F. M. Michael

From F. Marion Michael.

PHARMACEUTICAL CHEMIST,

No. 4 East Third Street, Dayton, Ohio.

[Marcet (Jan

Conversations
ON
CHEMISTRY,
In which the Elements of that Science are familiarly explained and illustrated
BY EXPERIMENTS AND PLATES.

TO WHICH ARE ADDED,
Some late Discoveries on the subject of the
FIXED ALKALIES,
BY H. DAVY, ESQ.
Of the Royal Society.

A Description and Plate of the
PNEUMATIC CISTERN
Of Yale College.—
AND,
A short Account of
ARTIFICIAL MINERAL WATERS
In the United States.

With an APPENDIX,
Consisting of TREATISES on
DYEING, TANNING AND CURRYING.

From Sidney's Press.
FOR INCREASE COOKE & CO. BOOK-SELLERS, N. HAVEN.
1809.

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.

VOL. I. ON SIMPLE BODIES.

APPENDIX.

CONVERSATIONS

ON

CHEMISTRY.

ON SIMPLE BODIES.

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 Alchymists, 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 alchymists 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 conveniencies 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 into 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 consists 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 follow :

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

Caroline. This is, indeed, a formidable list!

Mrs. B. Not so much 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 farther, 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 *dissimilar* 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 compleated.

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 chrystals, of a fine blue colour, and perfectly transparent. Of these I can shew 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 depend 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 deposites 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 destroys 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 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. Herschel.

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 subtile 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 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 subtile, 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. This 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 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 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* 1. *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 immoveable, 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 dilation on the dial-plate.

Emily. This is indeed a very curious instrument ; but I do not understand 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.

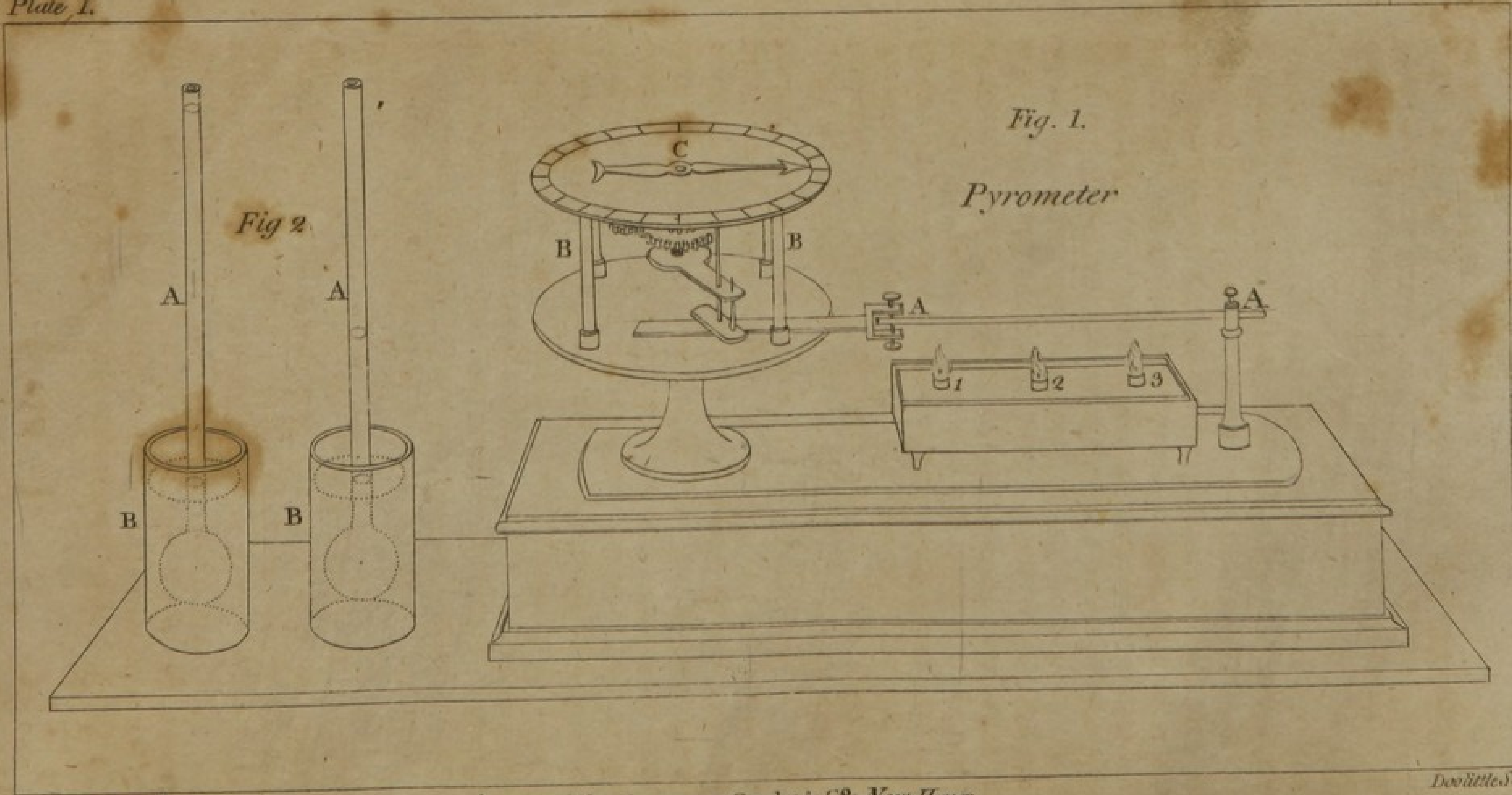
By submitting different bodies to the test of the pyrometer, it is found that they are far from dilating in the same proportion. Different metals expand in different degrees, and other kinds of solid bodies vary still more in this respect. But this different susceptibility of dilatation is still more 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 as I hold the bulb.

Emily. It certainly dilates, for I see it is rising into

PLATE I.

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 for Increase Cooke & Co. New Haven

Doolittle Sc.

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, *(Pate* 1. *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 began 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 spirits 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 spirits 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.

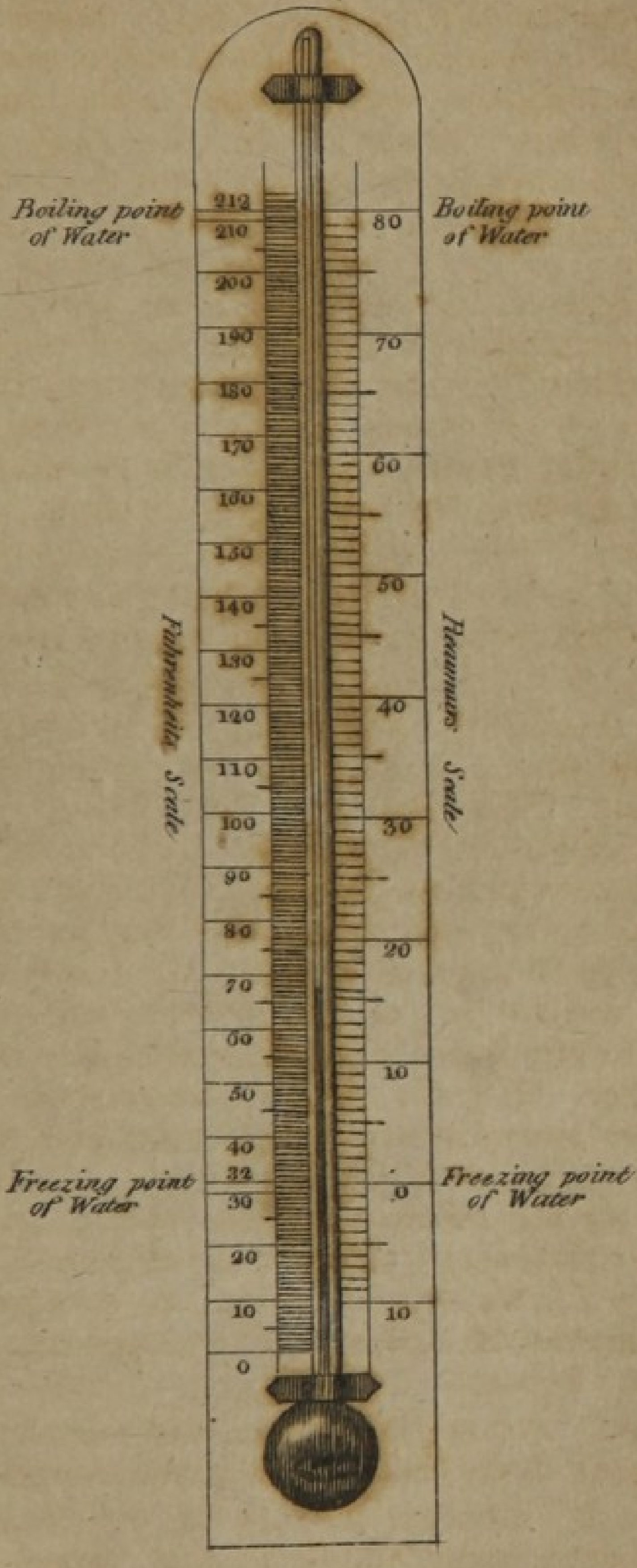
Emily. The variety of scale must be very inconvenient, and I should think liable to occasion confusion, when French and English experiments are compared.

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 spirits 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

THERMOMETER



Drawn by the Author

Doolittle Sc.

Engraved for Increase Cooke & C.º New Haven

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.

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.

Coroline. 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 by 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 suggested 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.

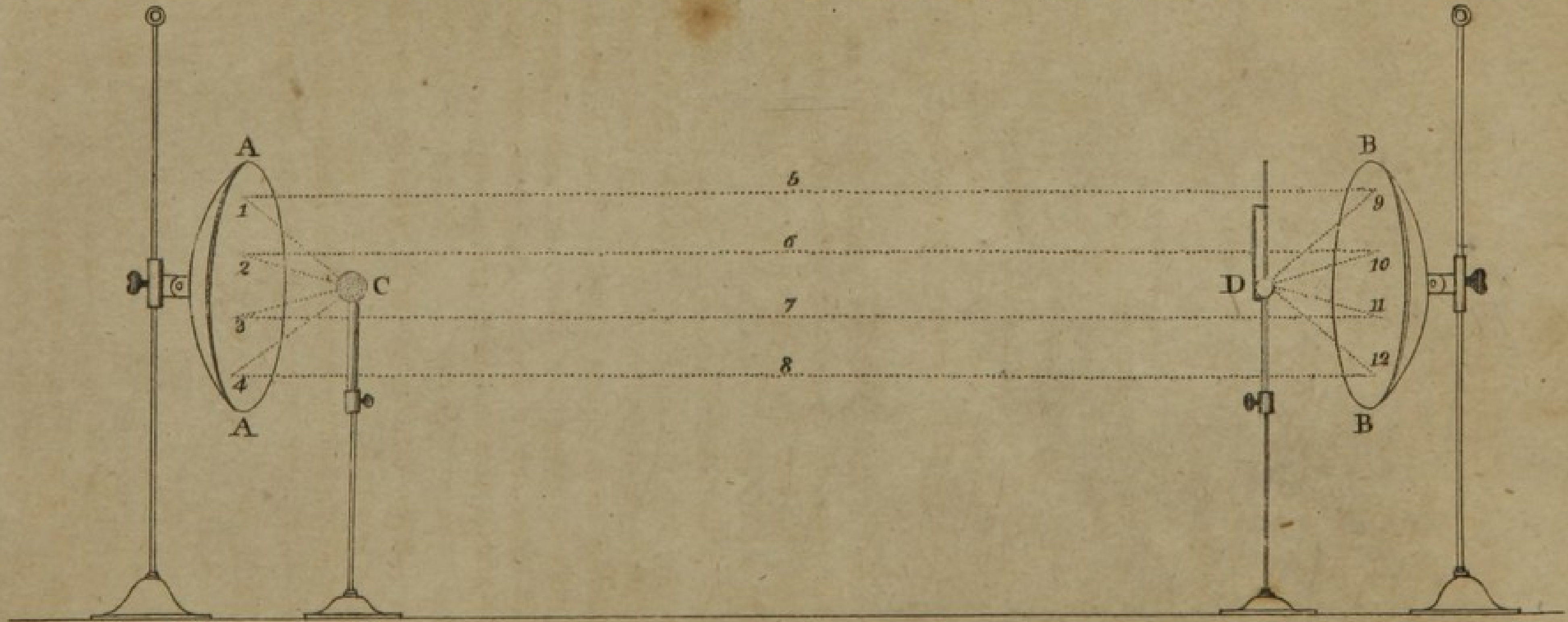
Caroline. Well, Mrs. B. since you have all nature to oppose to me, I believe that I must give up the point. But I wish I could *see* these rays of caloric, I should then have greater faith in them.

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, ac-

Mr. PICTETS APPARATUS FOR THE REFLECTION OF HEAT



Drawn by the Author

Engraved for Increase Cooke & Co. New Haven.

