed by burning, and that must be the case with all organized or manufactured substances, as you observed in a former conversation.

MRS. B.

A compound body is decomposed by combustion, in a way which generally precludes the possibility of restoring it to its former state; the oxygen, for instance, does not become fixed in the tinder, but it combines with its volatile parts, and flies off in the shape of gas, or watery vapour. You see, therefore, how vain it would be to attempt the recomposition of such bodies. But, with regard to simple bodies, or at least bodies whose constituents are not disturbed by the process of oxygenation or deoxygenation, it is often possible to restore them, after combustion, to their original state.—The metals, for instance, undergo no other alteration by combustion than a combination with oxygen; therefore, when the oxygen is taken from them, they return to their pure metallic state. But I shall say nothing further of this at present, as the metals will furnish ample subject for another morning; and they are the class of simple bodies that come next under our consideration.

CONVERSATION IX.

ON METALS.

MRS. B.

THE METALS, which we are now to examine, are bodies of a very different nature from those which we have hitherto considered. They do not, like the elements of gasses, elude the immediate observation of our senses; for they are the most brilliant, the most ponderous, and the most palpable substances in nature.

CAROLINE.

I doubt, however, whether the metals will appear to us so interesting, and give us so much entertainment as those mysterious elements which conceal themselves from our view. Besides, they cannot afford so much novelty; they are bodies with which we are already so well acquainted.

MRS. B.

But that acquaintance, you will soon perceive, is but very superficial; and I trust that you will find both novelty and entertainment in considering the metals in a chemical point of view. To treat of this subject fully, would require a whole course of lectures; for metals form of themselves a most important branch of practical chemistry. We must, therefore, confine ourselves to a general view of them. These bodies are seldom found naturally in their metallic form; they are generally more or less oxygenated or combined with sulphur, earths, or acids, and are often blended with each other. They are found in the bowels of the earth in most parts of the globe, but chiefly in mountainous districts, where the surface of the globe has suffered from earthquakes, volcanos, and other convulsions of nature. They are there spread in strata or beds, called veins, and these veins are composed of a certain quantity of metal, combined with various earthy substances, with which they form minerals of different nature and appearance, which are called *ores.*

CAROLINE.

I am now amongst old acquaintance, for my father has a lead-mine in Yorkshire, and I have heard a great deal about veins of ore, and of the *roasting* and *smelting* of the lead; but, I confess, that I do not understand in what these operations consist.

MRS. B.

Roasting is the process by which the volatile parts of the ore are evaporated; smelting, that by which the pure metal is afterwards separated from the earthy remains of the ore. This is done by throwing the whole into a furnace, and mixing with it certain substances, that will combine with the earthy parts and other foreign ingredients of the ore; the metal being the heaviest, falls to the bottom, and runs out by proper openings, in its pure metallic state.

EMILY.

You told us in a preceding lesson that metals had a strong affinity for oxygen. Do they not, therefore, combine with oxygen, when strongly heated in the furnace, and run out in the state of oxyds?

MRS. B.

No; for the scoriæ, or oxyd, which soon forms on the surface of the fused metal, when it is oxydable, prevent the air from having any further influence on the mass; so that neither combustion nor oxygenation can take place.

CAROLINE.

Are all the metals combustible?

MRS. B.

Yes, without exception; but their attraction for oxygen varies extremely: there are some that will combine with it only at a very high temperature, or by the assistance of acids; whilst there are others that oxydate of themselves very rapidly, even at the lowest temperature, as manganese, which scarcely ever exists in its metallic state, as it immediately absorbs oxygen on being exposed to the air, and crumbles to an oxyd in the course of a few hours.

EMILY.

Is it not from that oxyd that you extracted the oxygen gas?

MRS. B.

It is; so that, you see, this metal attracts oxygen at a low temperature, and parts with it when strongly heated.

EMILY.

Is there any other metal that oxydates at the temperature of the atmosphere?

MRS. B.

They all do, more or less, excepting gold, silver, and platina.

Copper, lead, and iron, oxydate slowly in the air, and cover themselves with a sort of rust, which is nothing but the gradual conversion of the surface into an oxyd. This rusty surface preserves the interior of the metal from oxydation, as it prevents the air from coming in contact with it.

CAROLINE.

So, then, what we commonly call rust, is only an oxyd of the metal?

MRS. B.

Exactly so.

EMILY.

When metals oxydate from the atmosphere without an elevation of temperature, some light and heat, I suppose, must be disengaged, though not in sufficient quantities to be sensible.

MRS. B.

Undoubtedly; and, indeed, it is not surprising that in this case the light and heat should not be sensible, when you consider how extremely slow, and, indeed, how imperfectly, most metals oxydate by mere exposure to the atmosphere. For the quantity of oxygen which metals are capable of absorbing, generally depends upon their temperature; and the absorption stops at various points of oxydation, according to the degree to which their temperature is raised.

EMILY.

That seems very natural; for the greater the quantity of caloric introduced into a metal, the fur-her its particles are separated from one another, and the more easily, therefore, can they attract the oxygen and combine with it.

MRS. B.

Certainly; and besides, in proportion as the resistance diminishes on one hand, the affinity increases on the other. When the metal oxygenates with sufficient rapidity for light and heat to become sensible, combustion actually takes place. But this only happens at very high temperatures, and the product is nevertheless an oxyd; for though, as I have just said, metals will combine with different proportions of oxygen, yet, with the exception of only three of them, they are not susceptible of acidification.

Metals change colour during the different degrees of oxydation which they undergo. Lead, when heated in contact with the atmosphere, first becomes grey; if its temperature be then raised, it turns yellow, and a still stronger heat changes it to red. Iron becomes successively a green, brown, and white oxyd. Copper changes from brown to blue, and lastly green.

EMILY.

Pray, is the white lead with which houses are painted prepared by oxydating lead?

MRS. B.

Yes; almost all the metallic oxyds are used as paints. Red lead is another oxyd of that metal. The various sorts of ochres chiefly consist of iron more or less oxydated. And it is a remarkable circumstance, that if you burn metals rapidly, the light or flame they emit during combustion partakes of the colours which the oxyd successively assumes.

CAROLINE.

How is that accounted for, Mrs. B.? For light, you know, does not proceed from the burning body, but from the decomposition of the oxygen gas? I hope you have a satisfactory answer to give me, for I am under some apprehensions for my favourite theory of combustion; and for the world I would not have it overthrown.

MRS. B.

Do not be alarmed, my dear; I do not think it was ever supposed to be in danger from this circumstance. The correspondence of the colour of the light with that of the oxyd which emits it, is, in all probability, owing to some particles of the metal which are volatilized and carried off by the caloric.

CAROLINE.

It is then a sort of metallic gas.

EMILY.

Why is it reckoned so unwholesome to breathe the air of a place in which metals are melting?

MRS. B.

For this double reason, that most metals in melting oxydate more or less at their surface, and thereby diminish the purity of the air; but more especially because the particles of the oxyd that are volatilized by the heat, and breathed with the air of the room, are very noxious. This is particularly the case with lead and arsenic. Besides, the large furnaces that are required for these fusions, contribute also materially to alter the salubrity of the air in those places where the process is carried on.

I must show you some instances of the combustion of metals; it would require the heat of a furnace to make them burn in the common air, but if we supply them with a stream of oxygen gas, we may easily accomplish it.

CAROLINE.

But it will still, I suppose, be necessary in some degree to raise their temperature; for the oxygen will not be able to penetrate such dense substances, unless the caloric forces a passage for it.

MRS. B.

This, as you shall see, is very easily done, particularly if the experiment be tried upon a small scale.—I begin by lighting this piece of charcoal with the candle, and then increase the rapidity of its combustion by blowing upon it with a blow-pipe. (PLATE IX. Fig. 21.)—

EMILY.

That I do not understand; for it is not every kind of air, but merely oxygen gas, that produces combustion. Now you said that in breathing we inspired, but did not expire, oxygen gas. Why, therefore, should the air which you breathe through the blow-pipe, promote the combustion of the charcoal?

MRS. B.

Because the air, which has but once passed through the lungs, is yet but little altered, a small portion only of its oxygen being destroyed; so that a great deal more is gained by increasing the rapidity of the current, by means of the blow-pipe, than is lost in consequence of the air passing once through the lungs, as you shall see—

EMILY.

Yes, indeed, it makes the charcoal burn much brighter.

MRS. B.

Whilst it is red hot, I shall drop some iron filings on it, and supply them with a current of oxygen gas, *Apparatus for the combustion of metals by means of oxygen gas.*

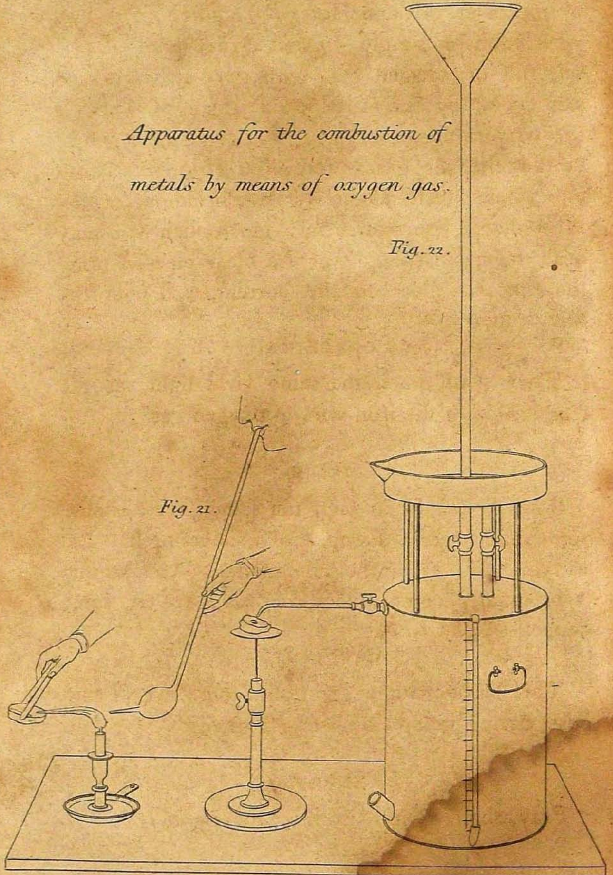


Fig. 21 Igniting charcoal with a taper & blow-pipe.—Fig. 22 Combustion of metals by means of a blow-pipe conveying a stream of oxygen gas from a gas holder.