Doolittle Sc.

cording 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 mirror. The rays of heat which fell on this mirror were reflected, agreeably to the property of concave mirrors, in a parrallel direction, so as to fall on a similar mirror, which was placed opposite 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 sevral 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.

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

PLATE III.

A A. and B B. Concave mirrors fixed on stands. C. heated bullet placed in the focus of the mirror A. D. The thermometer with its bulb placed in the focus of the mirror B. 1 2 3 4. Rays of caloric radiating from the bullet and falling on the mirror A. 5 6 7 8. The same rays reflected from the mirror A to mirror B. 9 10 11 12. The same rays reflected by the mirror B to the thermometer.

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 fecility 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 that not 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 proportionably 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 ye 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 more 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 shew 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 effects 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 ligher.

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 forty degrees, which is eight 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 condences, 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 affixed 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 forty 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 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.

PLATE IV.

Fig 5. Boiling water in a flask over a patent lamp.

Fig. 6. Ether evaporated and water frozen in the air pump. A. A phial of ether. B. Glass vessel containing water. C. C. Thermometers, one in the ether, the other in the water.

* 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.

Fig. 6.
Pneumatic Pump

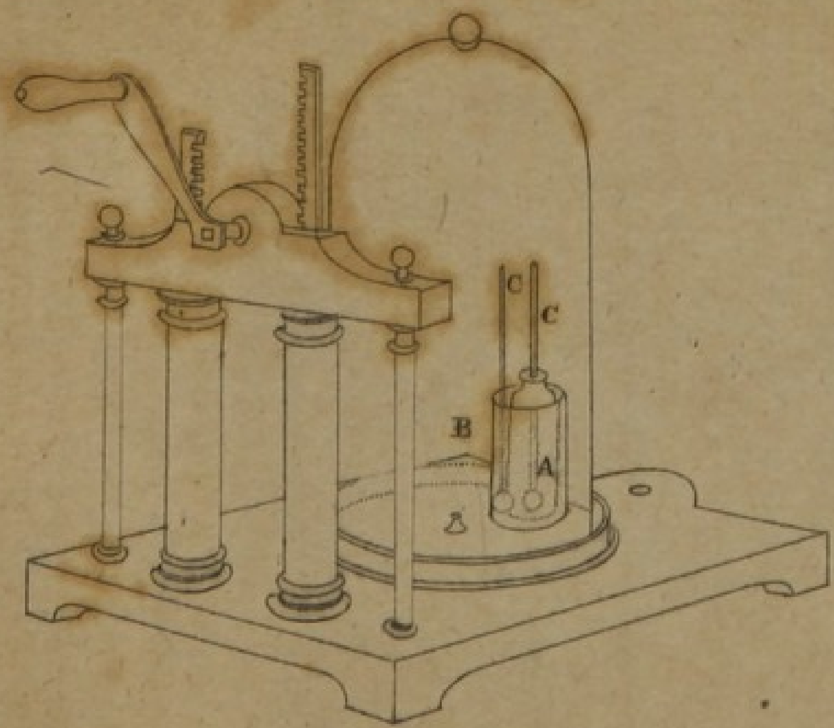
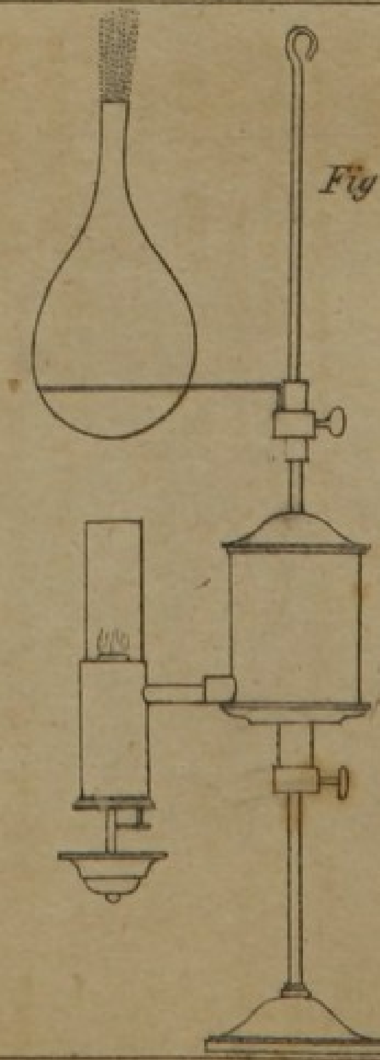


Fig 5.



Drawn by the Author

Engraved for Increase Cooke & C^o. New Haven

Doolittle Sc.

Emily. But the heat which rarefies the air enclosed in the water, must rarefy the water at the same time; therefore, 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 greater 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, depends 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 fecilitates 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 contribute 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 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

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

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?

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 in 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 absord caloric from it; 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 a 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!

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

* 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.

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 of 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

* Or the whole flask may be dipped in 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.

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 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 ridiating 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, aud 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 hêat 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 a 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, aud 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 be 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 no longer becomes latent; 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 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. This is another example of latent heat, producing a change of form. At first it converted a solid body into a liquid, and now it turns the liquid into vapour !

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 re-appear entirely, in the form of free caloric.

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

Mrs. B. For the purpose of shewing 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 form.

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. This method of heating liquids has been turned to advantage, in several economical establishments. At Leeds, for instance, there is a large dye-house, in which a great number of coppers are kept boiling by means of a single one, which is situated without the building, and which alone is heated by fire. The steam of this last is conveyed through pipes into the bottom of each of the other coppers, and it appears extremely singular to see all these coppers boiling, though there is not a particle of fire in the place.

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 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 order 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 to accomplish 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 change 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 radient 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 decends, 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 surprising 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 since 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 cubit inches, and this little measure contains exactly one cubit 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 into 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 bodies, in passing from a solid to a liquid form, or from the liquid state to that of vapour, absorbs heat; and that when the reverse takes 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 undergo a change of state, though no very sensible difference takes place in their form.

* This rule, if not universal, admits of very few exceptions.

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 most of them 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 has been 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 arrangement 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 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, while in a state of ebullition, 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 boils, 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 vessel, the inner surface of which is lined with ice, so as to form a sort of 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 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 will 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 a 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 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 shews 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 constiuent 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 subtile, 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 heterogenous 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 or AZOTIC GAS.

Emily. Pray what is a gas ?

Mrs. B. The name of *gas* is given to any aeriform fluid, which consists of some substances 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 basis 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 subtance, 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 breath more freely than our lungs could bear, if we respired oxygen gas alone. The nitrogen is no impediment either to respiration, or cumbustion; 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 subtile 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 shall 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 the 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 this 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 the 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 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 ?

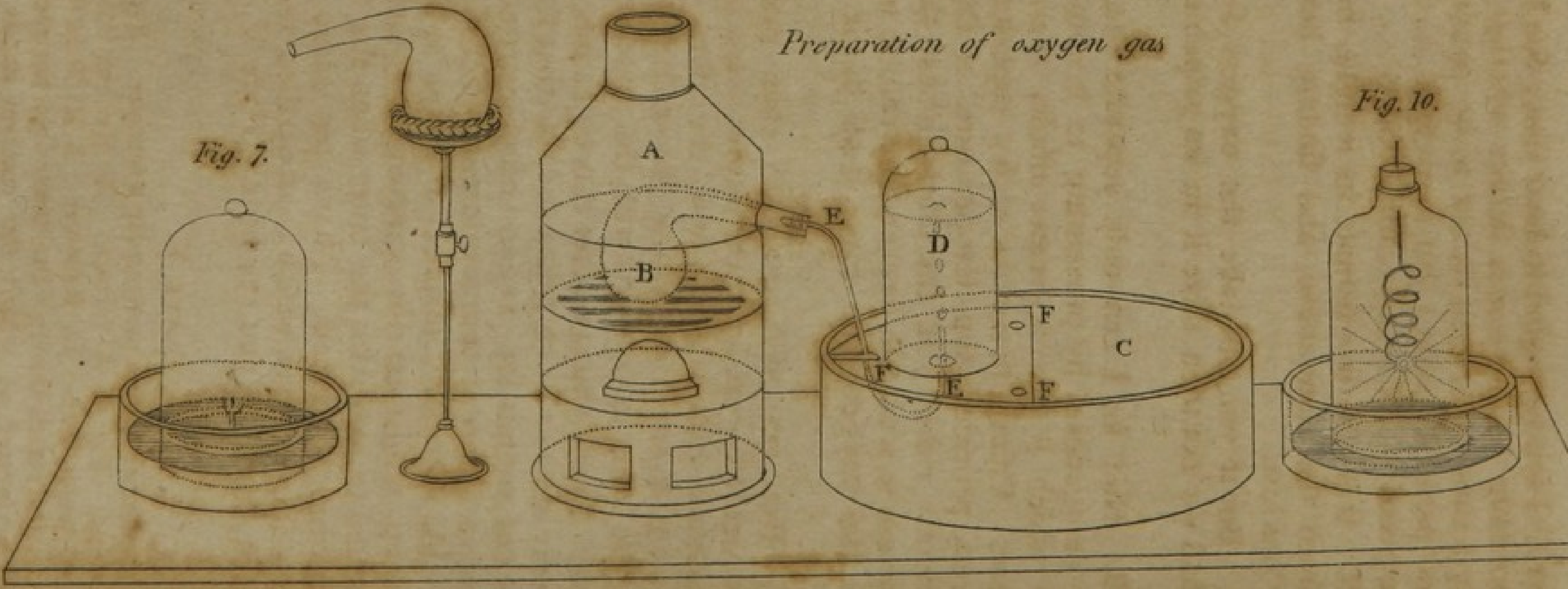
Mrs. B. Yes ; but the term is not confined to metals, though chiefly applied to them. Any body whatever, that has combined with a certain quantity of oxygen, either by means of oxydation or combustion, is called an *oxyd*, and is said to be *oxydated* or *oxygenated*.

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.

Fig. 8. Fig. 9.

Preparation of oxygen gas

Fig. 7. Fig. 10.



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 palpable 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.* 8.)

PLATE V.

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.

—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 you 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?

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 be 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. 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 cumbustion, 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 which 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 coloric 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 it produces, 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, the air within it will be deprived of its oxygen 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 próduce 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 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 produce water.*

Emily. And how does hydrogen produce 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) inflamable air.

Caroline. Really! Is it possible that water should be a combination of two gasses, and that one of them should be 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 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 oxyen being condensed into a solid, by the loss of caloric, and the hydrogen expanded into a gas, by the acquisition of it.

Mrs. B. Very well; but remember that the basis 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.

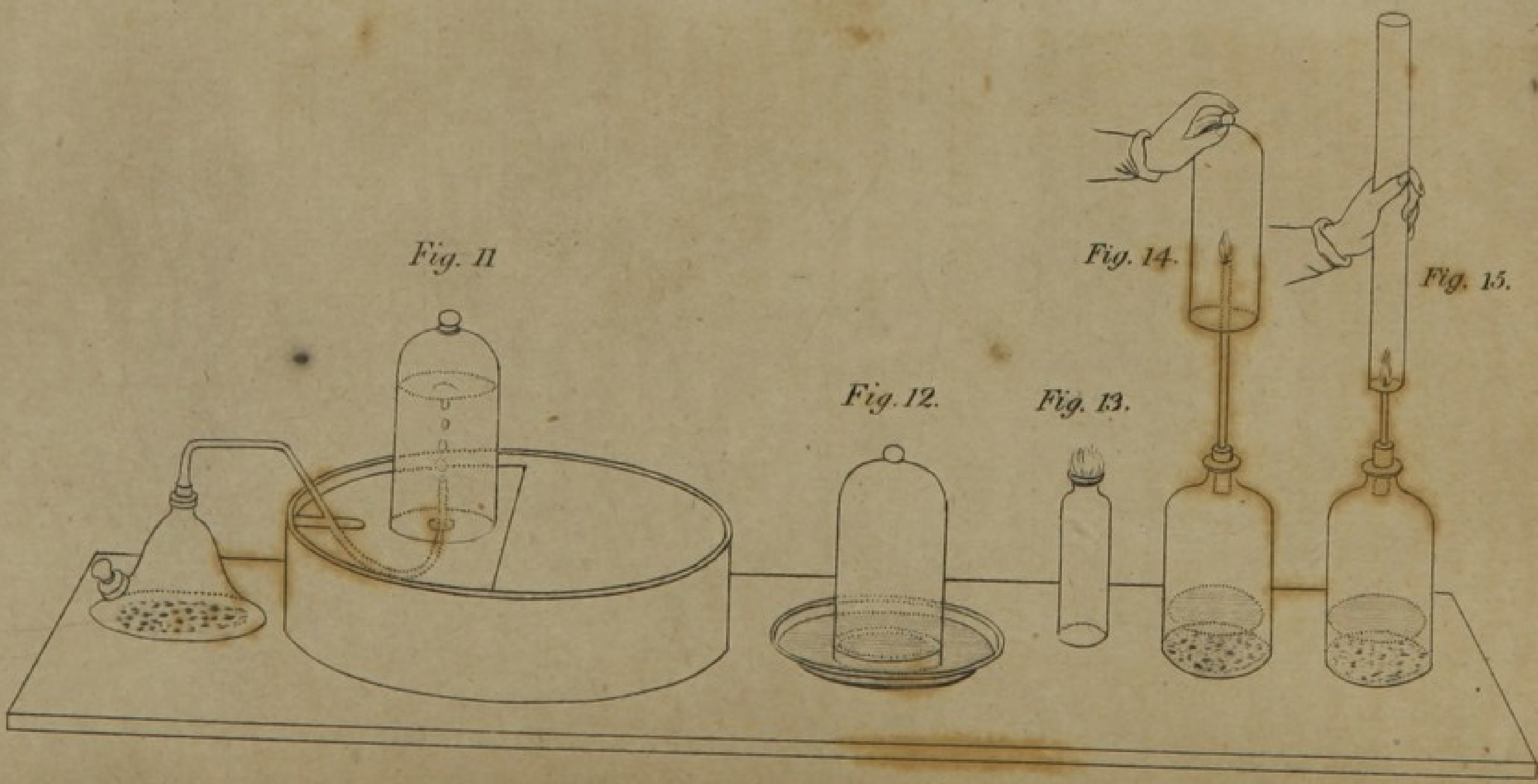
Mrs. B. The connection, or friendship, as you choose to call it, is much more intimate between oxygen and hydrogen, in the state of water, than between oxygen and nitrogen, in the atmosphere: for in the first case, there is a chemical union and condensation of the two substances; in the latter they are 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 according to our definition, it may, no doubt, be referred 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 metal; the decomposition of water by these latter means, take 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 va-



Drawn by the Author

Engraved for Increase Cook & C^o New Haven.

Doolittle Sc

pour, 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 fecilitate 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

PLATE VI.

Fig. 11. Apparatus for preparing and 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 founds by the combustion of hydrogen gas.

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 any where, the water in the saucer being equally effectual in preventing its escape as that in the bath. (*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 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 shewing it to 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 shew 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 noice 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 is here 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

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

afterwards it goes on of itself, because the candle finds a supply of caloric in the successive quantities of *chemical* heat which becomes *sensible* by the combination of the two gasses. But there are other accessary circumstances connected with the combustion of candles and lamps, which I cannot explain to you till 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 belong 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 the 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 shew you with hydrogen gas, which I think will entertain you. Have you ever blown bubbles with soap and water ?

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 ?

Fig. 16.

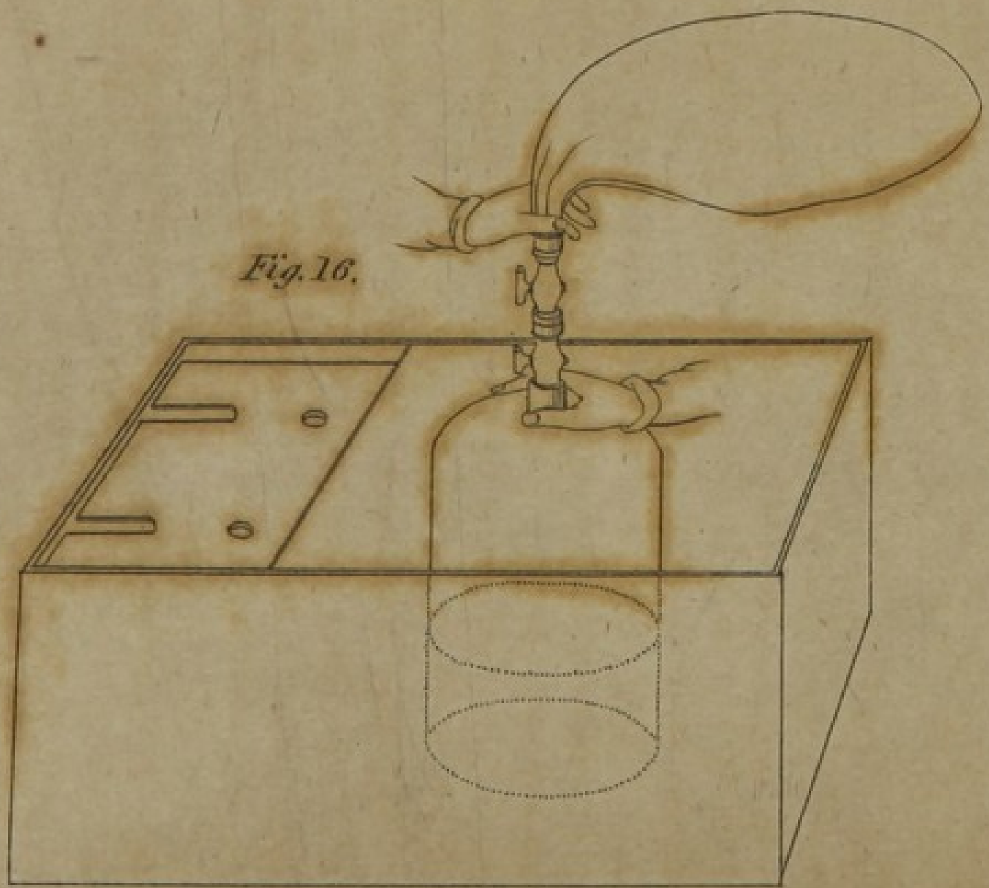
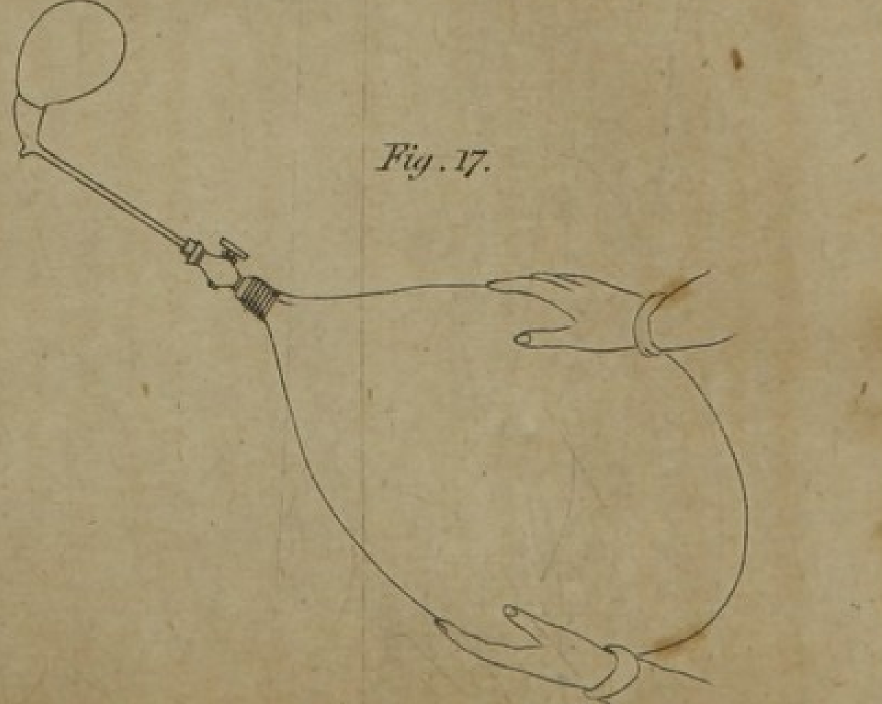


Fig. 17.



Drawn by the Author.

Engraved for Increase Cooke & C^o. New Haven.

Doolittle Sc.

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 burns 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 suc-

Plate VII.

Fig. 16. Apparatus for transferring gasses from a receiver into a bladder. Fig. 17. Apparatus for blowing ſoap bubbles.

ceed 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.

Air balloons are filled with this gas, and if they carried no other weight than their covering, would ascend as rapidly as these bubbles.

Caroline. Yet their covering must be much heavier than that of these bubbles?

Mrs. B. Not in proportion to the quantity of gas they contain. I do not know whether you have ever been present at the filling of a large balloon. The apparatus for that purpose is very simple. It consists of a number of vessels, either jars or barrels, in which the materials for the formation of the gas are mixed, each of these being furnished with a tube, and communicating with a long flexible pipe, which conveys the gas into the balloon.

Emily. But the fire balloons which were first invented, and have been since abandoned, on account of their being so dangerous, were constructed, I suppose, on a different principle.

Mrs. B. They were filled simply with atmospherical air, considerably rarefied, and the necessity of having a fire underneath the balloon, in order to preserve the rarefaction of the air within it, was the circumstance productive of so much danger.

If you are not yet tired of experiments, I have another to shew 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 tranferring 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. These phenomena, however, are most probably of an electrical nature. Yet various meteorological effects may be attributed to accidental detonations of hydrogen gas in the atmosphere; for 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 such meteors or luminous appearances as are occasionally seen in the atmosphere. Of this kind are probably those broad flashes which we often see on a summer evening, without hearing any detonation.

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, though 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.

On 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 may be discovered 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

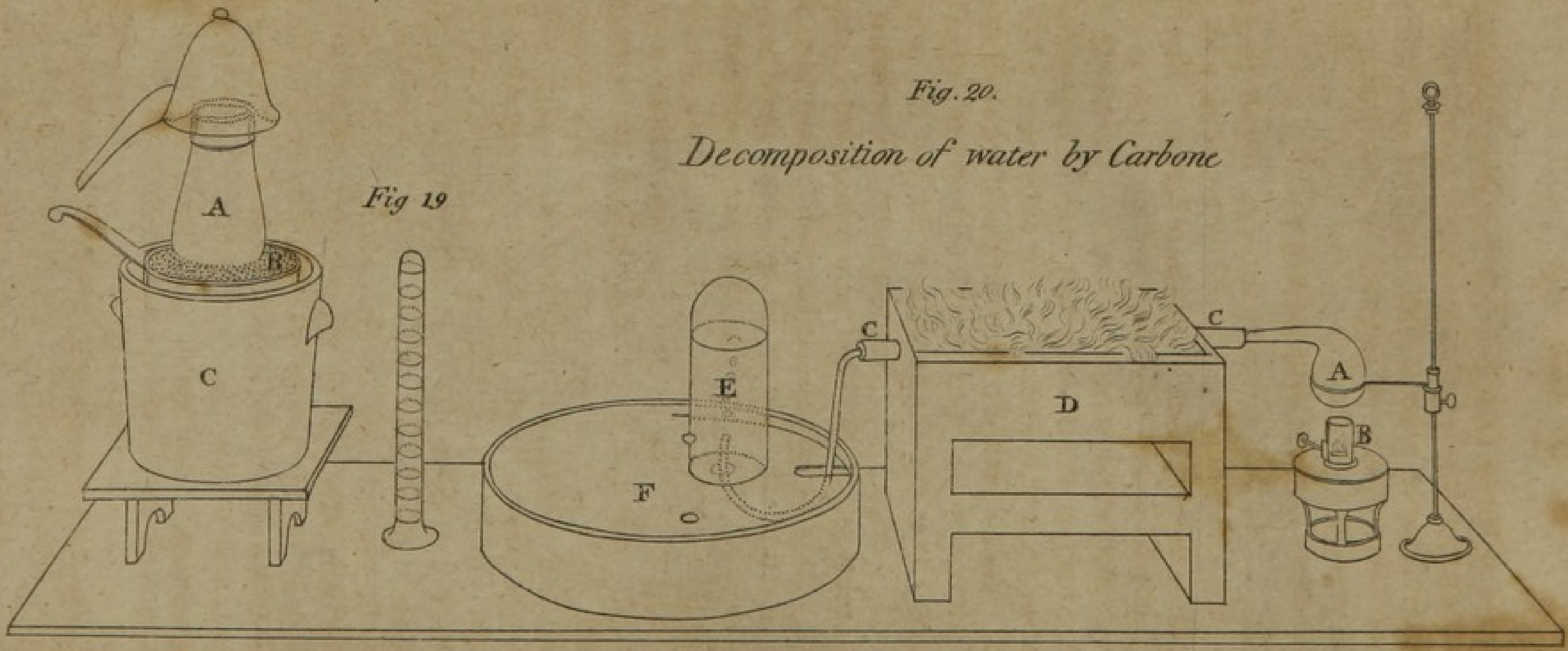
Fig. 18.

Sublimation of Sulphur

Fig 19

Fig. 20.

Decomposition of water by Carbone



Drawn by the Author

Engraved for Increase Cooke & Co. New Haven.

Doolittle Sc

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

PLATE VIII.