Drawn by the Author. *Engraved by Lowry.*

Published by Longman & Co. Decr. 3rd 1805

by means of this apparatus, (PLATE IX. Fig. 22.) which consists simply of a closed tin cylindrical vessel, full of oxygen gas, with two apertures and stop-cocks, by one of which a stream of water is thrown into the vessel through a long funnel, whilst by the other the gas is forced out through a blow-pipe adapted to it, as the water gains admittance.—Now that I pour water into the funnel, you may hear the gas issuing from the blow-pipe—I bring the charcoal close to the current, and pour the filings upon it—

CAROLINE.

They emit much the same vivid light, as the combustion of the iron wire in oxygen gas.

MRS. B.

The process is, in fact, the same; there is only some difference in the mode of conducting it. Let us burn some tin in the same manner—you see that it is equally combustible—Let us now try some copper—

CAROLINE.

This burns with a greenish flame; it is, I suppose, owing to the colour of the oxyd?

EMILY.

Pray, shall we not also burn some gold?

MRS. B.

That is not in our power, at least in this way. Gold, silver, and platina, are incapable of being oxydated by the greatest heat that we can produce by the common method. It is from this circumstance that they have been called perfect metals. Even these, however, have an affinity for oxygen; but their oxydation or combustion can only be performed by means of the Galvanic electricity. The spark given out by the Galvanic pile produces in the point of contact a greater degree of heat than any other process; and it is at this temperature only that the affinity of these metals for oxygen will enable them to act on each other.

I am sorry that I cannot show you the combustion of the perfect metals by this process, but it requires a considerable Galvanic battery. You will, however, see these experiments performed in the most perfect manner, when you attend the chemical lectures of the Royal Institution.

CAROLINE.

I think you said that metallic oxyds could be restored to their metallic state?

MRS. B.

Yes; this is called *reviving* a metal. Metals are in general capable of being revived by charcoal, when heated red hot, charcoal having, at that temperature, a greater attraction for oxygen than the metals. You need only, therefore, decompose, or unburn the oxyd, by depriving it of its oxygen, and the metal will be restored to its pure state.

EMILY.

But will the carbone, by this operation, be burnt, and be converted into carbonic acid?

MRS. B.

Certainly. There are other combustible substances to which metals at a high temperature will part with their oxygen. They will also yield it to each other, according to their several degrees of attraction for it; and if the oxygen goes into a more dense state in the metal which it enters, than it existed in that which it quits, a proportional disengagement of caloric will take place.

CAROLINE.

And cannot the oxyds of gold, silver, and platina, which are formed by means of the Galvanic spark, be restored to their metallic state?

MRS. B.

Yes, they may; but the intervention of a combustible body is not required; heat alone will take the oxygen from them, convert it into a gas, and revive the metal.

EMILY.

You said that rust was nothing but an oxyd of iron; how is it, then, that water, or merely dampness, produces it, which, you know, it very frequently does on steel grates, or any iron instruments.

MRS. B.

In that case the metal decomposes the water, or dampness (which is nothing but water in a state of vapour), and obtains the oxygen from it.

CAROLINE.

I thought that it was necessary to bring metals to a very high temperature to enable them to decompose water.

MRS. B.

It is so, if it is required that the process should be performed rapidly, and if any considerable quantity is to be decomposed. Rust, you know, is sometimes months in forming, and then it is only the surface of the metal that is oxydated.

EMILY.

Metals, then, that do not rust, are incapable of spontaneous oxydation, either by air or water?

MRS. B.

Yes; and this is the case with the perfect metals, which, on that account, preserve their metallic lustre so well.

CAROLINE.

When metals are oxydated by means of water, is there no sensible disengagement of light and heat?

MRS. B.

No; because the oxygen exists already in a dense state in water; and the portion of caloric that it parts with combines with the hydrogen to convert it into a gas.

EMILY.

Are all metals capable of decomposing water, provided their temperature be sufficiently raised?

MRS. B.

No; a certain degree of attraction is requisite, besides the assistance of heat. Water, you recollect, is composed of oxygen and hydrogen; and, unless the affinity of the metal for oxygen be stronger than that of hydrogen, it is in vain that we raise its temperature, for it cannot take the oxygen from the hydrogen. Iron, zinc, tin, and antimony, have a stronger affinity for oxygen than hydrogen has, therefore these four metals are capable of decomposing water. But hydrogen having an advantage over all the other metals with respect to its affinity for oxygen, it not only withholds its oxygen from them, but is even capable, in certain circumstances, of taking the oxygen from the oxyd of these metals.

EMILY.

I confess that I do not quite understand why hydrogen can take oxygen from those metals that do not decompose water.

CAROLINE.

Now I think I do perfectly. Lead, for instance, will not decompose water, because it has not so strong an attraction for oxygen, as hydrogen has. Well, then, suppose the lead to be in a state of oxyd; hydrogen will take the oxygen from the lead, and unite with it to form water, because hydrogen has a stronger attraction for oxygen, than oxygen has for lead; and it is the same with all the other metals which do not decompose water.

EMILY.

I understand your explanation, Caroline, very well; and I imagine that it is because lead cannot decompose water that it is so much employed for pipes for conveying that fluid.

MRS. B.

Certainly; lead is, on that account, particularly appropriate to such purposes; whilst, on the contrary, this metal, if it was oxydable by water, would impart to it very noxious qualities, as all oxyds of lead are more or less pernicious.

But, with regard to the oxydation of metals, there is a mode of effecting it more powerful than either of the former, which is by means of acids. These, you know, contain a much greater proportion of oxygen than either air or water; and will, most of them, easily yield it to metals. Have you never observed, that if you drop vinegar, lemon, or any acid, on the blade of a knife, or on a pair of scissars, it will immediately produce a spot of rust.

CAROLINE.

Yes, often; and I am very careful now to wipe off the acid immediately, to prevent the rust from forming.

EMILY.

Metals have, then, three ways of obtaining oxygen; from the atmosphere, from water, and from acids.

MRS. B.

The two first you have already witnessed, and I shall now show you how metals take the oxygen from an acid. This bottle contains nitric acid; I shall pour some of it over this piece of copper-leaf . . . . .

CAROLINE.

Oh, what a disagreeable smell!

EMILY.

And what is it that produces the effervescence and that thick yellow vapour?

MRS. B.

It is the acid, which being abandoned by the greatest part of its oxygen, is converted into a weaker acid, which escapes in the form of gas.

CAROLINE.

And whence proceeds this heat?

MRS. B.

Indeed, Caroline, I think you might now be able to answer that question yourself.

CAROLINE.

Perhaps it is that the oxygen enters into the metal in a more solid state than it existed in the acid, in consequence of which caloric is disengaged.

MRS. B.

You have found it out, you see, without much difficulty.

EMILY.

The effervescence is over; therefore I suppose that the metal is now oxydated.

MRS. B.

Yes. But there is another important connection between metals and acids, with which I must make you acquainted. Metals, when in the state of oxyds, are capable of being dissolved by acids. In this operation they enter into a chemical combination with the acid, and form an entirely new compound.

CAROLINE.

But what difference is there between the *oxydation* and the *dissolution* of a metal by an acid?

MRS. B.

In the first case, the metal merely combines with a portion of oxygen taken from the acid, which is thus partly deoxygenated, as in the instance you have just seen; in the second case, the metal, after being previously oxydated, is actually dissolved in the acid, and enters into a chemical combination with it, without producing any further decomposition or effervescence.—This complete combination of an oxyd and an acid forms a peculiar and important class of compound salts.

EMILY.

The difference between an oxyd and a compound salt, therefore, is very obvious: the one consists of a metal and oxygen; the other of an oxyd and an acid.

MRS. B.

Very well: and you will be careful to remember that the metals are incapable of entering into this combination with acids, unless they are previously oxydated; therefore, whenever you bring a metal in contact with an acid, it will be first oxydated and afterwards dissolved, provided that there be a sufficient quantity of acid for both operations.

There are some metals, however, whose solution is more easily accomplished, by diluting the acid in water; and the metal will, in this case, be oxydated, not by the acid, but by the water, which it will decompose. But in proportion as the oxygen of the water oxydates the surface of the metal, the acid combines with it, washes it off, and leaves a fresh surface for the oxygen to act upon: then other coats of oxyd are successively formed, and rapidly dissolved by the acid, which continues combining with the new-formed surfaces of oxyd till the whole of the metal is dissolved. During this process the hydrogen gas of the water is disengaged, and flies off with effervescence.

EMILY.

Was not this the manner in which the sulphuric acid assisted the iron filings in decomposing water?

MRS. B.

Exactly; and it is thus that several metals, which are incapable alone of decomposing water, are enabled to do it by the assistance of an acid, which, by continually washing off the covering of oxyd, as it is formed, prepares a fresh surface of metal to act upon the water.

CAROLINE.

The acid here seems to act a part not very different from that of a scrubbing-brush.—But pray would not this be a good method of cleaning grates and metallic utensils?

MRS. B.

You forget that acids have the power of oxydating metals, as well as that of dissolving their oxyds; so that by cleaning a grate in this way, you would create more rust than you could destroy.

CAROLINE.

True; how thoughtless I was to forget that! Let us watch the dissolution of the copper in the nitric acid; for I am very impatient to see the salt that is to result from it. The mixture is now of a beautiful blue colour; but I see no appearance of the formation of a salt; it seems to be a tedious operation.

MRS. B.

The crystallization of the salt requires some length of time to be completed; if, however, you are so impatient, I can easily show you a metallic salt already formed.

CAROLINE.

But that would not satisfy my curiosity half so well as one of our own manufacturing.

MRS. B.

It is one of our own preparing that I mean to show you. When we decomposed water a few days since, by the oxydation of iron filings, through the assistance of sulphuric acid, in what did the process consist?

CAROLINE.

In proportion as the water yielded its oxygen to the iron, the acid combined with the new-formed oxyd, and the hydrogen escaped alone.

MRS. B.

Very well; the result, therefore, was a compound salt, formed by the combination of sulphuric acid with oxyd of iron. It still remains in the vessel in which the experiment was performed. Fetch it, and we shall examine it.

EMILY.

What a variety of processes the decomposition of water, by a metal and an acid, implies! 1st, The decompostion of the water; 2dly, the oxydation of the metal; and 3dly, the formation of a compound salt.

CAROLINE.

Here it is, Mrs. B.—What beautiful green crystals! But we do not perceive any crystals in the solution of copper in nitrous acid?

MRS. B.

Because the salt is now suspended in the water which the nitrous acid contains, and will remain so till it is deposited in consequence of rest and cooling.

EMILY.

I am surprised that a body so opake as iron can be converted into such beautiful transparent crystals.

MRS. B.

It is the union with the acid that produces the transparency; for if the pure metal was melted, and afterwards permitted to cool and crystallize, it would be found just as opake as before.

EMILY.