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.

a very small scale. Those used in manufactures are generally made of copper, and are cf 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, it will in cooling, 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 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 that it burns with a faint blueish flame; and as I invert over it this receiver, white fumes arise from the sulphur and fill the vessel.—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 produce 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 discernable 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 upon 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 *sulphurous 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. Sulphurous 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 sulphurous acid is invisible, and it appears in the form of white smoke, only from its combining with the moisture. 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 feted 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 sulphurous 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 shews 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 interest in any 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 philospher'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 s 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 other new simple bodies may be discovered?

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 *phosphorus* 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 ogygen 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 phosphorus 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 phosphorus 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 cambustible 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 the same 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 thereby formed carries off some minute particles of phosphorus, with which it forms phosphorated hydroden 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 phosphorous.

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 process 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 simply in separating it from other substances with which it is found combined in nature.

Carbone forms a considerable part of the solid matter of all organized bodies; but it is most abundant in the vegatable 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 be 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 fill it. 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 an 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 is 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 chrystalization, 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 know 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. You might as well my dear 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, 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 are made, 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 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 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 migh 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 is supposed to exist 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 others parts of the vegetable 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 hasten 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 portion of 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 since the gas within it retains an aeriform 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 promoted by shaking the receiver.

Emily. The charcoal is now extinguished, though it is not nearly consumed; it has such an extaordinary 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 absord 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, since 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 artifical 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. A gas we may conceive though very prejudicial to breathe, may be 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 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 combustion.

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 plaster, 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 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 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, makes 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.

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 salad 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 salad 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 accessary 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*, consist 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 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 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 purer 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 lesson, 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 the 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 buried 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, volcanoes, 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, prevents 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, a process which depends on the gradual conversion of the surface into an oxyd. This rusty surface preserves the interior metal from oxydation, as it prevents the air from coming in contact with it. Strictly speaking, however, the word rust applies only to the oxyd, which forms on the surface of iron, when exposed to air and moisture, which oxyd appears to be united with a small portion of carbonic acid.

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 with which metals are capable of combining, 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 further 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 happens only 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 five 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.

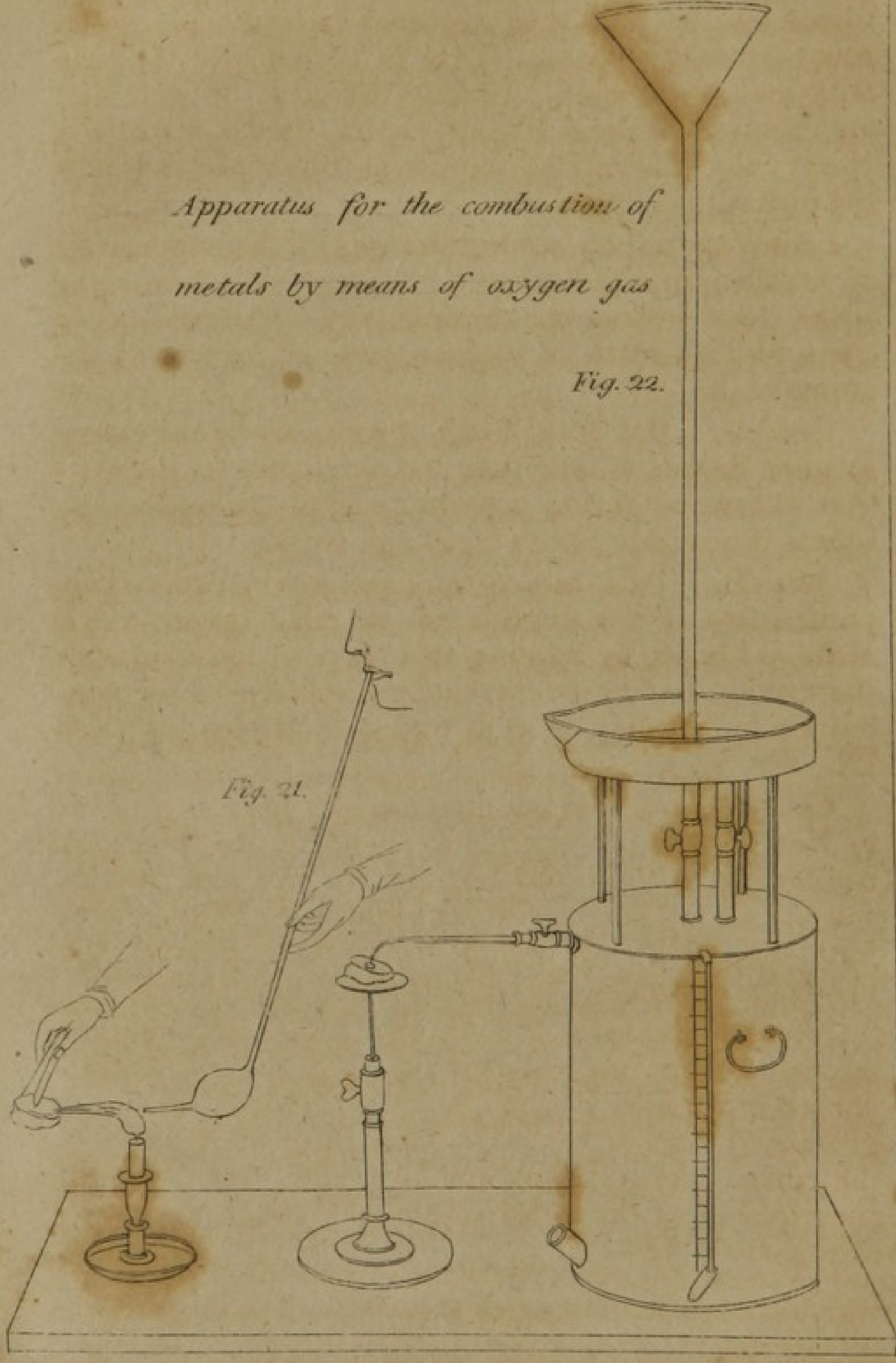
Emily. Why is it reckoned so unwholesome to breath the air of a place in which metals are melting?

Mrs. B. For this double reason, that most metals in melting oxydate more or less at their surface, and

Apparatus for the combustion of metals by means of oxygen gas

Fig. 22.

Fig. 21.



Drawn by the Author. Doolittle Sc.

Engraved for Increase Cooke & Co. New Haven 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 shew 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 partion 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—

PLATE IX.

Fig. 21. Igniting charcoal with a taper and blow-pipe. Fig. 22. Combustion of metals by means of a blow-pipe conveying a stream of oxygen gas from a gas-holder.

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, by means of this apparatus *(Plate* IX. *Fig.* 22.*)* which consits 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 drop 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 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 very high temperature only that the affinity of these metals for oxygen will enable them to act on each other.

I am sorry that I cannot shew 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 the oxyds of metals 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 electric fluid, 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 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 or 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 disolved 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 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 the 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 there is 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 shew 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 shew 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 decomposition 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 opaque as iron can be converted into such 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 opaque 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 that 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 be 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*, and 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 be taken from a metal with which it is combined, only 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

* 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.

remembering them.—In the first place, acids will yield their oxygen to metals. Secondly, they will 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.

A curious combination of metals has lately very much attracted the attention of the scientific world: I mean the stones that fall from the atmosphere. They all consist principally of native or pure iron which is never formed in that state in the bowels of the earth; and contain also a small quantity of nickle and chrome, a combination likewise new in the mineral kingdom.

These circumstances have led many scientific persons to believe that those substances have fallen from the moon or some other planet, while others are of opinion either that they are formed in the atmosphere, or are projected into it by some unknown volcano on the surface of our globe.

Caroline. I have heard much of these stones, but I believe many people are of opinion that they are formed on the earth, and laugh at their pretended celestial origin.

Mrs. B. The fact of their falling is so well ascertained, that I think no person who has at all investigated the subject, can now entertain any doubt of it. Specimens of these stones have been discovered in all parts of the world, and to each of them has some tradition or story of its fall been found connected. And as the analysis of all the specimens affords precisely the same results, we have thus a very strong proof that they all proceed from the same source. It is to Mr. Howard that philosophers are indebted, for having first analysed these stones, and directed their attention to this interesting subject.

But we must not suffer this digression to take up too much of our time.

The combinations of metals with each other are called alloys; thus brass is an alloy of copper and zinc; bronze, of copper and tin, &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. Tin alone, however, would be too soft a metal to be worked for common use, and all the tin vessels or utensils are in fact made of plates of iron thinly coated with tin, which prevents the iron from rusting.

Caroline. Say rather *oxydating*, 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 engaged by chemistry, that it sometimes leads me into ridiculous observations. Every thing in nature I refer to chemistry, and have often been laughed at 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 beating 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 congeals only at 72° below the freezing point.

Emily. That is to say, that in order to freeze, it requires a temperature 72° 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 several other metals; and, if mixed with any of them in a sufficient proportion, it penetrates the solid metal, softens it, loses it own fluidity, and forms an *amalgam*, which 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.

Emily. In the list of metals there are some whose names I have never before heard mentioned.

Mrs. B. There are several that have been recently discovered, whose properties are yet but little known, as for instance, titanium which was discovered by the Revd. Mr. Gregor, in the tin mines of Cornwall; columbium, which has lately been discovered by Mr. Hatchett; and osmium, iridium, palladium, and rhodium, all of which Dr. Woolaston and Mr. Tennant found mixed with crude platina.

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 so 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 its very poisonous properties.

Caroline. Is it possible that oxygen can impart poisonous qualities? That valuable substance which produces light, and 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 might 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 depend 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 muriatic 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 shall 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 remember it. 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 what 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 among the simple bodies, as it was not, till lately, supposd 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 chrystals 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 farther 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 favourity 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 substance 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 has 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, the 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 to produce acids; and hydrogen, to produce 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.* [*See Note page* 164.]

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 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 opaque body as soap, should transform that opaque 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 opaque 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 silicious earth is obtained be mixed with any metallic particles, or other substance which cannot be vitrified, the glass will be discoloured, or defaced by opaque 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 proportion 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 shew 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—

C*aroline.* 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 mportant, 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 it is even prefered 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 alkakli 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 Lybia, 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 thro' 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 ammoniacal 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 liquefied 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 harthorn. 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 Lybian 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 Lybia, as it originally was, is now chiefly prepared in Europe, by chemical processes. Ammonia, although principally extracted from this salt, can only be produced by a great variety of other substances. The horns of cattle, especially those of the dear, 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.

* 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.

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,	GARGONIA.

The five 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 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 expense 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 discrimated, no single one can be exclusively called an element; and as none of them have been decomposed, they have 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 great 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.

Mrs. B. 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 phénomena 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. 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 metalic 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 silicious earths, 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 metal; 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 silicious 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 silicious 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 silicious 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 silicious 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 mortars, &c.

I said before, that silicious 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 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 will 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 vallies, 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 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 opaque 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 opaque 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 shewing 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 quick the 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 super-abundant acid which it meets with in the stomach.

Emily. I am surprised that it is so perfectly clear: is does not at all partake of the whiteness of 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 re-appear 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 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 re-appears 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 little 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 re-dissolved, 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 re-appears, 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 (being the weakest) readily yields it; but these combinations we shall have an opportunity of noticing more particularly hereafter. It unites 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 mortars, stucco, plaster, &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 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. It is, however, frequently taken in its caustic state as a remedy for flatulence. 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 neighborhood 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.

Conversations

ON

CHEMISTRY.

VOLUME II.

ON COMPOUND BODIES.

Conversations

ON

CHEMISTRY.

ON COMPOUND BODIES.

Conversation XII.

ON THE ATTRACTION OF COMPOSITION.

Mrs. B.

HAVING completed our examination of the simple or elementary bodies, we are now to proceed to those of a compound nature; but before we enter on this extensive subject, it will be necessary to make you acquainted with the principal laws by which chemical combinations are governed.

You recollect, I hope, what we have formerly said of the nature of the attraction of composition, or chemical attraction, or affinity, as it is also called?

Emily. Yes, I think perfectly; it is the attraction that subsists between bodies of a different nature, which occasions them to combine and form a compound, when they come in contact.

Mrs. B. Very well; your definition comprehends the first law of chemical attraction, which is, that *it takes place only between bodies of a different nature*; as, for instance, between an acid and an alkali; between oxygen and a metal, &c.

Caroline. That we understand of course; for the attraction between particles of a similar nature is that of aggregation, or cohesion, which is independant of any chemical power.

Mrs. B. The second law of chemical attraction is, that *it takes place only between the most minute particles of bodies;* therefore, the more you divide the particles of the bodies to be combined, the more readily they act upon each other.

Caroline. That is again a circumstance which we might have supposed; for the finer the particles of the two substances are, the more easily and perfectly they will come in contact with each other, which must greatly facilitate their union. It was for this purpose, you said, that you used iron filings in preference to wires or pieces of iron, for the decomposition of water.

Mrs. B. It was once supposed that no mechanical power could divide bodies into particles sufficiently minute for them to act upon each other; and that, in order to produce the extreme division requisite for a chemical action, one, if not both of the bodies, should be in a fluid state. There are, however, a few instances, in which two solid bodies very finely pulverized, exert a chemical action on one another; but such exceptions to the general rule are very rare indeed.