I do not understand the exact meaning of *crystallization?*

MRS. B.

You recollect that when a solid body is dissolved either by water or caloric, it is not decomposed; but that its integrant parts are only suspended in the solvent. When the solution is made in water, the integrant particles of the body will, on the water being evaporated, again unite into a solid mass, by the force of their mutual attraction. But when the body is dissolved by caloric alone, nothing more is necessary, in order to make its particles reunite, than to reduce its temperature. And, in general, if the solvent, whether water or caloric, be slowly separated by evaporation or by cooling, and care taken that the particles be not agitated during their reunion, they will arrange themselves in regular masses, each individual substance assuming a peculiar form or arrangement; and this is what is called crystallization.

EMILY.

Crystallization, therefore, is simply the reunion of the particles of a solid body that has been dissolved in a fluid.

MRS. B.

That is a very good definition of it. But I must not forget to observe, that *heat* and *water* may unite their solvent powers; and, in this case, crystallization may be hastened by cooling, as well as by evaporating the liquid.

CAROLINE.

But if the body dissolved is of a volatile nature, will it not evaporate with the fluid?

MRS. B.

A crystallizable body, held in solution only by water, is scarcely ever so volatile as the fluid itself, and care must be taken to manage the heat, so that it may be sufficient to evaporate the water only.

I should not omit to mention that bodies, in crystallizing from their watery solution, always retain a small portion of water, which remains confined in the crystal in a solid form, and does not reappear, unless the body loses its crystalline state. This is called the *water of crystallization.*

It is also necessary that you should here more particularly remark the difference, to which we have formerly alluded, between the simple solution of bodies either in water or in caloric, and the solution of metals in acids; in the first case, the body is merely divided by the solvent into its minutest parts. In the latter, a similar effect is, indeed, produced; but it is by means of a chemical combination between the metal and the acid, in which both lose their characteristic properties. The first is a mechanical operation, the second a chemical process. We may, therefore, distinguish them by calling the first a *simple solution,* the other a *chemical solution.* Do you understand this difference?

EMILY.

Yes; *simple solution* can affect only the attraction of aggregation. But *chemical solution* implies also an attraction of composition, that is to say, an actual combination between the solvent and the body dissolved.

MRS. B.

You have expressed your idea very well indeed.

But you must observe, also, that whilst a body may be separated from its solution in water or caloric, simply by cooling or by evaporation; an acid can only be taken from a metal with which it is combined, by stronger affinities, which produce a decomposition.

EMILY.

I think that you have rendered the difference between these two kinds of solution so obvious, that we can never confound them.

MRS. B.

Notwithstanding, however, the real difference which there appears to be between these two operations, they are frequently confounded. Indeed, several modern chemical writers, of great eminence, have even thought proper to generalize the idea of solution, and to suppress entirely the distinction introduced by the great Lavoisier, which I have taken so much pains to explain, and which I confess appears to me to render the subject much clearer.

EMILY.

Are the perfect metals susceptible of being dissolved and converted into compound salts by acids?

MRS. B.

Gold is acted upon by only one acid, the *oxygenated* *muriatic*, a very remarkable acid, which, when in its most concentrated state, dissolves gold or any other metal, by burning them rapidly.

Gold can, it is true, be dissolved likewise by a mixture of two acids, commonly called *aqua regia*; but this mixed solvent derives that property from containing the peculiar acid which I have just mentioned. Platina is also acted upon by this acid only; but silver is dissolved by several of them—

CAROLINE.

I think you said that some of the metals might be so strongly oxydated as to become acid?

MRS. B.

There are five metals, arsenic, molybdena, chrome, tungsten, and columbium *, which are susceptible of combining with a sufficient quantity of oxygen to be converted into acids.

CAROLINE.

Acids are connected with metals in such a variety of ways, that I am afraid of some confusion in remembering them.—In the first place, acids will yield their oxygen to metals. Secondly, they will

* Columbium, which has not long since been discovered by Mr. Hatchett, was inadvertently omitted in the enumeration of the simple bodies given in the first conversation.

combine with them in their state of oxyds, to form compound salts; and lastly, several of the metals are themselves susceptible of acidification.

MRS. B.

Very well; but though metals have so great an affinity for acids, it is not with that class of bodies alone that they will combine. They are most of them, in their simple state, capable of uniting with sulphur, with phosphorus, with carbone, and with each other; these combinations, according to the nomenclature which was explained to you on a former occasion, are called *sulphurets*, *phosphorets*, *carburets*, &c.

The metallic phosphorets offer nothing very remarkable. The sulphurets form the peculiar kind of mineral called *pyrites*, from which certain kinds of mineral waters, as those of Harrogate, derive their chief chemical properties. In this combination, the sulphur, together with the iron, have so strong an attraction for oxygen, that they obtain it both from the air and from water, and by condensing it in a solid form, produce the heat which raises the temperature of the water in such a remarkable degree.

EMILY.

But if pyrites obtain oxygen from water, that water must suffer a decomposition, and hydrogen gas be evolved?

MRS. B.

That is actually the case in the hot springs alluded to, which give out an extremely fetid gas, composed of hydrogen impregnated with sulphur.

CAROLINE.

If I recollect right, steel and plumbago, which you mentioned in the last lesson, are both carburets of iron?

MRS. B.

Yes; and they are the only carburets of much consequence. The combinations of metals with each other are called alloys; thus brass is an alloy of copper and zinc; bronze, of copper and iron, &c.

EMILY.

And is not pewter also a combination of metal?

MRS. B.

It is. The pewter made in this country, is mostly composed of tin, with a very small proportion of zinc and lead.

CAROLINE.

Block-tin is a kind of pewter, I believe?

MRS. B.

No; it is iron plated with tin, which renders it more durable, as tin will not so easily rust.

CAROLINE.

Say rather *oxydate*, Mrs. B.—Rust is a word that should be exploded in chemistry.

MRS. B.

Take care, however, not to introduce the word oxydate instead of rust, in general conversation; for either you will not be understood, or you will be laughed at for your conceit.

CAROLINE.

I confess that my attention is, at present, so much engrossed by chemistry, that it sometimes leads me into ridiculous observations. Every thing in nature I refer to chemistry, and have often been ridiculed for my continual allusions to it.

MRS. B.

You must be more cautious and discreet in this respect, my dear, otherwise your enthusiasm, although proceeding from a sincere admiration of the science, will be attributed to pedantry.

Metals differ very much in their affinity for each other; some will not unite at all, others readily combine together, and on this property of metals the art of *soldering* depends.

EMILY.

What is soldering?

MRS. B.

It is joining two pieces of metal together, by heating them, with a thin plate of a more fusible metal interposed between them. Thus tin is a solder for lead; brass, gold, or silver, are solder for iron, &c.

CAROLINE.

And is not *plating* metals something of the same nature?

MRS. B.

In the operation of plating, two metals are united, one being covered with the other, but without the intervention of a third; iron or tin may thus be covered with gold or silver.

EMILY.

Mercury appears to me of a very different nature from the other metals.

MRS. B.

One of its greatest peculiarities is that it retains a fluid state at the temperature of the atmosphere. All metals are fusible at different degrees of heat, and they have likewise each the property of freezing or becoming solid at a certain fixed temperature. Mercury solidifies only at 72° below the freezing point.

EMILY.

That is to say, that in order to freeze, it requires a temperature 72 degrees colder than that at which water freezes.

MRS. B.

Exactly so.

CAROLINE.

But is the temperature of the atmosphere ever so low as that?

MRS. B.

Scarcely ever, at least in any inhabited part of the globe; therefore mercury is never found solid in nature, but it may be congealed by artificial cold; I mean such intense cold as can be produced by some chemical mixtures.

CAROLINE.

And can mercury be made to boil and evaporate?

MRS. B.

Yes, like any other liquid; only it requires a much greater degree of heat. At the temperature of 600°, it begins to boil and evaporate like water.

Mercury combines with gold, silver, tin, and with many other metals; and, if mixed with any of them in a sufficient proportion, it penetrates the solid metal, softens it, loses its own fluidity, and forms an *amalgam*.

EMILY.

What is an amalgam?

MRS. B.

It is the name given to the combination of any metal with mercury, forming a substance more or less solid, according as the mercury or the other metal predominates.

CAROLINE.

Arsenic has been mentioned amongst the metals; I had no notion that it belonged to that class of bodies, for I had never seen it but as a powder, and never thought of it but as a most deadly poison.

MRS. B

In its pure metallic state, I believe, it is not poisonous; but it has so great an affinity for oxygen, that it absorbs it from the atmosphere at its natural temperature; you have seen it, therefore, only in its state of oxyd, when, from its combination with oxygen, it has acquired poisonous properties.

CAROLINE.

Is it possible that oxygen can impart poisonous qualities? That valuable substance which produces light, fire, and which all bodies in nature are so eager to obtain!

MRS. B.

Most of the metallic oxyds are poisonous, and derive this property from their union with oxygen. The white lead, so much used in paint, owes its pernicious effects to oxygen. In general oxygen, in a concrete state, appears to be particularly destructive in its effects on flesh or any animal matter; and those oxyds are most caustic that have an acrid burning taste, which proceeds from the metal having but a slight affinity for oxygen, and therefore easily yielding it to the flesh which it corrodes and destroys.

EMILY.

What is the meaning of the word *caustic*, which you have just used?

MRS. B.

It expresses that property which some bodies possess, of disorganizing and destroying animal matter, by operating a kind of combustion, or at least a chemical decomposition. You must often have heard of caustics used to burn warts, or other animal excrescences; most of these bodies owe their destructive power to the oxygen with which they are combined. The common caustic, called *lunar caustic*, is a compound formed by the union of nitric acid and silver; and it is supposed to owe its caustic qualities to the oxygen contained in the nitric acid,

CAROLINE.

But, pray, are not acids still more caustic than oxyds, as they contain a greater proportion of oxygen?

MRS. B.

Some of the acids are; but the caustic property of a body depends not only upon the quantity of oxygen which it contains, but also upon its slight affinity for that principle, and the consequent facility with which it yields it.

EMILY.

Is not this destructive property of oxygen accounted for?

MRS. B.

It proceeds probably from the strong attraction of oxygen for hydrogen; for if the one rapidly absorbs the other from the animal fibre, a disorganization of the substance must ensue.

EMILY.

Caustics are then very properly said to *burn* the flesh, since the combination of oxygen and hydrogen is an actual combustion.

CAROLINE.

Now, I think, this effect would be more properly termed an oxydation, as there is no disengagement of light and heat.

MRS. B.

But there really is a sensation of heat produced by the action of caustics; and the caloric that is disengaged must, I think, partly, if not wholly, proceed from the oxygen which the caustic yields to the flesh.

CAROLINE.

Yet the oxygen of a caustic is not in a gaseous state, and can therefore have no caloric to part with?

MRS. B.

In whatever state oxygen exists, we may suppose that, like every other body in nature, it retains some portion of caloric; and if, in combining with the hydrogen of the flesh, it becomes more dense than it previously was in the caustic, it must part with caloric whilst this change is taking place. I believe I have once before observed that we may, in a great measure, judge of the comparative degree of solidity which oxygen assumes in a body, by the quantity of caloric liberated during its combination; and when we find, that, in its passage from one body to another, heat is evolved, we may be certain that it exists in a more solid state in the latter.

EMILY.

But if oxygen is so caustic, why does not that contained in the atmosphere burn us?

MRS. B.

Because it is in a gaseous state, and has a greater attraction for its caloric than for the hydrogen of our bodies. Besides, should the air be slightly caustic, we are in a great measure sheltered from its effects by the skin; you all know how much a wound, however trifling, smarts on being exposed to it.

CAROLINE.

It is a curious idea, however, that we should live in a slow fire. But, if the air was caustic, would it not have an acrid taste?

MRS. B.

It possibly may have such a taste; though in so slight a degree, that custom has rendered it insensible.

CAROLINE.

And why is not water caustic? When I dip my hand into water, though cold, it ought to burn me from the caustic nature of its oxygen.

MRS. B.

Your hand does not decompose the water; the oxygen in that state is much better supplied with hydrogen than it would be by animal matter, and if its causticity depends on its affinity for that principle, it will be very far from quitting its state of water to act upon your hand. You must not forget that oxyds are caustic in proportion as the oxygen adheres slightly to them.

EMILY.

Since the oxyd of arsenic is poisonous, its acid, I suppose, is fully as much so?

MRS. B.

Yes; it is one of the strongest poisons in nature.

EMILY.

There is a poison called *verdigris*, which forms on brass and copper when not kept very clean; and this, I have heard, is an objection to these metals being made into kitchen utensils. Is this poison likewise occasioned by oxygen?

MRS. B.

It is produced by the intervention of oxygen; for verdigris is a compound salt formed by the union of vinegar and copper; it is of a beautiful green colour, and much used in painting.

EMILY.

But, I believe, verdigris is often formed on copper when no vinegar has been in contact with it.

MRS. B.

Not real verdigris, but compound salts, somewhat resembling it, may be produced by the action of any acid on copper.

There is a beautiful green salt produced by the combination of cobalt with nitric acid, which has the singular property of forming what is called *sympathetic ink*. Characters written with this solution are invisible when cold, but when a gentle heat is applied, they assume a fine blueish-green colour.

CAROLINE.

I think one might draw very curious landscapes with the assistance of this ink; I would first make a water-colour drawing of a winter scene, in which the trees should be leafless and the grass scarcely green; I would then trace all the verdure with the invisible ink, and whenever I chose to create spring, I should hold it before the fire, and its warmth would cover the landscape with a rich verdure.

MRS. B.

That will be a very amusing experiment, and I advise you by all means to try it.—I must now, however, take my leave of you; we have had a very long lecture, and I hope you will be able to rememit. Do not forget to write down all you can recollect of this conversation, for the subject is of great importance, though it may not appear at first very entertaining.

CONVERSATION X.

ON ALKALIES.

MRS. B.

After having taken a general view of combustible bodies, we now come to the ALKALIES, and the EARTHS, which compose the class of incombustibles; that is to say, of such bodies as do not combine with oxygen at any known temperature.

CAROLINE.

I am afraid that the incombustible substances will not be near so interesting as the others; for I have found nothing in chemistry that has pleased me so much as the theory of combustion.

MRS. B.

Do not however depreciate the incombustible bodies before you are acquainted with them; you will find they also possess properties highly important and interesting.

Some of the earths bear so strong a resemblance in their properties to the alkalies, that it is a difficult point to know under which head to place them. The celebrated French chemist, Fourcroy, has classed two of them (Barytes and Strontites) with the alkalies; but, as lime and magnesia have almost an equal title to that rank, I think it better not to separate them, and therefore have adopted the common method of classing them with the earths, and of distinguishing them by the name of *alkaline earths.*

We shall first take a review of the alkalies, of which there are three species: POTASH, SODA, and AMMONIA. The two first are called *fixed alkalies*, because they exist in a solid form at the temperature of the atmosphere, and require a great heat to be volatilized. The third, ammonia, has been distinguished by the name of *volatile alkali*, because its natural form is that of gas.

CAROLINE.

Ammonia? I do not recollect that name in the list of simple bodies.

MRS. B.

The reason why you do not find it there is, that it is a compound; and if I introduce it to your acquaintance now, it is on account of its close connection with the two other alkalies, which it resembles essentially in its nature and properties.

Indeed, it is not long since ammonia has resigned its place amongst the simple bodies, as it was not, till lately, supposed to be a compound; nor is it improbable that potash and soda may some day undergo the same fate, as they are strongly suspected of being compounds also.

The general properties of alkalies are, an acrid burning taste, a pungent smell, and a caustic action on the skin and flesh.

CAROLINE.

How can they be caustic, Mrs. B., since they do not contain oxygen?

MRS. B.

Whatever substance has an affinity for any one of the constituents of animal matter, sufficiently powerful to decompose it, is entitled to the appellation of caustic. The alkalies, in their pure state, have a very strong attraction for water, for hydrogen, and for carbone, which, you know, are the constituent principles of oil, and it is chiefly by absorbing these substances from animal matter, that they effect its decomposition; for, when diluted with a sufficient quantity of water, or combined with any oily substance, they lose their causticity.

But, to return to the general properties of alkalies—they change the colour of syrup of violets, and other blue vegetable infusions, to green; and have, in general, a very great tendency to unite with acids, although the respective qualities of these two classes of bodies form a remarkable contrast.

We shall examine the result of the combination of acids and alkalies more particularly when we have completed our general view of the simple bodies. It will be sufficient at present to inform you, that whenever acids are brought in contact with alkalies, or alkaline earths, they unite with a remarkable eagerness, and form compounds perfectly different from either of their constituents; these compounds are called *neutral*, or *compound salts.*

CAROLINE.

Are they of the same kind as the salts formed by the combination of a metal and an acid?

MRS. B.

Yes; they are analogous in their nature, although different in many of their properties.

A methodical nomenclature, similar to that of the acids, has been adopted for the compound salts. Each individual salt derives its name from its constituents, so that every name implies a knowledge of the composition of the salt.

The three alkalies, the alkaline earths and the metals, are called *salifiable bases* or *radicals*, and the acids, *salifying principles.* The name of each salt is composed both of that of the acid and the salifiable base; and it terminates in *at* or *it*, according to the degree of oxygenation of the acid. Thus, for instance, all those salts which are formed by the combination of the sulphuric acid with any of the salifiable bases, are called *sulphats*, and the name of the radical is added for the specific distinction of the salt; if it be potash, it will compose a *sulphat of potash*; if ammonia, *sulphat of ammonia*, &c.

EMILY.

The crystals which we obtained from the combination of iron and sulphuric acid, were therefore *sulphat of iron*?

MRS. B.

Precisely; and those which we prepared by dissolving copper in nitric acid, *nitrat of copper*, and so on. But this is not all; if the salt be formed by that class of acids which ends in *ous* (which, you know, indicates a less degree of oxygenation), the termination of the name of the salt will be in *it*, as *sulphit of potash*, *sulphit of ammonia*, &c.

EMILY.

There must be an immense number of compound salts, since there is so great a variety of salifiable radicals, as well as of salifying principles.

MRS. B.

Their real number cannot be ascertained, since it increases every day as the science advances. But, before we proceed further in the investigation of the compound salts, it is necessary that we should examine the nature of the ingredients from which they are composed. Let us therefore return to the alkalies. The dry white powder which you see in this phial is pure caustic POTASH; it is very difficult to preserve it in this state, as it attracts with extreme avidity the moisture from the atmosphere, and if the air were not perfectly excluded, it would in a very short time be actually melted.

EMILY.

It is then, I suppose, always found in a liquid state?

MRS. B.

No; it exists in nature in a great variety of forms and combinations, but is never found in its pure separate state; it is combined with carbonic acid, with which it exists in every part of the vegetable kingdom, and is most commonly obtained from the ashes of vegetables, which compose the substance that remains after all the other parts have been volatilized by combustion.

CAROLINE.

But you once said, that after the volatile parts of a vegetable were evaporated, the substance that remained was charcoal?

MRS. B.

What, my dear? Do you still confound the processes of simple volatilization and combustion? In order to procure charcoal we evaporate such parts as can be reduced to vapour by heat alone; but when we burn the vegetable, we volatilize the carbone also, by converting it into carbonic acid gas.

CAROLINE.

That is true; I hope I shall make no more mistakes in my favourite theory of combustion.

MRS. B.

Potash derives its name from the *pots* in which the vegetables from which it was obtained used formerly to be burnt; the alkali remained mixed with the ashes at the bottom, and was thence called potash.

CAROLINE.

There is some good sense in this name, as it will always remind us of the operation, and of the general source from which this alkali is derived.

EMILY.

The ashes of a wood fire, then, are potash, since they are vegetable ashes?

MRS. B.

They always contain more or less potash, but are very far from consisting of that alone, as they are a mixture of various earths and salts which remain after the combustion of vegetables, and from which it is not easy to separate the alkali in its pure form. The process by which potash is obtained, even in the imperfect state in which it is used in the arts, is much more complicated than simple combustion. It was once deemed impossible to separate it entirely from all foreign substances, and it is only in chemical laboratories that it is to be met with in the state of purity in which you find it in this phial. Wood-ashes are, however, valuable for the alkali which they contain, and are used for some purposes without any further preparation. Purified in a certain degree, they make what is commonly called *pearl-ash*, which is of great efficacy in taking out grease, in washing linen, &c.; for potash combines readily with oil or fat, with which it forms a compound well known to you under the name of *soap*.

CAROLINE.

Really! Then I should think it would be better to wash all linen with pearl-ash than with soap, as, in the latter case, the alkali, being already combined with oil, must be less efficacious in extracting grease.

MRS. B.

Its effect would be too powerful on fine linen, and would injure its texture; pearl-ash is therefore only used for that which is of a strong coarse kind. For the same reason you cannot wash your hands with plain potash; but, when mixed with oil in the form of soap, it is soft as well as cleansing, and is therefore much better adapted to the purpose.

Caustic potash, as we already observed, acts on the skin, and animal fibre, in virtue of its attraction for water and oil, and converts all animal matter into a kind of saponaceous jelly.