Emily. In all the combinations that we have hitherto seen, one of the constituents has, I believe, been either liquid or aeriform. In combustions, for instance, the oxygen is taken from the atmosphere, in which it existed in the state of gas; and whenever we have seen acids combine with metals or with alkalies, they were either in a liquid or an aeriform state.

Mrs. B. The third law of chemical attraction is, *that it can take place between two, three, four or even a greater number of bodies.*—Can you recollect any examples of these double, triple, and quadruple combinations?

Caroline. Oxyds and acids are bodies composed of two constituents; compound salts of three: but I recollect no instance of the combination of four principles, unless it be amongst the earths in the formation of stones.

Mrs. B. Such examples very frequently occur amongst the earths; but you might have quoted, as instances of quadruple compounds, all those that result from the combination of acids with ammonia, or volatile alkali.

Caroline. True. As ammonia is itself a compound, its union with the acids, which are also composed of two principles, must form a quadruple combination.

Mrs. B. You will soon become acquainted with a great variety of these complicated compounds. The fourth law of chemical attraction is, that *a change of temperature always takes place at the moment of combination.* This is occasioned by the change of capacity for heat, which takes place in bodies, when passing from a simple to a combined state. Do you recollect any instance of this, Emily?

Emily. Yes; when lime, or any of the alkalies, or alkaline earths, combine with, and solidify water, the whole of its heat of liquidity is set at liberty.

Mrs. B. I had rather that you had chosen any other instance, as the union of water with the alkalies and alkaline earths is not, strictly speaking, a chemical combination; for the water remains in the state of water tho' condensed and solidified in the alkali; and can be separated from it and restored to its fluid state, merely by the restitution of its heat of liquidity.

I am going to show you a very striking instance of the change of temperature arising from the combination of different bodies.—I shall pour some nitrous acid on this small quantity of oil of turpentine—the oil will instantly combine with the oxygen of the acid, and produce a considerable change of temperature.

Caroline. What a blaze! The temperature of the oil and the acid must be elevated, indeed, to produce such a violent combustion.

Mrs. B. There is, however, a peculiarity in this combustion, which is, that the oxygen, instead of being derived from the atmosphere alone, is principally supplied by the acid itself.

Emily. And are not all combustions instances of the change of temperature produced by the chemical combination of two bodies?

Mrs. B. Undoubtedly; when oxygen loses its gaseous form in order to combine with a solid body, it becomes condensed, and the caloric evolved produces the elevation of temperature. The specific gravity of bodies is at the same time altered by chemical combination; for in consequence of a change of capacity for heat, a change of density must be produced.

Caroline. That was the case with the sulphuric acid and water, which by being mixed together, gave out a great deal of heat, and proportionally increased in density.

Mrs. B. I do not think the instance to which you refer is quite in point; for there does not appear to be what we have called a true chemical combination between sulphuric acid and water, since they are only mixed together, and undergo no other change than a loss of caloric, so that they may be separated again from each other merely by evaporating the water. Yet you have truly observed in this instance that the particles of the two fluids so far penetrate each other, as to form a more compact substance, in consequence of which a quantity of latent heat is forced out, and there is an increase of sphecific gravity.

The 5th law of chemical attraction is, that *the properties which characterise bodies when separate, are altered or destroyed by their combination.*

Caroline. Certainly; what, for instance, can be so different from water as the hydrogen and oxygen gasses?

Emily. Or what more unlike sulphat of iron, than iron or sulphuric acid?

Caroline. But of all metamorphoses, that of sand and potash intc glass, is the most striking!

Mrs. B. Every chemical combination is an illustration of this rule. But let us proceed—

The 6th law is, that *the force of chemical affinity, between the constituents of a body, is estimated by that which is required for their separation.* This force is by no means proportional to the facility with which bodies unite; for manganese, for instance, which, you know, has so great an attraction for oxygen, that it is never found in a metallic state, yields it more easily than any other metal.

Caroline. And likewise lime, which has a great attraction for carbonic acid, yields it to any of the other acids, and even to heat alone.

Emily. But, Mrs. B. you speak of estimating the force of attraction between bodies, by the force required to separate them ; how can you measure these forces ?

Mrs. B. They cannot be precisely *measured*, but they are comparatively ascertained by experiment, and can be represented by numbers which express the relative degrees of attraction.

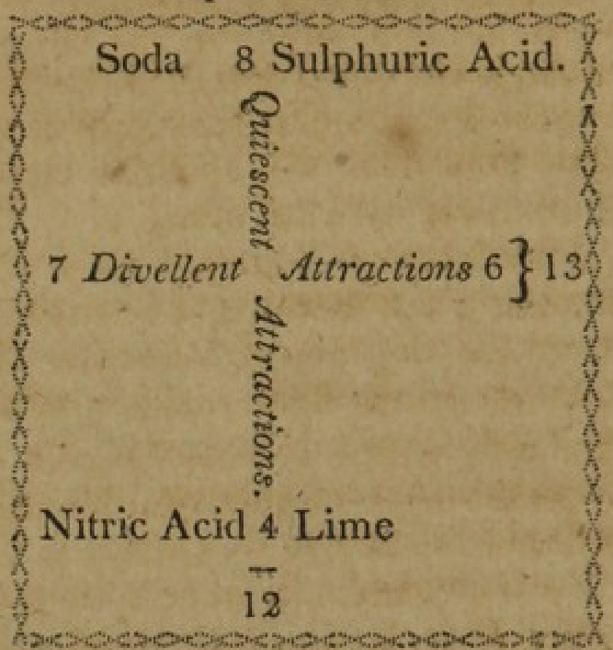
The 7th law is, that *bodies have amongst themselves different degrees of attraction.* Upon this law (which you may have discovered yourselves long since), the whole science of chemistry depends ; for it is by means of the various degrees of affinity which bodies have for each other, that all the chemical compositions and decompositions are effected. Thus if you pour sulphuric acid on soap, it will combine with the alkali to the exclusion of the oil, and form a sulphat of potash. Every chemical fact or experiment is an instance of the same kind ; and whenever the decomposition of a body is performed by the addition of any single new substance, it is said to be effected by *simple elective attractions.* But it often happens that no simple substance will decompose a body, and, that, in order to effect this, you must offer to the compound a body which is itself composed of two, or sometimes three principles, which would not, each separately, perform the decomposition. In this case there are two new compounds formed in consequence of a reciprocal decomposition and recomposition. All instances of this kind are called *double elective attractions.*

Caroline. I confess I do not understand this clearly.

Mrs. B. You will easily comprehend it by the assistance of this diagram, in which the reciprocal forces of attraction are represented by numbers :

Original Compound.
Sulphat of Soda.

Result Nitrat of Soda.



Result Sulphat of Lime.

Original Compound.
Nitrat of Lime.

We here suppose that we are to decompose sulphat of soda; that is, to separate the acid from the alkali: if, for this purpose we add some lime, in order to make it combine with the acid, we shall fail in our attempt, because the soda and the sulphuric acid attract each other by a force which is (by way of supposition) represented by the number 8; while the lime tends to unite with this acid by an affinity equal only to the number 6. It is plain, therefore, that the sulphat of soda will not be decomposed, since a force equal to 8 cannot be overcome by a force equal only to 6.

Caroline. So far, this appears very clear.

Mrs. B. If, on the other hand, we endeavour to decompose this salt by nitric acid, which tends to combine with soda, we shall be equally unsuccessful, as nitric acid tends to unite with the alkali by a force equal only to 7.

In neither of these cases of simple elective attraction, therefore, can we accomplish our purpose. But let us previously combine together the lime and nitric acid, so as to form a nitrat of lime, a compound salt, the constituents of which are united by a power equal to 4. If then we present this compound to the sulphat of soda, a decomposition will ensue, because the sum of the forces which tend to preserve the two salts in their actual state, is not equal to that of the forces which tend to decompose them, and to form new combinations. The nitric acid, therefore, will combine with the soda, and the sulphuric acid with the lime.

Caroline. I understand you now very well. This double effect takes place because the numbers 8 and 4, which represent the degrees of attraction of the constituents of the two origal salts, make a sum less than the numbers 7 and 6, which represent the degrees of attraction of the two new compounds that will in consequence be formed.

Mrs. B. Precisely so.

Caroline. But what is the meaning of *quiescent* and *divellent* forces, which are written in the diagram?

Mrs. B. Quiescent forces are those which tend to preserve compounds in a state of rest, or such as they actually are: divellent forces are those which tend to destroy that state of combination, and to form new compounds.

These are the principal circumstances relative to the doctrine of chemical attractions, which have been laid down as rules by modern chemists; a few others might be mentioned respecting the same theory, but of less importance, and such as would take us too far from our plan. I should, however, not omit to mention that Mr. Berthollet, a celebrated French chemist, has shewn, that whenever in chemical operations there is a display of contrary attractions, the combinations which take place depend not only upon the affinities, but also, in some degree, on the proportions of the substances concerned.

Conversation XIII.

On Compound Bodies.

Mrs. B.

Having now given you some idea of the laws by which chemical attractions are governed, we may proceed to the examination of bodies that are formed in consequence of these attractions.

The first class of compounds that present themselves to our notice, in our gradual ascent to the most complicated combinations, are bodies composed of only two principles. The sulphurets, phosphorets, carburets, &c. are of this description; but the most numerous and important of these compounds are the combinations of oxygen with the various simple substances with which it has a tendency to unite. Of these you have already acquired some knowledge, and I hope you will not be at a loss to tell me the general names by which the combinations of oxygen with other substances are distinguished?

Emily. I believe you told us that all the combinations of oxygen produced either oxyds or acids?

Mrs. B. Very right; and with what simple bodies will oxygen combine, Caroline!

Caroline. With all the elementary substances, excepting the earths and alkalies.

Mrs. B. Very well, my dear; we may now, therefore, come to the oxyds and acids. Of the metallic oxyds, you have already some general notions. This ubject, though highly interesting in its details, is not of sufficient importance to our concise view of chemistry, to be particularly treated of; but it is absolutely necessary that you should be better acquainted with the acids, and likewise with their combinations with the alkalies, which form the triple compound called Neutral Salts.

You have, I believe, a clear idea of the nomenclature by which the base (or radical) of the acid, and the various degrees of acidification, are expressed?

Emily. Yes, I think so; the acid is distinguished by the name of its base, and its degree of acidity by the termination of that name in *ous* or *ic*; thus sulphur*ous* acid is that formed by the smallest proportion of oxygen combined with sulphur; sulphur*ic* acid is that which results from the combination of sulphur with the greatest quantity of oxygen.

Mrs. B. A still greater latitude may, in many cases, be allowed to the proportions of oxygen than can be combined with acidifiable radicals; for several of these radicals are susceptible of uniting with a quantity of oxygen so small as to be insufficient to give them the properties of acids; in these cases therefore, they are converted into oxyds. Such is sulphur, which by exposure to the atmosphere with a degree of heat inadequate to produce inflammation, absorbs a small proportion of oxygen, which colours it red or brown. This therefore is the first degree of oxygenation of sulphur; the 2d converts it into sulphur*ous* acid; the 3d into sulphur*ic* acid; and, 4thly, if it was found capable of combining with a still larger proportion of oxygen, it would then be termed *super-oxygenated sulphuric acid.*

Emily. Are these various degrees of oxygenation common to all acids?

Mrs. B. No; they vary much in this respect; some are susceptible of only one degree of oxygenation; others, of two, or three; there are but very few that will admit of more.

Caroline. The modern nomenclature must be of immense advantage in pointing out so easily the nature of the acids, and their various degrees of oxygenation.

Mrs. B. Certainly. But great as are the advantages of the new nomenclature in this respect, it is not possible to apply it in its full extent to all the acids, because the radicals or bases of some of them are still unknown.

Caroline. If you are acquainted with the acid, I cannot understand how its basis can remain unknown; you have only to separate the oxygen from it by elective attractions, and the basis must remain alone?

Mrs. B. This is not always so easily accomplished as you imagine; for there are some acids which no chemist has hitherto been able to decompose by any means whatever. It appears that the bases of these undecompounded acids have so strong an attraction for oxygen, that they will yield it to no other substance; and in that case, you know, all the efforts of the chemists are vain.

Emily. But if these acids have never been decomposed, should they not be classed with the simple bodies; for you have repeatedly told us that the simple bodies are rather such as chemists are unable to decompose, than such as are really supposed to consist of only one principle?

Mrs. B. Analogy affords us so strong a proof of the compound nature of the undecompounded acids, that I never could reconcile myself to classing them with the simple bodies, though this division has been adopted by several chemical writers. It is certainly the most strictly regular; but, as a systematical arrangement is of use only to assist the memory in retaining facts, we may, I think be allowed to deviate from it when there is danger of producing confusion by following it too closely:—and this, I believe, would be the case, if you were taught to consider the undecompounded acids as elementary bodies.