EMILY.

Are vegetables the only source from which potash can be derived?

MRS. B.

No: for though far most abundant in vegetables, it is by no means confined to that class of bodies, being found also on the surface of the earth mixed with various minerals, especially with earths and stones, whence it is supposed to be conveyed into vegetables by the roots of the plant. It is also met with, though in very small quantities, in some animal substances. The most common state of potash is that of *carbonat*; I suppose you understand what that is?

EMILY.

I believe so; though I do not recollect that you ever mentioned the word before. If I am not mistaken, it must be a compound salt formed by the union of carbonic acid with potash.

MRS. B.

Very true; you see how admirably the nomenclature of modern chemistry is adapted to assist the memory; when you hear the name of a compound, you necessarily learn what are its constituents; and when you are acquainted with the constituents, you can immediately name the compound that they form.

CAROLINE.

Pray, how were bodies arranged and distinguished before this nomenclature was introduced?

MRS. B.

Chemistry was then a much more difficult study; for every substance had an arbitrary name, which it derived either from the person who discovered it, as *Glauber's salts* for instance, or from some other circumstance relative to it, though quite unconnected with its real nature, as *potash*.

These names have been retained for some of the simple bodies; for as this class is not numerous, and therefore can easily be remembered, it has not been thought necessary to change them.

EMILY.

Yet I think it would have rendered the new nomenclature more complete to have methodized the names of the elementary as well as of the compound bodies, though it could not have been done in the same manner. But the names of the simple substances might have indicated their nature, or, at least, some of their principal properties; and if, like the acids and compound salts, all the simple bodies had a similar termination, they would have been immediately known as such. So complete and regular a nomenclature would, I think, have given a clearer and more comprehensive view of chemistry, than the present, which is a medley of the old and new terms.

MRS. B.

But you are not aware of the difficulty of introducing into science an entire set of new terms; it obliges all the teachers and professors to go to school again; and if some of the old names, that are least exceptionable, were not left as an introduction to the new ones, few people would have had industry and perseverance enough to submit to the study of a completely new language; and the inferior classes of artists, who can only act from habit and routine, would, at least, for a time, have felt material inconvenience from a total change of their habitual terms. From these considerations, Lavoisier and his colleagues, who invented the new nomenclature, thought it most prudent to leave a few links of the old chain, in order to connect it with the new one. Besides, you may easily conceive the inconvenience which might arise from giving a regular nomenclature to substances, the simple nature of which is always uncertain; for the new names might, perhaps, have proved to have been founded in error. And, indeed, cautious as the inventors of the modern chemical language have been, it has already been found necessary to modify it in many respects. In those few cases, however, in which new names have been adopted to designate simple bodies, these names have been so contrived as to indicate one of the chief properties of the body in question; this is the case with oxygen, which, as I explained to you, signifies the generator of acids; and hydrogen, the generator of water.

But to return to the alkalies.—We shall now try to melt some of this caustic potash in a little water, as a circumstance occurs during its solution very worthy of observation.—Do you feel the heat that is produced?

CAROLINE.

Yes, I do; but is not this directly contrary to our theory of caloric, according to which heat is disengaged when fluids become solid, and cold produced when solids are melted?

MRS. B.

The latter is really the case in all solutions; and if the solution of caustic alkalies seems to make an exception to the rule, it does not, I believe, form any solid objection to the theory. The matter may be explained thus: When water first comes in contact with the potash, it produces an effect similar to the slakeing of lime, that is, the water is solidified in combining with the potash, and thus loses its latent heat; this is the heat that you now feel, and which is, therefore, produced not by the melting of the solid, but by the solidification of the fluid. But when there is more water than the potash can absorb and solidify, the latter then yields to the solvent power of the water; and if we do not perceive the cold produced by its melting, it is because it is counterbalanced by the heat previously disengaged *.

A very remarkable property of potash is the formation of glass by its fusion with silicious earth. You are not yet acquainted with this last substance further than its being in the list of simple bodies. It is sufficient, for the present, that you should know that sand and flint are chiefly composed of it: alone, it is infusible; but mixed with potash, it

* If, however, this defence of the general theory be true, it ought to be found, on accurate examination, that a certain quantity of heat ultimately disappears: or should this explanation be rejected, the phenomenon might be accounted for by supposing that a solution of alkali in water has less capacity for heat than either water or alkali in their separate state.

melts when exposed to the heat of a furnace, combines with the alkali, and runs into glass.

CAROLINE.

Who would ever have supposed that the same substance that converts transparent oil into such an opake body as soap, should transform that opake substance, sand, into transparent glass!

MRS. B.

The transparency, or opacity of bodies, does not, I conceive, depend so much upon their intimate nature, as upon the arrangement of their particles; we cannot have a more striking instance of this, than that which is afforded by the different states of carbone, which, though it commonly appears in the form of a black opake body, sometimes assumes the most dazzling transparent form in nature, that of diamond, which, you recollect, is nothing but carbone, and which, in all probability, derives its beautiful transparency from the peculiar arrangement of its particles during their crystallization.

EMILY.

I never should have supposed that the formation of glass was so simple a process as you describe it.

MRS. B.

It is by no means an easy operation to make perfect glass; for if the sand, or flint, from which the siliceous earth is obtained be mixed with any metallic particles, or other substance which cannot be vitrified, the glass will be discoloured, or defaced, by opake specks.

CAROLINE.

That I suppose is the reason why objects so often appear irregular and shapeless through a common glass window.

MRS. B.

This species of imperfection proceeds, I believe, from another cause. It is extremely difficult to prevent the lower part of the vessels in which the materials of glass are fused, from containing a more dense vitreous matter than the upper, on account of the heavier ingredients falling to the bottom. When this happens, it occasions the appearance of veins or waves in the glass, from the difference of density in its several parts, which produces an irregular refraction of the rays of light that pass through it.

Another species of imperfection sometimes arises from the fusion not being continued for a length of time sufficient to combine the two ingredients completely, or from the due proportions of potash and silex (which are as two to one), not being carefully observed; the glass, in those cases, will be liable to alteration from the action of the air, of salts, and especially of acids, which will effect its decomposition by combining with the potash, and forming compound salts.

EMILY.

What an extremely useful substance potash is!

MRS. B.

Besides the great importance of potash in the manufactures of glass and soap, it is of very considerable utility in many of the other arts, and in its combinations with several acids, particularly the nitric, with which it forms saltpetre.

CAROLINE.

Then saltpetre must be a *nitrat of potash?* But we are not yet acquainted with the nitric acid?

MRS. B.

We shall, therefore, defer entering into the particulars of these combinations, till we come to a general review of the compound salts. In order to avoid confusion, it will be better at present to confine ourselves to the alkalies.

EMILY.

Cannot you show us the change of colour which you said the alkalies produced on blue vegetable infusions?

MRS. B.

Yes; very easily. I shall dip a piece of white paper into this syrup of violets, which, you see, is of a deep blue, and dyes the paper of the same colour.—As soon as it is dry, we shall dip it into a solution of potash, which, though itself colourless, will turn the paper green—

CAROLINE.

So it has, indeed! And do the other alkalies produce a similar effect?

MRS. B.

Exactly the same.—We may now proceed to SODA, which, however important, will detain us but a very short time; as in all its general properties it very strongly resembles potash; indeed, so great is their similitude, that they have been long confounded, and they can now scarcely be distinguished except by the difference of the salts which they form with acids.

The great source of this alkali is the sea, where, combined with a peculiar acid, it forms the salt with which the waters of the ocean are so strongly impregnated.

EMILY.

Is not that the common table salt?

MRS. B.

The very same; but again we must postpone entering into the particulars of this interesting combination, till we treat of the neutral salts. Soda may be obtained from common salt; but the easiest and most usual method of procuring it, is by the combustion of marine plants, an operation perfectly analogous to that by which potash is obtained from vegetables.

EMILY.

From what does soda derive its name?

MRS. B.

From a plant called by us *soda*, and by the Arabs *kali*; which affords it in great abundance. Kali has, indeed, given its name to the alkalies in general.

CAROLINE.

Does soda form glass and soap, in the same manner as potash?

MRS. B.

Yes, it does; it is of equal importance in the arts, and is even preferred to potash for some purposes; but you will not be able to distinguish their properties, till we examine the compound salts which they form with acids; we must therefore leave soda for the present, and proceed to AMMONIA, or the VOLATILE ALKALI.

EMILY.

I long to hear something of this alkali; is it not of the same nature as hartshorn?

MRS. B.

Yes, it is, as you will see by and by. This alkali is seldom found in nature in its pure state; it is most commonly extracted from a compound salt called *sal ammoniac*, which was formerly imported from *Ammonia*, a region of Libya, from which both the salt and the alkali derive their names. The crystals contained in this bottle are specimens of this salt, which consists of a combination of ammonia and muriatic acid.

CAROLINE.

Then it should be called *muriat of ammonia*; for though I am ignorant what muriatic acid is, yet I know that its combination with ammonia cannot but be so called; and I am surprised to see sal ammoniac inscribed on the label.

MRS. B.

That is the name by which it has been so long known, that the modern chemists have not yet succeeded in banishing it altogether; and it is still sold under that name by druggists, though by scientific chemists it is more properly called muriat of ammonia.

EMILY.

By what means can the ammonia be separated from the muriatic acid?

MRS. B.

By a display of chemical attractions; but this operation is too complicated for you to understand, till you are better acquainted with the agency of affinities.

EMILY.

And when extracted from the salt, what kind of substance is ammonia?

MRS. B.

Its natural form at the temperature of the atmosphere, when free from combination, is that of gas; and in this state it is called *ammoniacal gas.* But it mixes very readily with water, and can be thus obtained in a liquid form.

CAROLINE.

You said that ammonia was a compound; pray, of what principles is it composed?

MRS. B.

It was discovered a few years since, by Berthollet, a celebrated French chemist, that it consisted of about one part of hydrogen to four parts of nitrogen. Having heated ammoniacal gas under a receiver, by causing the electrical spark to pass repeatedly through it, he found that it increased considerably in bulk, lost all its alkaline properties, and was actually converted into hydrogen and nitrogen gasses.

EMILY.

Ammoniacal gas must, I suppose, be very heavy, since it expands so much when decomposed?

MRS. B.

Compared with hydrogen gas, it certainly is; but it is considerably lighter than oxygen gas, and only about half the weight of atmospherical air. It possesses most of the properties of the fixed alkalies; but cannot be of so much use in the arts on account of its volatile nature. It is, therefore, never employed in the manufacture of glass, but it forms soap with oils equally as well as potash and soda: it resembles them likewise in its strong attraction for water; for which reason it can be collected in a receiver over mercury only.

CAROLINE.

I do not understand this?

MRS. B.

Do you recollect the method which we used to collect gasses in a glass receiver over water?

CAROLINE.

Perfectly.

MRS. B.

Ammoniacal gas has so strong a tendency to unite with water, that, instead of passing through that fluid, it would be instantaneously absorbed by it. We can therefore neither use water for that purpose, nor any other liquid of which water is a component part; so that, in order to collect this gas, we are obliged to have recourse to mercury (a liquid which has no action upon it), and we use a mercurial bath, instead of a water-bath, as we did on former occasions. Water impregnated with this gas, is nothing more than the fluid which you mentioned at the beginning of the conversation—hartshorn; it is the ammoniacal gas escaping from the water which gives it so powerful a smell.

EMILY.

But there is no appearance of effervescence in hartshorn?

MRS. B.

Because the particles of gas that rise from the water are too subtle and minute for their effect to be visible.

Water diminishes in density by being impregnated with this gas; and this augmentation of bulk increases its capacity for caloric.

EMILY.

In making hartshorn, then, or impregnating water with ammonia, heat must be absorbed, and cold produced?

MRS. B.

That effect would take place if it was not counteracted by another circumstance; the gas is liquified by incorporating with the water, and gives out its latent heat. The condensation of the gas more than counterbalances the expansion of the water; therefore, upon the whole, heat is produced.—But if you dissolve ammoniacal gas with ice or snow, cold is produced.—Can you account for that?

EMILY.

The gas, in being condensed into a liquid, must give out heat; and, on the other hand, the snow or ice, in being rarefied into a liquid, must absorb heat; so that, between the opposite effects, I should have supposed the original temperature would have been preserved.

MRS. B.

But you have forgotten to take into the account the rarefaction of the water (or melted ice) by the impregnation of the gas; and this is the cause of the cold which is ultimately produced.

CAROLINE.

Is the *sal volatile* (the smell of which so strongly resembles hartshorn) likewise a preparation of ammonia?

MRS. B.

It is carbonat of ammonia dissolved in water; and which, in its concrete state, is commonly called salts of hartshorn. Ammonia is caustic like the fixed alkalies, as you may judge by the pungent effects of hartshorn, which cannot be taken internally, or applied to delicate external parts, without being plentifully diluted with water.—Oil and acids are very excellent antidotes for alkaline poisons; can you guess why?

CAROLINE.

Perhaps, because the oil combines with the alkali, and forms soap, and thus destroys its caustic properties; and the acid converts it into a compound salt, which, I suppose, is not so pernicious as caustic alkali.

MRS. B.

Precisely so.

Ammoniacal gas, if it be mixed with atmospherical air, and a burning taper repeatedly plunged into it, will burn with a large flame of a peculiar yellow colour.

EMILY.

I thought that all the alkalies were incombustible?

CAROLINE.

Besides, you say that flame is produced by the combustion of hydrogen only?

MRS. B.

And is not hydrogen gas one of the constituents of ammoniacal gas? Therefore, though generally speaking, the alkalies are incombustible, yet one of the constituents of ammonia is eminently combustible.

EMILY.

I own I had forgotten that ammonia was a compound. But pray tell me, can ammonia be procured from this Libyan salt only.

MRS. B.

So far from it, that it is contained in, and may be extracted from, all animal substances whatever. Hydrogen and nitrogen are two of the chief constituents of animal matter; it is therefore not surprising that they should occasionally meet and combine in those proportions that compose ammonia. But this alkali is more frequently generated by the spontaneous decomposition of animal substances; the hydrogen and nitrogen gasses that arise from putrified bodies combine, and form the volatile alkali.

Muriat of ammonia, instead of being exclusively brought from Libya, as it originally was, is now chiefly prepared in Europe by chemical processes.

Ammonia, although principally extracted from this salt, can also be produced by a great variety of other substances. The horns of cattle, especially those of the deer, yield it in abundance, and it is from this circumstance that a solution of ammonia in water has been called hartshorn. It may likewise be procured from wool, flesh, and bones; in a word, any animal substance whatever yields it by decomposition.

We shall now lay aside the alkalies, however important the subject may be, till we treat of their combination with acids. The next time we meet we shall examine the earths, which will complete our review of the class of simple bodies, after which we shall proceed to their several combinations.

CONVERSATION XI.

ON EARTHS.

MRS. B.

THE EARTHS, which we are to-day to examine, are ten in number:

SILEX,	STRONTITES,
ALUMINE,	YTTRIA,
BARYTES,	GLUCINA,
LIME,	ZIRCONIA,
MAGNESIA,	AGUSTINA*.

The four last are of very late discovery; their properties are but imperfectly known; and as they have not yet been applied to use, it will be unnecessary to enter into any particulars respecting them; we shall confine our remarks, therefore, to the six first. The earths in general are, like the alkalies, incombustible substances.

CAROLINE.

Yet I have seen turf burnt in the country, and it

* The existence of agustina, as a simple earth, is now questioned by some chemists.

makes an excellent fire; the earth becomes red hot, and produces a very great quantity of heat.

MRS. B.

It is not the earth that burns, my dear, but the roots, grass, and other remnants of vegetables that are intermixed with it. The caloric, which is produced by the combustion of these substances, makes the earth red hot, and this being a bad conductor of heat, retains its caloric a long time; but were you to examine it when cooled, you would find that it had not absorbed one particle of oxygen, nor suffered any alteration from the fire. Earth is however, from the circumstance just mentioned, an excellent reflector of heat, and owes its utility, when mixed with fuel, solely to that property. It is in this point of view that Count Rumford has recommended balls of incombustible substances to be arranged in fire-places, and mixed with the coals, by which means the caloric disengaged by the combustion of the latter, is more perfectly reflected into the room, and an expence of fuel is saved.

Earth, you know, was supposed to be one of the four elements; but now that a variety of earths have been discovered and clearly discriminated, no single one can be exclusively called an element; and as none of them have been decomposed, they have all an equal title to the rank of simple bodies, which are the only elements that we now acknowledge.—

It is from these earths, either in their simple state, or mixed together and combined with other minerals, that the solid part of our globe is formed.

EMILY.

When I think of the great variety of soils, I am astonished that there are not a greater number of earths to form them.

MRS. B.

You might, indeed, almost confine that number to four; for barytes, strontites, and the others of late discovery, act but so small a part in this great theatre, that they cannot be reckoned as essential to the general formation of the globe. And you must not confine your idea of earths to the formation of soil; for rock, marble, chalk, slate, sand, flint, and all kinds of stones, from the precious jewels to the commonest pebbles; in a word, all the immense variety of mineral products, may be referred to some of these earths, either in a simple state, or combined the one with the other, or blended with other ingredients.

CAROLINE.

Precious stones composed of earth! That seems very difficult to conceive.

EMILY.

Is it more extraordinary than that the most precious of all jewels, diamond, should be composed of carbone? But diamond forms an exception, Mrs. B—; for, though a stone, it is not composed of earth.

EMILY.

I did not specify the exception, as I knew you were so well acquainted with it. Besides, I would call diamond a mineral rather than a stone, as the latter term always implies the presence of some earth.

CAROLINE.

I cannot conceive how such coarse materials can be converted into such beautiful productions.

MRS. B.

We are very far from understanding all the secret resources of nature; but I do not think the spontaneous formation of the crystals, which we call precious stones, one of the most difficult phenomena to comprehend.

By the slow and regular work of ages, perhaps of hundreds of ages, these earths may be gradually dissolved by water, and as gradually deposited by their solvent in the slow and undisturbed process of crystallization. The regular arrangement of their particles, during their reunion in a solid mass, gives them that brilliancy, transparency, and beauty, for which they are so much admired; and renders them in appearance so totally different from their rude and primitive ingredients.

CAROLINE.

But how does it happen that they are spontaneously dissolved, and afterwards crystallized?

MRS. B.

The scarcity of many kinds of crystals, as rubies, emeralds, topazes, &c. shows that their formation is not an operation very easily carried on in nature. But cannot you imagine that when water, holding in solution some particles of earth, filters through the crevices of hills or mountains, and at length dribbles into some cavern, each successive drop may be slowly evaporated, leaving behind it the particle of earth which it held in solution? You know that crystallization is more regular and perfect, in proportion as the evaporation of the solvent is slow and uniform; Nature, therefore, who knows no limit of time, has, in all works of this kind, an infinite advantage over any artist who attempts to imitate such productions.

EMILY.

I can now conceive that the arrangement of the particles of earth, during crystallization, may be such as to occasion transparency, by admitting a free passage to the rays of light; but I cannot understand why crystallized earths should assume such beautiful colours as most of them do. Sapphire, for instance, is of a celestial blue; ruby, a deep red; topaz, a brilliant yellow?

MRS. B.

Nothing is more simple than to suppose that the arrangement of their particles is such, as to transmit some of the coloured rays of light, and to reflect others, in which case the stone must appear of the colour of the rays which it reflects. But, besides, it frequently happens that the colour of a stone is owing to a mixture of some metallic matter.

CAROLINE.

Pray, are the different kinds of precious stones each composed of one individual earth, or are they formed of a combination of several earths?

MRS. B.

A great variety of materials enters into the composition of most of them; not only several earths, but sometimes salts and metals. The earths, however, in their simple state, frequently form very beautiful crystals; and, indeed, it is in that state only that they can be obtained perfectly pure.

EMILY.

Pray is not the Derbyshire spar produced by the crystallization of earths, in the way you have just explained? I have been in some of the subterraneous caverns where it is found, which are such as you have described.

MRS. B.

Yes; but this spar is a very imperfect specimen of crystallization; it consists of a great variety of ingredients confusedly blended together, as you may judge by its opacity, and by the various colours and appearances which it exhibits.

But, in examining the earths in their most perfect and agreeable form, we must not lose sight of that state in which they are most commonly found, and which, if less pleasing to the eye, is far more interesting by its utility. Before we proceed further, however, I should observe, that although the earths are considered as simple substances (as chemists have not succeeded in decomposing them), yet there is considerable reason to suppose that they, as well as the alkalies, are compound bodies. From the circumstance of their being incombustible, it has been conjectured, with some plausibility, that they may possibly be bodies that have already been burnt, and which, being saturated with oxygen, will not combine with any additional quantity of that principle.

CAROLINE.

But if they have been burnt, they must contain oxygen, which would easily be discovered?

MRS. B.