Emily. I am sure you would not deviate from the methodical arrangement without good reason. But pray what are the names of these undecompounded acids?

Mrs. B. There are three of that description:

The *Muriatic acid.*
The *Boracic acid.*
The *Fluoric acid.*

Since these acids cannot derive their names from their radicals, they are called after the compound substances from which they are extracted.

Caroline. We have heard of a great variety of acids; pray how many are there in all?

Mrs. B. I believe there are reckoned at present thirty-four, and their number is constantly increasing, as the science improves; but the most important, and those to which we shall almost entirely confine our attention, are but few. I shall, however, give you a general view of the whole; and then we shall more particularly examine those that are the most essential.

This class of bodies was formerly divided into mineral, vegetable, and animal acids, according to the substances from which they were extracted.

Caroline. That I should think must have been an excellent arrangement; why was it altered!

Mrs. B. Because in many cases it produced confusion. In which class, for instance, would you place carbonic acid?

Caroline. Now I see the difficulty. I should be at a loss where to place it, as you have told us that it exists in the animal, vegetable, and mineral kingdoms.

Emily. There would be the same objection with repect to phosphoric acid, which, though obtained chiefly from bones, can also, you said, be found in small quantities in stones, and likewise in some plants.

Mrs. B. You see, therefore, the propriety of changing this mode of classification. These objections do not exist in the present nomenclature; for the composition and nature of each individual acid is in some degree pointed out, instead of the class of bodies from which it is extracted; and, with regard to the more general division of acids, they are classed under these four heads:

1st. Acids of known and simple bases, which are formed by the union of these bases with oxygen.

They are the following:

The *Sulphuric*	Acids of known and simple bases.
Carbonic	
Nitric	
Phosphoric	
Arsenical	
Tungstenic	
Molybdenic	

2dly. Those of unknown bases:

The *Muriatic* *Boracic* *Fluoric*	Acids of unknown bases.

These two classes comprehend the most anciently known and most important acids. The sulphuric, nitric, and muriatic, were formerly, and are still frequently, called *mineral acids*.

3dly. Acids that have double or binary radicals, and which consequently consist of triple combinations.— These are the vegetable acids whose common radical is a compound of hydrogen and carbone.

Caroline. But if the basis of all the vegetable acids be the same, it should form but one acid; it may indeed combine with different proportions of oxygen, but the nature of the acid must be the same?

Mrs. B. The only difference that exists in the bases of vegetable acids, is the various proportions of hydrogen and carbone from which it is composed. But this is enough to produce a number of acids apparently very dissimilar. That they do not, however, differ essentially, is proved by their susceptibility of being converted into each other, by the addition or subtraction of a portion of hydrogen or of carbone.

The names of these acids are,

The *Acetic* *Oxalic* *Tartarous* *Citric* *Malic* *Gallic* *Mucous* *Benzoic* *Succinic* *Camphoric* *Suberic*	Acids of double bases, being of vegetable origin.

The 4th class of acids consists of those which have triple radicals, and are therefore of a still more compound nature. This class comprehends the animal acids, which are:

The *Lactic* *Prussic* *Formic* *Bombic* *Sebacic* *Zoonic* *Lithic*	Acids of triple bases, or animal acids.

I have given this summary account or enumeration of the acids, as you may find it more satisfactory to have at once an outline, or general notion of the extent of the subject; but we shall now confine ourselves to the two first classes, which require our more immediate attention; and defer the remarks which we shall have to make on the others, till we treat of the chemistry of the animal and vegetable kingdoms.

The acids of simple and known radicals are all capable of being decomposed by combustible bodies, to which they yield their oxygen. If, for instance, I pour a drop of sulphuric acid on this piece of iron, it will produce a spot of rust; you know what that is?

Caroline. Yes, it is an oxyd, formed by the oxygen of the acid combining with the iron.

Mrs. B. In this case you see the sulphur deposits the oxygen by which it was acidified on the metal.—And again, if we pour some acid on a compound combustible substance, (we shall try it on this piece of wood) it will combine with one or more of the constituents of that substance, and occasion a decomposition.

Emily. It has changed the colour of the wood to black. How is that?

Mrs. B. The oxygen deposited by the acid has burnt it; you know that wood in burning becomes black before it is reduced to ashes. Whether it derives the oxygen which burns it from the atmosphere, or from any other source, the chemical effect on the wood is the same. In the case of real combustion, wood becomes black because it is reduced to the state of charcoal by the evaporation of its other constituents. But can you tell me the reason why wood turns black when burnt by the application of an acid?

Caroline. First, tell me what are the ingredients of wood ?

Mrs. B. Hydrogen and carbone are the chief constituents of wood, as of all other vegetable substances.

Caroline. Well, then, I suppose that the oxygen of the acid combines with the hydrogen of the wood, to form water; and that the carbone of the wood, remaining alone, appears of its usual black colour.

Mrs. B. Very well, indeed, my dear; that is certainly the most plausible explanation.

Emily. Would not this be a good method of making charcoal ?

Mrs. B. It would be an extremely expensive, and I believe, very imperfect method; for the action of the acid on the wood, and the heat produced by it, are far from sufficient to deprive the wood of all its evaporable parts.

Caroline. What is the reason that vinegar, lemon, and the acids of fruits, do not produce this effect on wood ?

Mrs. B. They are vegetable acids whose bases are composed of hydrogen and carbone; the oxygen, therefore, will not be disposed to quit this radical, where it is already united with hydrogen. The strongest of these may, perhaps, yield a little of their oxygen to the wood, and produce a stain upon it; but the carbone will not be sufficiently uncovered to assume its black colour. Indeed, the several mineral acids themselves possess this power of charring wood in very different degrees.

Emily. Cannot vegetable acids be decomposed by any combustibles ?

Mrs. B. No; because their radical is composed of two substances which have a greater attraction for oxygen than any known body.

Caroline. And are those strong acids which burn and decompose wood, capable of producing similar effects on the skin and flesh of animals ?

Mrs. B. Yes; all the mineral acids, and one of them more especially, possess powerful caustic qualities. They actually corrode and destroy the skin and flesh: but they do not produce upon these exactly the same alteration as they do on wood, probably because there is a great proportion of nitrogen and other substances in animal matter, which prevents the separation of carbone from being so conspicuous.

Conversation XIV.

Of the Sulphuric and Phosphoric Acids: or the combinations of Oxygen with Sulphur and Phosphorus; and of the Sulphats and Phosphats.

Mrs. B.

In addition to the general survey which we have taken of acids, I think you will find it interesting to examine individually a few of the most important of them, and likewise some of their principal combinations with the alkalies, alkaline earths, and metals. The first of the acids, in point of importance, is the SULPHURIC, formerly called *oil of vitriol.*

Caroline. I have known it a long time by that name, but had no idea that it was the same fluid as sulphuric acid. What resemblance or connection can there be between oil of vitriol and this acid?

Mrs. B. Vitriol is the common name for sulphat of iron, a salt which is formed by the combination of sulphuric acid and iron; the sulphuric acid was formerly obtained by distillation from this salt, and it very naturally received its name from the substance which afforded it.

Caroline. But it is still usually called oil of vitriol?

Mrs. B. Yes; a sufficient length of time has not yet elapsed, since the invention of the new nomenclature, for it to be generally disseminated; but as it is adopted by all scientific chemists, there is every reason to suppose that it will gradually become universal. When I received this bottle from the chemist's, the name written on the label was *oil of vitriol*; but, as I knew you were very punctilious in regard to the nomenclature, I changed it, and substituted the modern name.

Emily. This acid has neither colour nor smell, but it appears much thicker than water.

Mrs. B. It is twice as heavy as water, and has, you see, an oily consistence.

Caroline. And it is probably from this circumstance that it has been called an oil, for it can have no real claim to that name, as it does not contain either hydrogen or carbone, which are the essential constituents of oil.

Mrs. B. Certainly; and therefore it would be the more absurd to retain a name which owed its origin to such mistaken analogy.

Sulphuric acid, in its purest state, would be a concrete substance, but its attraction for water is such, that it is impossible to preserve it in that state; it is, therefore, always seen in a liquid form, such as you here find it. One of the most striking properties of sulphuric acid is that of evolving a considerable quantity of heat when mixed with water; this I have already shewn you.

Emily. Yes, I recollect it; but what was the degree of heat produced by that mixture?

Mrs. B. The thermometer may be raised by it to 300, which is considerably above the degree of boiling water.

Caroline. Then water might be made to boil in that mixture.

Mrs. B. Nothing more easy, provided that you employ sufficient quantities of acid and of water, and in the due proportions. The greatest heat is produced by a mixture of one part of water to four of the acid: we shall make a mixture of these proportions, and immerse this thin glass tube, which is full of water, into it.

Caroline. The vessel feels extremly hot, but the water does not boil yet.

Mrs. B. You must allow some time for the heat to penetrate the tube, and raise the temperature of the water to the boiling point—

Caroline. Now it boils—and with increasing violence.

Mrs. B. But it will not continue boiling long; for the mixture gives out heat only while the particles of the water and the acid are mutually penetrating each other: as soon as the new arrangement of those particles is effected, the mixture will gradually cool, and the water return to its former temperature.

You have seen the manner in which sulphuric acid decomposes all combustible substances, whether animal, vegetable, or mineral, and burns them by means of its oxygen?

Caroline. I have very unintentionally repeated the experiment on my gown, by letting a drop of the acid fall upon it, and it has made a stain, which, I suppose, will never wash out.

Mrs. B. No, certainly; for, before you can put it into water, the spot will become a hole, as the acid has literally burnt the muslin.

Caroline. So it has indeed! Well, I will fasten the stopper and put the bottle away, for it is a dangerous substance.—Oh, now I have done worse still, for I have spilt some on my hand!

Mrs. B. It is then burned, as well as your gown, for you know that oxygen destroys animal as well as vegetable matter; and, as far as the decomposition of the skin of your finger is effected, there is no remedy; but, by washing it immediately in water, you will dilute the acid, and prevent any farther injury.

Caroline. It feels extremely hot, I assure you.

Mrs. B. You have now learned, by experience, how cautiously this acid must be used. You will soon become acquainted with another acid, the nitric, which though it produces less heat on the skin, destroys it still quicker, and makes upon it an indelible stain. You should never handle any substances of this kind, without previously dipping your fingers in water, which will weaken their caustic effects.—But since you will not repeat the experiment, I must put in the stopper, for the acid attracts the moisture from the atmosphere, which would destroy its strength and purity.

Emily. Pray how can sulphuric acid be extracted from sulphat of iron by distillation?

Mrs. B. The process of distillation, you know, consists in separating substances from one another by means of their different degrees of volatility, and by the introduction of a new chemical agent, caloric. Thus, if sulphat of iron be exposed in a retort to a proper degree of heat, it will be decomposed, and the sulphuric acid will be volatilized.

Emily. But now that the process of forming acids by the combustion of their radicals is known, why should not this method be used for making sulphuric acid?

Mrs. B. This is actually done in most manufactures; but the usual method of preparing sulphuric acid does not consist in burning the sulphur in oxygen gas, (as we formerly did by way of experiment), but in heating it together with another substance, nitre, which yields oxygen in sufficient abundance to render the combustion in common air rapid and complete.

Caroline. This substance, then, answers the same purpose as oxygen gas?

Mrs. B. Exactly. In manufactures the combustion is performed in a leaden chamber, with water at the bottom, to receive the vapour, and assist its condensation. The combustion is, however, never so perfect, but that a quantity of sulphurous acid is formed at the same time; for you recollect that the sulphurous acid differs from the sulphuric only by containing less oxygen.

From its own powerful properties, and from the various combinations into which it enters, sulphuric acid is of great importance in many of the arts.

It is used also as a medicine in a state of great dilution; for were it taken internally, in a concentrated state, it would prove a most dangerous poison.

Caroline. I am sure it would burn the throat and stomach.

Mrs. B. Can you think of any thing that would prove an antidote to this poison ?

Caroline. A large draught of water to dilute it.

Mrs. B. That would certainly weaken the power of the acid, but it would increase the heat to an intolerable degree. Do you recollect nothing that would destroy its deleterious properties more effectually ?

Emily. An alkali might, by combining with it ; but then, a pure alkali is itself a poison, on account of its causticity.

Mrs. B. There is no necessity that the alkali should be caustic. Soap, in which it is combined with oil : or magnesia, either in a state of carbonat, or mixed with water, would prove the best antidotes.

Emily. In those cases, then, I suppose, the potash and the magnesia would quit their combinations to form salts with the sulphuric acid ?

Mrs. B. Precisely.

We may now make a few observations on the sulphur*ous* acid, which we have found to be the product of sulphur slowly and imperfectly burnt.—This acid is distinguished by is pungent smell, and its gaseous form.

Caroline. Its aeriform state is, I suppose, owing to the smaller proportion of oxygen, which renders it lighter than sulphur*ic* acid ?

Mrs. B. Probably ; for by adding oxygen to the weaker acid, it may be converted into the stronger kind. But this change of state may also be connected with a change of affinity with regard to caloric.

Emily. And may sulphurous acid be obtained from sulphuric acid by a diminution of oxygen ?

Mrs. B. Yes : it can be done by bringing any combustible substance in contact with the acid. This decomposition is most easily performed by some of the metals ; these absorb a portion of the oxygen from the sulphuric acid, which is thus converted into the sulphurous, and flies off in its gaseous form.

Caroline. And cannot the sulphurous acid itself be decomposed and reduced to sulphur ?

Mrs. B. Yes ; if this gas be heated in contact with charcoal, the oxygen of the acid will combine with it, and the pure sulphur be regenerated.

Sulphurous acid is readily absorbed by water ; and in this liquid state it is found particularly useful in bleaching linen and woollen cloths, and is much used in manufactures for those purposes. I can shew you its effect in destroying colours, by taking out any iron mould, or vegetable stain—I think I see a spot on your gown, Emily, on which we may try the experiment.

Emily. It is the stain of mulberries ; but I shall be almost afraid of exposing my gown to the experiment, after seeing the effect which the sulphuric acid produced on that of Caroline—

Mrs. B. There is no such danger from the sulphurous ; but the experiment must be made with great caution ! for, during the formation of sulphurous acid by combustion, there is always some sulphuric produced.

Caroline. But where is your sulphurous acid ?

Mrs. B. We may easily prepare some ourselves, simply by burning a match ; we must first wet the stain with a little water, and now hold it in this way, at a little distance, over the lighted match : the vapour that arises from it is sulphurous acid, and the stain, you see, gradually disappears.

Emily. I have frequently taken out stains by this means, without understanding the nature of the process. But why is it necessary to wet the stain before it is exposed to the acid fumes ?

Mrs. B. The moisture attracts and absorbs the sulphurous acid ; and it serves likewise to dilute any particles of sulphuric acid which might injure the linen.

Sulphur is susceptible of a third combination with oxygen, in which the proportion of the latter is too small to render the sulphur acid. It acquires this slight oxygenation by mere exposure to the atmosphere, without any elevation of temperature : in this case, the sulphur does not change its natural form, but is only discoloured, being changed to red or brown ; and in this state it is an oxyd of sulphur.

Before we take leave of the sulphuric acid, we shall say a few words of its principal combinations. It unites with all the alkalies, alkaline earths, and metals, to form compound salts.

Caroline. Pray, give me leave to interrupt you for a moment : you have never mentioned any other salts than the compound or neutral salts ; is there no other kind ?

Mrs. B. The term *salt* has been used, from time immemorial, as a kind of general name, for any substance that has savour, odour, is soluble in water, and crystallizable, whether it be of an acid, an alkaline, or compound nature ; but the compound salts alone retain that appellation in modern chemistry.

The most important of the salst, formed by the combination of the sulphuric acid, are, first, *sulphat of potash*, formerly called *sal polychrest ;* this is a very bitter salt, much used in medicine ; it is found in the ashes of most vegetables, but it may be prepared artificially by the immediate combination of sulphuric acid and potash. This salt is easily soluble in boiling water. Solubility is, indeed, a property, common to all salts ; and they always produce cold in melting.

Emily. That must be owing to the caloric which they absorb in passing from a solid to a fluid form.

Mrs. B. That is, certainly, the most probable explanation.

Sulphat of soda, commonly called Glauber's salt, is another medicinal salt, which is still more bitter than the preceding. We must prepare some of these compounds, that you may observe the phenomena which takes place during their formation. We need only pour some sulphuric acid over the soda which I put into this glass.

Caroline. What an amazing heat is disengaged. I thought you said that cold was produced by the melting of salts !

Mrs. B. But you must observe that we are now *making* not *melting* a salt. Heat is disengaged during the formation of compound salts, because the acid goes into a more dense state in the salt than that in which it existed before. A faint light is also emitted, which may sometimes be perceived in the dark, *Emily.* If the oxygen, in combining with the alkali, disengages light and heat, an actual combustion takes place.

Mrs. B. Not so fast, my dear ; recollect that the alkalies are incombustible substances, and incapable of combining with oxygen singly. They are not acted on by this principle, unless it presents itself in a state of union with another body ; and, therefore, the combination of an acid with an alkali cannot be called combustion.

Caroline. Will this sulphat of soda become solid ?

Mrs. B. We have not, I suppose, mixed the acid and the alkali in the exact proportions that are required for the formation of the salt, otherwise the mixture would have been almost immediately changed to a solid mass ; but, in order to obtain it in crystals, as you see it in this bottle, it would be necessary first to dilute it with water, and afterwards evaporate the water, during which operation the salt would gradually crystallize.

Caroline. But of what use is the addition of water, if it is afterwards to be evaporated ?

Mrs. B. When suspended in water, the acid and the alkali are more at liberty to act on each other, their union is more complete, and the salt assumes the regular form of crystals during the slow evaporation of its solvent.

Sulphat of soda liquefies by heat, and effloresces in the air.

Emily. Pray what is the meaning of the word *effloresces ?* I do not recollect your having mentioned it before.

Mrs. B. A salt is said to effloresce when it loses its water of crystallization on being exposed to the atmosphere, and is thus gradually converted into a dry powder : you may observe that these crystals of sulphat of soda are far from possessing the transparency which belongs to their crystalline state ; they are covered with a white powder, occasioned by their having been exposed to the atmosphere, which has deprived their surface of its lustre, by obsorbing its water of crystallization. Salts are, in general, either *efflorescent* or *deliquescent*; this latter property is precisely the reverse of the former; that is to say, deliquescent salts absorb water from the atmosphere, and are moistened and gradually melted by it. Muriat of lime is an instance of great deliquescence.

Emily. But are there no salts that have the same degree of attraction for water as the atmosphere, and that will consequently not be affected by it?

Mrs. B. Yes; there are many such salts; as, for instance, common salt, sulphat of magnesia, and a variety of others.

Sulphat of lime is very frequently met with in nature, and constitutes the well known substance called *gypsum*, or *plaster of Paris.*

Sulphat of magnesia, commonly called *Epsom salt*, is another very bitter medicine, which is obtained from sea-water and from several springs, or may be prepared by the direct combination of its ingredients.

We have formerly mentioned *sulphat of alumine* as constituting the common alum; it is found in nature chiefly in the neighborhood of volcanos, and is particularly useful in the arts, from its strong astringent qualities. It is chiefly employed by dyers and calico-printers to fix colours; and is used also in the manufacture of leather.

Sulphuric acid combines also with the metals.

Caroline. One of these combinations, *sulphat of iron*, we are already well acquainted with.

Mrs. B. That is the most important metallic salt formed by sulphuric acid, and the only one that we shall here notice. It is of great use in the arts; and in medicine, it affords a very valuable tonic: it is of this salt that most of those preparations called *steel medicines* are composed.

C*aroline.* But does any carbone enter into these compositions to form steel?

Mrs. B. Not an atom; they are, therefore, very improperly called steel; but it is the vulgar appellation, and medical men themselves often comply with the general custom.

Sulphat of iron may be prepared, as you have seen, by dissolving iron in sulphuric acid; but it is generally obtained from the natural production called *Pyrites*, which, being a sulphuret of iron, requires only exposure to the atmosphere to be oxydated, in order to form the salt; this, therefore, is much the most easy way of procuring it on a large scale.

Emily. I am surprised to find that both acids and compound salts are generally obtained from their various combinations, rather than from the immediate union of their ingredients.

Mrs. B. Were the simple bodies always at hand, their combination would naturally be the most convenient method of forming compounds; but you must consider that, in most instances, there is great difficulty and expense in obtaining the simple ingredients from their combinations; it is, therefore, often more expedient to procure compounds from the decomposition of other compounds. But to return to the sulphat of iron. There is a certain vegetable acid called *Gallic acid*, which has the remarkable property of precipitating this salt black.—I shall pour a few drops of the gallic acid into this solution of sulphat of iron—

Caroline. It is become as black as ink!

Mrs. B. And it is ink in reality. Common writing ink is a precipitate of sulphat of iron by gallic acid; the black colour is owing to the formation of gallat of iron, which being insoluble, remains suspended in the fluid.

This acid has also the property of altering the colour of iron in its metallic state. You may frequently see its effects on the blade of a knife that has been used to cut certain kinds of fruits.

Caroline. True; and that is perhaps the reason that a silver knife is preferred to cut fruits; the gallic acid, I suppose, does not act upon silver.—Is this acid found in all fruits?

Mrs. B. It is contained, more or less, in the rind of most fruits and roots, especially the radish, which, if scraped with a steel or iron knife, has its bright red colour changed to a deep purple, the knife being at the same time blackened. But the vegetable substance in which the gallic acid most abounds is *nutgall*, a kind of excrescence that grows on oaks, and from which the acid is commonly obtained for its various purposes.

Mrs. B. We now come to the PHOSPHORIC and PHOSPHOROUS ACIDS. In treating of phosphorus, you have seen how these acids may be obtained from it by combustion?

Emily. Yes; but I should be much surprised if it was the usual method of obtaining them, since it is so very difficult to procure phosphorus in its pure state.

Mrs. B. You are right, my dear; the phosphoric acid, for general purposes, is extracted from bones, in which it is contained in the state of phosphat of lime; from this salt the phosphoric acid is separated by means of the sulphuric, which combines with the lime. In its pure state, phosphoric acid is either liquid or solid, according to its degree of concentration.

Amongst the salts formed by this acid, *phosphat of lime* is the only one that affords much interest; and this, we have already observed, constitutes the basis of all bones. It is also found in very small quantities in some vegetables.

Conversation XV.

Of the nitric and carbonic acids; or the combinations of oxygen with nitrogen and carbone; and of the nitrats and carbonats.

Mrs. B.

I am almost afraid of introducing the subject of the NITRIC ACID, as I am sure that I shall be blamed by Caroline, for not having made her acquainted with it before.

Caroline. Why so, Mrs. B—?

Mrs. B. Because you have long known its radical, which is nitrogen or azote; and, in treating of that element, I did not even hint that it was the basis of an acid.

Caroline. Indeed, that appears to me a great omission; for you have made us acquainted with all the other acids, in treating of their radicals.

Emily. I would advise you not to be too hasty in your censure, Caroline; for I dare say that Mrs. B. had some very good reason for not mentioning this acid sooner.

Mrs. B. I do not know whether you will think the reason sufficiently good to acquit me; but the omission, I assure you, did not proceed from negligence. You may recollect that nitrogen was one of the first simple bodies which we examined; you were then ignorant of the theory of combustion, which I believe was, for the first time, mentioned in that lesson; and therefore it would have been in vain, at that time, to have attempted to explain the nature and formation of acids.

Caroline. I wonder, however, that it never occurred to us to inquire whether nitrogen could be acidified; for, as we knew it was classed amongst the combustible bodies, it was natural to suppose that it might produce an acid.

Mrs. B. That is not a necessary consequence; for it might combine with oxygen only in the degree requisite to form an oxyd. But you will find that nitrogen is susceptible of various degrees of oxygenation, some of which convert it merely into an oxyd, and others give it all the acid properties.

The acids, resulting from the combination of oxygen with nitrogen, are called the NITROUS and NITRIC acids. We will begin with the NITRIC, in which nitrogen is in the highest state of oxygenation. This acid naturally exists in the form of gas; but it is so extremely soluble in water, and has so great an affinity for it, that one grain of water will absorb and condense ten grains of acid gas, and form the limpid fluid which you see in this bottle.

Caroline. What a strong offensive smell it has!

Mrs. B. This acid contains a greater abundance of oxygen than any other, but it retains it with very little force.

Emily. Then it must be a powerful caustic, both from the facility with which it parts with its oxygen, and the quantity which it affords?

Mrs. B. Very well, Emily; both cause and effect are exactly such as you describe: nitric acid burns and destroys all kinds of organized matter. It even sets fire to some of the most combustible substances. We shall pour a little of it over this piece of dry warm charcoal—you see it inflames it immediately; it would do the same with oil of turpentine, phosphorus, and several other very combustible bodies. This shews you how easily this acid is decomposed by combustible bodies, since these effects must depend upon the absorption of its oxygen.

Nitric acid has been used in the arts from time immemorial, but it is not more than twenty five years that its chemical nature has been ascertained. The celebrated Mr. Cavendish discovered that it consisted of about 10 parts of nitrogen, and 25 of oxygen.* These principles, in their gaseous state, combine at a high temperature; and this may be effected by repeatedly passing the electrical spark through a mixture of the two gasses.

Emily. The nitrogen and oxygen gasses, that compose the atmosphere, do not combine, I suppose, because their temperature is not sufficiently elevated?