Not if their attraction for it be so strong that they will yield it to no other substance; for, during its state of combination, the properties of oxygen may be so altered, as to be concealed entirely from our observation; and it is possible that this may be the case with the earths. Let us suppose them, for instance, to have been originally some peculiar metals, whose affinity for oxygen was so great, that they attracted it from every substance, and consequently would yield it to none; such metals must ever exist in the state of oxyds; and, as we should not have known them under their metallic form, we could not consider them as metals, but should distinguish them by some specific name, as we have done with regard to the earths.

CAROLINE.

That, indeed, seems very probable; for metals, when oxydated, become to all appearance a kind of earthy substance.

EMILY.

But have the earths any of the properties of the metallic oxyds?

MRS. B.

Their strongest feature of resemblance is their property of combining with the acids to form compound salts.

You must not, however, consider the idea of earths being burnt bodies, as any thing more than mere conjecture; for whatever may be their constituents, until we succeed in decomposing them, we cannot consider them in any other light than as simple bodies.

EMILY.

Pray which of the earths are endued with alkaline properties?

MRS. B.

All of them, more or less; but there are four, barytes, magnesia, lime, and strontites, which are called *alkaline earths*, because they possess those qualities in so great a degree, as to entitle them, in most respects, to the rank of alkalies. They combine and form compound salts with acids in the same way as alkalies; they are, like them, susceptible of a considerable degree of causticity, and are similarly acted upon by chemical tests.—The other earths, silex and alumine, with one or two others of late discovery, are in some degree more earthy, that is to say, they possess more completely the properties common to all the earths, which are, insipidity, dryness, unalterableness in the fire, infusibility, &c.

CAROLINE.

Yet, did you not tell us that silex, or siliceous earth, when mixed with an alkali, was fusible, and ran into glass?

MRS. B.

Yes, my dear; but the characteristic properties of earths, which I have mentioned, are to be considered as belonging to them in a state of purity only; a state in which they are very seldom to be met with in nature.—Besides these general properties, each earth has its own specific characters, by which it is distinguished from any other substance. Let us therefore review them separately.

Silex, or silica, abounds in flint, sand, sandstone, agate, jasper, &c.; it forms the basis of many precious stones, and particularly of those that strike fire with steel. It is rough to the touch, scratches and wears away metals; it is acted upon by no acid but the fluoric, and is not soluble in water by any known process; but nature certainly dissolves it by means with which we are unacquainted, and thus produces a variety of siliceous crystals, and amongst these *rock crystal*, which is the purest specimen of this earth. Silex appears to have been intended by Providence to form the solid basis of the globe, to serve as a foundation for the original mountains, and give them that hardness and durability which has enabled them to resist the various revolutions which the surface of the earth has successively undergone. From these mountains siliceous rocks have, during the course of ages, been gradually detached by torrents of water, and brought down in fragments; these, in the violence and rapidity of their descent, are sometimes crumbled to sand, and in this state form the beds of rivers and of the sea, chiefly composed of siliceous materials. Sometimes the fragments are broken without being pulverized by their fall, and assume the form of pebbles, which gradually become rounded and polished.

EMILY.

Pray what is the true colour of silex, which forms such a variety of different coloured substances? Sand is brown, flint is nearly black, and precious stones are of all colours?

MRS. B.

Pure silex, such as is found only in the chemist's laboratory, is perfectly white, and the various colours which it assumes, in the different substances you have just mentioned, proceed from the different ingredients with which it is mixed in them.

CAROLINE.

I wonder that silex is not more valuable, since it forms the basis of so many precious stones.

MRS. B.

You must not forget that the value we set upon precious stones, depends in a great measure upon the scarcity with which nature affords them; for, were those productions either common, or perfectly imitable by art, they would no longer, notwithstanding their beauty, be so highly esteemed. But the real value of siliceous earth, in many of the most useful arts, is very extensive. Mixed with clay, it forms the basis of all the various kinds of earthen ware, from the most common utensils to the most refined ornaments.

EMILY.

And we must not forget its importance in the formation of glass with potash.

MRS. B.

Nor should we omit to mention, likewise, many other important uses of silex, such as being the chief ingredient of some of the most durable cements, of mortar, &c.

I said before, that siliceous earth combined with no acid but the fluoric; it is for this reason that glass is liable to be attacked by that acid only, which, from its strong affinity for silex, forces that substance from its combination with the potash, and thus destroys the glass.

We will now hasten to proceed to the other earths, for I am rather apprehensive of your growing weary of this part of our subject.

CAROLINE.

The history of the earths is not quite so entertaining as that of the other simple substances.

MRS. B.

Perhaps not; but it is absolutely indispensable that you should know something of them; for they form the basis of so many interesting and important compounds, that their total omission would throw great obscurity on our general outline of chemical science. We shall, however, review them in as cursory a manner as the subject can admit of.

ALUMINE derives its name from a compound salt called *alum*, of which it forms the basis.

CAROLINE.

But it ought to be just the contrary, Mrs. B.—; the simple body should give, instead of taking, its name from the compound.

MRS. B.

Very true, my dear; but as the compound salt was known long before its basis was discovered, it was natural enough when that earth was at length separated from the acid, that it should derive its name from the compound from which it was obtained. However, to remove your scruples, we will call the salt according to the new nomenclature, *sulphat of alumine.* From this combination, alumine may be obtained in its pure state; it is then soft to the touch, makes a paste with water and hardens in the fire. In nature, it is found chiefly in clay, which contains a considerable proportion of this earth; it is very abundant in fuller's earth, slate, and a variety of other mineral productions. There is indeed scarcely any mineral substance more useful to mankind than alumine. In the state of clay, it forms large strata of the earth, gives consistency to the soil of valleys, and of all low and damp spots, such as swamps and marshes. The beds of lakes, ponds, and springs, are almost entirely of clay; instead of allowing of the filtration of water, as sand does, it forms an impenetrable bottom, and by this means water is accumulated in the caverns of the earth, producing those reservoirs whence springs issue, and spout out at the surface.

EMILY.

I always thought that these subterraneous reservoirs of water were bedded by some hard stone, or rock, which the water could not penetrate.

MRS. B.

That is not the case; for in the course of time water would penetrate, or wear away silex, or any other kind of stone, while it is effectually stopped by clay, or alumine.

The solid compact soils, such as are fit for corn, owe their consistence in a great measure to alumine; this earth is therefore used to improve sandy or chalky soils, which do not retain a sufficient quantity of water for the purpose of vegetation.

Alumine is the most essential ingredient in all potteries. It enters into the composition of brick, as well as in that of the finest china; the addition of silex and water hardens it, renders it susceptible of a degree of vitrification, and makes it perfectly fit for its various purposes.

CAROLINE.

I can scarcely conceive that brick and china should be made of the same materials.

MRS. B.

Brick consists almost entirely of baked clay; but a certain proportion of silex is essential to the formation of earthen or stone ware. In common potteries sand is used for that purpose; a more pure silex is, I believe, necessary for the composition of porcelain, as well as a finer kind of clay; and these materials are, no doubt, more carefully prepared, and curiously wrought, in the one case than in the other. Porcelain owes its beautiful semi-transparency to a commencement of vitrification.

EMILY.

But the commonest earthen ware, though not transparent, is covered with a kind of glazing.

MRS. B.

That precaution is equally necessary for use as for beauty, as the ware would be liable to be spoiled and corroded by a variety of substances, if not covered with a coating of this kind. In porcelain it consists of enamel, which is a fine white opake glass, formed of metallic oxyds, sand, salts, and such other materials as are susceptible of vitrification. The glazing of common earthen ware is made chiefly of oxyd of lead, or sometimes merely of salt, which, when thinly spread over earthen vessels, will, at a certain heat, run into opake glass.

CAROLINE.

And of what nature are the colours which are used for painting china?

MRS. B.

They are all composed of metallic oxyds, so that these colours, instead of receiving injury from the application of fire, are strengthened and developed by its action, which causes them to undergo different degrees of oxydation.

Alumine and silex are not only often combined by art, but they have in nature a very strong tendency to unite, and are found combined, in different proportions, in various gems and other minerals. Indeed, many of the precious stones, such as ruby, oriental sapphire, amethyst, &c. consist chiefly of alumine.

We may now proceed to the alkaline earths. I shall say but a few words on BARYTES, as it is hardly ever used, except in chemical laboratories. It is remarkable for its great weight, and its strong alkaline properties, such as destroying animal substances, turning green some blue vegetable colours, and showing a powerful attraction for acids; this last property it possesses to such a degree, particularly with regard to the sulphuric acid, that it will always detect its presence in any substance or combination whatever, by immediately uniting with it and forming a sulphat of barytes. This renders it a very valuable chemical test. It is found pretty abundantly in nature in the state of carbonat, from which the pure earth can be easily separated.

The next earth we have to consider is LIME. This is a substance of too great and general importance to be passed over so slightly as the last.

Lime is strongly alkaline. In nature it is not met with in its simple state, as its affinity for water and carbonic acid is so great, that it is always found combined with these substances, with which it forms the common lime-stone; but it is separated in the kiln from these ingredients, which are volatilized whenever a sufficient degree of heat is applied.

EMILY.

Pure lime, then, is nothing but lime-stone, which has been deprived, in the kiln, of its water and carbonic acid?

MRS. B.

Precisely; in this state it is called *quick-lime*, and is so caustic, that it is capable of decomposing the dead bodies of animals very rapidly, without their undergoing the process of putrefaction.—I have here some quick-lime, which is kept carefully corked up in a bottle to prevent the access of air; for were it at all exposed to the atmosphere, it would absorb both moisture and carbonic acid gas from it, and be soon slaked. Here is also some lime-stone—we shall pour a little water on each, and observe the effects that result from it.

CAROLINE.

How the quick-lime hisses! It is become excessively hot!—It swells, and now it bursts and crumbles to powder, while the water on the lime-stone appears to produce no kind of alteration.

MRS. B.

Because the lime-stone is already saturated with water, whilst the quick-lime, which has been deprived of it in the kiln, combines with it with very great avidity, and produces this prodigious disengagement of heat, the cause of which I formerly explained to you; do you recollect it?

EMILY.

Yes; you said that the heat did not proceed from the lime, but from the water which was *solidified*, and thus parted with its heat of liquidity.

MRS. B.

Very well. If we continue to add successive quantities of water to the lime, after being slaked and crumbled as you see, it will then gradually be diffused in the water, till it will at length be dissolved in it, and entirely disappear; but for this purpose it requires no less than 700 times its weight of water. This solution is called *lime-water.*

CAROLINE.

How very small, then, is the proportion of lime dissolved!

MRS. B.

Barytes is still of more difficult solution; it dissolves only in 900 times its weight of water: but it is much more soluble in the state of crystals. The liquid contained in this bottle is lime-water; it is often used as a medicine, chiefly, I believe, for the purpose of combining with, and neutralizing, the superabundant acid which it meets with in the stomach.

EMILY.

I am surprised that it is so perfectly clear; it does not at all partake of the whiteness of the lime.

MRS. B.

Have you forgotten that, in solutions, the solid body is so minutely subdivided by the fluid, as to become invisible, and therefore will not in the least degree impair the transparency of the solvent?

I said that the attraction of lime for carbonic acid was so strong, that it would absorb it from the atmosphere. We may see this effect by exposing a glass of lime-water to the air; the lime will then separate from the water, combine with the carbonic acid, and reappear on the surface in the form of a white film, which is carbonat of lime, commonly called *chalk*.

CAROLINE.

Chalk is, then, a compound salt! I never should have supposed that those immense beds of chalk, that we see in many parts of the country, were a salt.—Now, the white film begins to appear on the surface of the water; but it is far from resembling hard solid chalk.

MRS. B.

That is owing to its state of extreme division;

in a little time it will collect into a more compact mass, and subside at the bottom of the glass.

If you breathe into lime-water, the carbonic acid, which is mixed with the air that you expire, will produce the same effect. It is an experiment very easily made—I shall pour some lime-water into this glass tube, and, by breathing repeatedly into it, you will soon perceive a precipitation of chalk—

EMILY.

I see already a small white cloud formed.

MRS. B.

It is composed of minute particles of chalk; at present it floats in the water, but it will soon subside.

Carbonat of lime, or chalk, you see, is insoluble in water, since the lime which was dissolved reappears when converted into chalk; but you must take notice of a very singular circumstance, which is, that chalk is soluble in water impregnated with carbonic acid.

CAROLINE.

It is very curious, indeed, that carbonic acid gas should render lime soluble in one instance, and insoluble in the other!

MRS. B.

I have here a bottle of Seltzer water, which, you know, is strongly impregnated with carbonic acid—let us pour a little of it into a glass of lime-water.—You see that it immediately forms a precipitation of carbonat of lime?

EMILY.

Yes, a white cloud appears.

MRS. B.

I shall now pour an additional quantity of the Seltzer water into the lime-water—

EMILY.

How singular! The cloud is redissolved, and the liquid is again transparent.

MRS. B.

All the mystery depends upon this circumstance, that carbonat of lime is soluble in carbonic acid, whilst it is insoluble in water; the first quantity of carbonic acid, therefore, which I introduced into the lime-water, was employed in forming the carbonat of lime, which remained visible, until an additional quantity of carbonic acid dissolved it. Thus, you see, when the lime and carbonic acid are in proper proportions to form chalk, the white cloud appears, but when the acid predominates, the chalk is no sooner formed than it is dissolved.

CAROLINE.

That is now the case; but let us try whether a further addition of lime-water will again precipitate the chalk.

EMILY.

It does, indeed! The cloud reappears, because, I suppose, there is now no more of the carbonic acid than is necessary to form chalk; and, in order to dissolve the chalk, a superabundance of acid is required.

MRS. B.

We have, I think, carried this experiment far enough; every repetition would but exhibit the same appearances.

Lime combines with most of the acids, to which the carbonic (as being the weakest) readily yields it; but these combinations we shall have an opportunity of noticing more particularly hereafter. It combines with phosphorus, and with sulphur, in their simple state; in short, of all the earths, lime is that which nature employs most frequently and most abundantly, in its innumerable combinations. It is the basis of all calcareous earths and stones; we find it likewise in the animal and the vegetable creations.

EMILY.

And in the arts is not lime of very great utility?

MRS. B.

Scarcely any substance more so; you know that it is a most essential requisite in building, as it constitutes the basis of all cements, such as mortar, stucco, plaister, &c.

Lime is also of infinite importance in agriculture; it lightens and warms soils that are too cold, and compact, in consequence of too great a proportion of clay.—But it would be endless to enumerate the various purposes for which it is employed; and you know enough of it to form some idea of its importance: we shall, therefore, now proceed to the third alkaline earth, MAGNESIA.

CAROLINE.

I am already pretty well acquainted with that earth; it is a medicine.

MRS. B.

It is in the state of carbonat that magnesia is usually employed medicinally; it then differs but little in appearance from its simple form, which is that of a very fine light white powder. It dissolves in 2000 times its weight of water, but forms with acids extremely soluble salts. It has not so great an attraction for acids as lime, and consequently yields them to the latter. It is found in a great variety of mineral combinations, such as slate, mica, amianthus, and more particularly in a certain lime-stone, which has lately been discovered by Mr. Tennant to contain it in very great quantities. It does not attract and solidify water, like lime; but, when mixed with water and exposed to the atmosphere, it slowly absorbs carbonic acid from the latter, and thus loses its causticity. Its chief use in medicine is, like that of lime, derived from its readiness to combine with, and neutralize, the acid which it meets with in the stomach.

EMILY.

Yet, you said that it was taken in the state of carbonat, in which case it is already combined with an acid?

MRS. B.

Yes; but the carbonic is the last of all the acids in the order of affinities; it will therefore yield the magnesia to any of the others. Pure magnesia would perhaps be too caustic to be taken internally.—Combined with sulphuric acid, magnesia forms another and more powerful medicine, commonly called *Epsom salt.*

CAROLINE.

And properly, *sulphat of magnesia*, I suppose? Pray why was it ever called Epsom salt?

MRS. B.

Because there is a spring in the neighbourhood of Epsom, which contains this salt in great abundance.

The last alkaline earth which we have to mention is STRONTIAN, or STRONTITES, discovered by

Dr. Hope a few years ago. It so strongly resembles barytes in its properties, and is so sparingly found in nature, and of so little use in the arts, that it will not be necessary to enter into any particulars respecting it. One of the most remarkable characteristic properties of strontites, is, that its salts, when dissolved in spirit of wine, tinge the flame of a deep red, or blood colour.

We shall here conclude this lecture; and, at our next meeting, you will be introduced to a subject, totally different from any of the preceding.

END OF THE FIRST VOLUME.

Printed by C. Mercier, and Co.
Northumberland-court, Strand, London.

sponding Taste and Beauty. The Drawings are almost wholly new.

5. The Maps will be double the Size usually given in similar Publications, and are drawn and engraved under the Direction of Mr. ARROWSMITH.

6. A Part, or Half Volume, Price 18s. each, has hitherto been published once in about four Months; and, in Consequence of some Arrangements lately adopted, the Public may with Confidence rely upon a more frequent Publication.

7. A few Copies are printed off on Royal Paper, with Proof Impressions of the Plates, Price 1l. 16s. each Part.

II.

The CHEMICAL LECTURES of the late celebrated Dr. JOSEPH BLACK, Regius Professor of Chemistry in the Uuiversity of Edinburgh; published from the Author's Manuscripts,

By JOHN ROBISON, LL. D.

Professor of Natural Philosophy in the University of Edinburgh.

With Notes, philosophical and historical, by the Editor, partly for Illustration of the Text, and partly in order to ascertain the Claims of Dr. Black, and other eminent Philosophers of these Kingdoms, to the great Discoveries and Improvements which have been made in this Science, especially since the Year 1756. In 2 large Vols. 4to. embellished with a Head of the Author. Price 3l. 3s. in Boards.

III.

A GENERAL SYSTEM OF CHEMICAL KNOWLEDGE; and its Application to the Phenomena of NATURE and ART.

By A. F. FOURCROY,

Of the National Institute of France, Counsellor of State, Professor of Chemistry at various public Establishments, Member of many Academies, &c.

Translated from the original French,

By WILLIAM NICHOLSON.

In 11 Vols. 8vo. together with a Set of Synoptic Tables in large Folio. Price 5l. 5s. in Boards.

The Tab[illegible]s may be had separate. Price 1l. 1s.

IV.

ELEMENTS OF CHEMISTRY AND NATURAL HISTORY. To which is prefixed, the Philosophy of Chemistry.

By A. F. FOURCROY.
The fifth Edition, with Notes,
By JOHN THOMSON,
Surgeon, Edinburgh.
In 3 Vols. Royal 8vo. Price 1l. 11s. 6d. in Boards.

" This edition has a claim to our attention, on account of the notes which have been added by the editor; and which we have indeed perused with much pleasure. Mr. Thomson has not, like many editors, contented himself with giving the text of his author, with only a few superficial remarks; on the contrary, he has added many copious and valuable notes to each chapter, the selection and number of which discover much judgment, and considerable extent of chemical reading. By these notes, also, this edition has in a great measure been made to keep pace with the rapid progress of chemical science, since the publication of the original work. The Notes on the Animal Kingdom, Part IV. are particularly instructive and interesting. The same may indeed be said nearly of the whole; and we have no doubt that this edition will be found highly useful to chemical students."

Monthly Review, December 1801.

*** The First Edition of this Work consisted of 5000 Copies, and a Second Edition of all the early Parts being called for in this early Stage of its Publication, an adequate Idea may be formed of the Estimation in which it is held by the Public. The following are its principal Recommendations:—

1. The Plan of this Work is intended as an Improvement upon similar Publications, being a Medium between the Plan of a Dictionary and that of Treatises; and comprehending the Advantages of each. The History and Outlines of each Science are given under its appropriate Title; and its various Divisions, which can be more satisfactorily explained in separate Articles, than in the Body of a Treatise, are introduced under their respective Terms. This is indeed the only proper Plan of a Dictionary intended for Reference when Information is required, which is expected to be found under its most ready and familiar Term in the Alphabet.

2. The Editor is of acknowledged Learning and Industry, and of unquestionable Experience in this Department of literary Labour; the greater Part of his Life having been employed in editing and improving the last Edition of Mr Chambers's Dictionary, and in collecting Materials for the present Work.

3. Among the Gentlemen, who have engaged to contribute their Assistance to this Work, are many of distinguished Eminence; and the List is continually augmenting, no Opportunity being neglected to engage the Co-operation of any Gentleman whose Services can be of real Utility.

4. The Embellishments are of a very superior Description, and will form, when completed, an incomparably more elegant and correct Set of scientific and other Plates than has ever been produced. The scientific Subjects are engraved by Mr. Lowry, whose accurate Knowledge and improved Method of Execution, in this Branch of the Art, have not been equalled. The Subjects of Natural History, &c. are chiefly engraved by Mr. Milton and Mr. Scott, with corre-

ERRATA.

Page 136, line 7, Fig. 9, *read* Fig. 8.
—— 155, —— 13, *after hydrogen, add the word* expanded.
—— 186, —— 19, } Sulphureous, *read* Sulphurous.
—— 188, —— 7 and 10, }
—— 241, —— 13, three, *read* five.
—— 304, —— 5, Emily, *read* Mrs. B.