Caroline. But in a thunder storm, when the lightning repeatedly passes through them, may it not produce nitric acid; we should be in a strange situation if a violent storm should at once convert the atmosphere into nitric acid.

Mrs. B. There is no danger of it my dear; the lightning can affect but a very small portion of the atmosphere, and though it were occasionally to produce a little nitric acid, yet this never could happen to such extent as to be perceivable.

* The proportions stated by Mr. Davy, in his Chemical Researches, are as 1 to 2. 389.

Emily. But how could the nitric acid be known, and used, before the method of combining its constituents was discovered?

Mrs. B. Before that period the nitric acid was obtained, and it is indeed still extracted for the common purposes of art, from the compound salt which it forms with potash, commonly called *nitre.*

Caroline. Why is it called so? Pray, Mrs. B. let these old unmeaning names be entirely given up, by us at least; and let us call this salt *nitrat of potash.*

Mrs. B. With all my heart; but it is necessary that I should, at least, mention the old names, and more especially those that are yet in common use; otherwise, when you meet with them, you would not be able to understand their meaning.

Emily. And how is the acid obtained from this salt?

Mrs. B. By the intervention of sulphuric acid, which combines with the potash, and sets the nitric acid at liberty. This I can easily shew you, by mixing some nitrat of potash and sulphuric acid in this retort, and heating it over a lamp; the nitric acid will come over in the form of vapour, which we shall collect in a glass bell. This acid diluted in water is commonly called *aqua fortis*, if Caroline will allow me to mention that name.

Caroline. I have often heard that aqua fortis will dissolve almost all metals; it is no doubt because it yields its oxygen so easily.

Mrs. B. Yes; and from this powerful solvent property, it derived the name of aqua fortis, or strong water. Do you not recollect that we oxydated, and afterwards dissolved some copper in this acid?

Emily. If I remember right, the nitrat of copper was the first instance you gave us of a compound salt.

Caroline. Can the nitric acid be completely decomposed and converted into nitrogen and oxygen?

Emily. That cannot be the case, Caroline, since the acid can be decomposed only by the combination of its constituents with other bodies.

Mrs. B. True; but caloric is sufficient for this purpose. By making the acid pass through a red hot porcelain tube, it is decomposed ; the nitrogen and oxygen regain the caloric which they had lost in combining, and are thus both restored to their gaseous state.

The nitric acid may also be partly decomposed, and is by this means converted into NITROUS ACID.

Caroline. This conversion must be easily effected, as the oxygen is so slightly combined with the nitrogen.

Mrs. B. The partial decomposition of nitric acid is readily effected by most metals ; but it is sufficient to expose the nitric acid to a very strong light to make it give out oxygen gas, and be thus converted into nitrous acid. Of this acid there are various degrees, according to the proportions of oxygen which it contains ; the strongest and that into which the nitric acid is first converted, is of a yellow colour, as you see it in this bottle.

Caroline. How it fumes when the stopper is taken out.

Mrs. B. The acid exists naturally in a gaseous state, and is here so strongly concentrated in water that it is constantly escaping.

Here is another bottle of nitrous acid, which, you see is of an orange red colour ; this acid is weaker, the nitrogen being combined with a smaller quantity of oxygen ; and with a still less proportion of oxygen it is an olive green colour, as it appears in this third bottle. In short, the weaker the acid, the deeper is its colour.

Nitrous acid acts still more powerfully on some inflammable substances than the nitric.

Emily. I am surprised at that, as it contains less oxygen.

Mrs. B. But, on the other hand, it parts with its oxygen much more readily : you may recollect that we once inflamed oil with this acid.

The next combinations of nitrogen and oxygen form only oxyds of nitrogen, the first of which is commonly called *nitrous air :* or more properly *nitric oxyd gas.* This may be obtained from nitric acid, by exposing the latter to the action of metals, as in dissolving them it does not yield the whole of its oxygen, but retains a portion of this principle sufficient to convert it into this peculiar gas, a specimen of which I have prepared, and preserved within this inverted glass bell.

Emily. It is a perfectly invisible elastic fluid.

Mrs. B. Yes; and it may be kept any length of time in this manner over water, as it is not, like the nitric and nitrous acids, absorbable by it. It is rather heavier than atmospherical air, and is incapable of supporting either combustion or respiration. I am going to incline the glass gently on one side, so as to let some of the gas escape—

Emily. How very curious!—It produces orange fumes like the nitrous acid! that is the more extraordinary, as the gas within the glass is perfectly invisible.

Mrs. B. It would give me much pleasure if you could make out the reason of this curious change without requiring any further explanation.

Caroline. It seems, by the colour and smell, as if it were converted into nitrous acid gas: yet that cannot be, unless it combines with more oxygen; and how can it obtain oxygen the very minute it escapes from the glass?

Emily. From the atmosphere, no doubt. Is it not so, Mrs. B.?

Mrs. B. You have guessed it; as soon as it comes in contact with the atmosphere it absorbs from it the additional quantity of oxygen necessary to convert it into nitrous acid gas.—And, if I now remove the bottle entirely from the water, so as to bring at once the whole of the gas into contact with the atmosphere, this conversion will appear still more striking.

Emily. Look, Caroline, the whole capacity of the bottle is instantly tinged of an orange colour!

Mrs. B. Thus you see it is the most easy process imaginable to convert *nitrous oxyd gas* into *nitrous acid gas.* The property of attracting oxygen from the atmosphere, without any elevation of temperature, has occasioned this gaseous oxyd being used as a test for ascertaining the degree of purity of the atmosphere. I am going to show you how it is applied to this purpose. —You see this graduated glass tube, which is closed at one end; (*Plate* VIII. *Fig.* 19.)—I first fill it with water, and then introduce a certain measure of nitrous gas, which, not being absorbable by water, passes thro' it, and occupies the upper part of the tube. I must now add rather above two thirds of oxygen gas, which will just be sufficient to convert the nitric oxyd gas, into nitrous acid gas.

Caroline. So is has !—I saw it turn of an orange colour ; but it immediately afterwards disappeared entirely, and the water, you see, has risen, and almost filled the tube.

Mrs. B. That is because the acid gas is absorbable by water, and in proportion as the gas impregnates the water, the latter rises in the tube. When the oxygen gas is very pure, and the required proportion of nitric oxyd gas very exact, the whole is absorbed by the water ; but if any other gas be mixed with the oxygen, instead of combining with the nitric oxyd, it will remain and occupy the upper part of the tube ; or, if the gasses be not in the due proportion, there will be a residue of that which predominates.—Before we leave this subject, I must not forget to remark, that nitric acid may be formed by dissolving nitric oxyd gas in nitric acid. This solution may be effected simply by making bubbles of nitric oxyd gas pass through nitric acid.

Emily. That is to say, that nitrogen, at its highest degree of oxygenation, being mixed with nitrogen at its lowest degree of oxygenation, will produce a kind of intermediate substance, which is nitric acid.

Mrs. B. You have stated the fact with great precision.—There are various other methods of preparing nitrous oxyd, and of obtaining it from compound bodies ; but it is not necessary to enter into these particulars. It remains for me only to mention another curious modification of oxygenated nitrogen, which has been distinguished by the name of *gaseous oxyd of nitrogen.* It is but lately that this gas has been accurately examined, and its properties have been chiefly investigated by Mr. Davy. It has obtained also the name of *exhilirating* gas, from the very singular property which that gentleman has discovered in it, of elevating the animal spirits, when inhaled into the lungs, to a degree sometimes resembling delirium or intoxication.

Caroline. It is respirable, then ?

Mrs. B. It can scarcely be called respirable, as it would not support life for any length of time ; but it may be breathed for a few moments without any other effects, than the singular exhiliration of spirits I have just mentioned. It affects different people, however, in a very different manner. Some become violent, even outrageous : others experience a languor, attended with faintness ; but most agree in opinion, that the sensations it excites are extremely pleasant.

Caroline. I think I should like to try it—how do you breath it ?

Mrs. B. By collecting the gas in a bladder, to which a short tube with a stop-cock is adapted ; this is applied to the mouth with one hand, whilst the nostrils are kept closed with the other, that the common air may have no access. You then alternately inspire, and expire the gas, till you perceive its effects. But I cannot consent to your making the experiment ; for the nerves are sometimes unpleasantly affected by it, and I would not run any risk of that kind.

Emily. I should like, at least, to see somebody breathe it ; but pray by what means is this curious gas obtained ?

Mrs. B. It is procured from *nitrat of ammonia*, an artificial salt, which yields this gas on the application of a gentle heat—I have put some of the salt into a retort, and by the aid of a lamp the gas will be extricated—

Caroline. Bubbles of air begin to escape through the neck of the retort into the water apparatus ; will you not collect them ?

Mrs. B. The gas that first comes over is never preserved, as it consists of little more than the common air which was in the retort ; besides, there is always in this experiment a quantity of watery vapour which must come away before the nitrous oxyd appears.

Emily. Watery vapour ! Whence does that proceed ? there is no water in nitrat of ammonia !

Mrs. B. You must recollect that there is in every salt a quantity of water of crystallization, which may be evaporated by heat alone. But, besides this, water is actually generated in this experiment, as you will see presently. But first tell me, what are the constituent parts of nitrat of ammonia?

Emily. Ammonia, and nitric acid: this salt, therefore, contains three different elements, nitrogen and hydrogen, which produce the ammonia; and oxygen, which, with nitrogen, forms the acid.

Mrs. B. Well, then, in this process the ammonia is decomposed; the hydrogen quits the nitrogen to combine with some of the oxygen of the nitric acid, and forms with it the watery vapour which is now coming over. When that is effected, what will you expect to find?

Emily. Nitrous acid instead of nitric acid, and nitrogen instead of ammonia.

Mrs. B. Exactly so; and the nitrous acid, and nitrogen combine, and form the gaseous oxyd of nitrogen, in which the proportion of oxygen is 37 parts to 63 of nitrogen.

You may have observed, that for a little while no bubbles of air have come over, and we have perceived only a stream of vapour condensing as it issued into the water.—Now bubbles of air again make their appearance, and I imagine that by this time all the watery vapour is come away, and that we may begin to collect the gas. We may try whether it is pure by filling a phial with it, and plunging a taper into it—yes, it will do now, for the taper burns brighter than in the common air, and with a greenish flame.

Caroline. But how is that? I thought no gas would support combustion but oxygen.

Mrs. B. Or any gas that contains oxygen, and is ready to yield it, which is the case with this in a considerable degree; it is not, therefore, surprising that it should accelerate the combustion of the taper.

You see that the gas is now produced in great abundance; we shall collect a large quantity of it, and I dare say we shall find some of the family who will be curious to make the experiment of respiring it. Whilst this process is going on, we may take a general survey of the most important combination of the nitric and nitrous acids with the alkalies.

The first of these is *nitrat of potash*, commonly called *nitre*, or *saltpetre*.

Caroline. Is not that the salt with which gunpowder is made ?

Mrs. B. Yes. Gunpowder is a mixture of five parts of nitre to one of sulphur, and one of charcoal.— Nitre from its great proportion of oxygen, and from the facility with which it yields it, is the basis of most detonating compositions.

Emily. But what is the cause of the violent detonation of gunpowder when set fire to ?

Mrs. B. Detonation may proceed from two causes ; the sudden formation or destruction of an elastic fluid. In the first case, when either a solid or liquid is instantaneously converted into an elastic fluid, the prodigious and sudden expansion of the body strikes the air with great violence, and this concussion produces the sound called detonation.

Caroline. That I comprehend very well ; but how can a similar effect be produced by the destruction of a gas ?

Mrs. B. A gas can be destroyed only by condensing it to a liquid or solid state ; when this takes place suddenly, the gas, in assuming a new and more compact form, produces a vacuum into which the surrounding air rushes with great impetuosity ; and it is by that rapid and violent motion that the sound is produced.— In all detonations, therefore, gasses are either suddenly formed, or destroyed. In that of gunpowder, can you tell me which of these two circumstances takes place ?

Emily. As gunpowder is a solid, it must, of course, produce the gasses in its detonation ; but how, I cannot tell.

Mrs. B. The constituents of gunpowder, when heated to a certain degree, enter into a number of new combinations, and are instantaneously converted into a variety of gasses, the sudden expansion of which gives rise to the detonation, *Caroline.* And in what instance does the destruction or condensation of gasses produce detonation?

Mrs. B. I can give you one with which you are well acquainted; the sudden combination of the oxygen and hydrogen gasses.

Caroline. True; I recollect perfectly that hydrogen detonates with oxygen when the two gasses are converted into water.

Mrs. B. But let us return to the nitrat of potash. This salt is decomposed when exposed to heat, and mixed with any combustible body, such as carbone, sulphur, or metals, these substances oxydating rapidly at the expense of the nitrat. I must shew you an instance of this.—I expose to the fire some of the salt in a small iron ladle, and when it is sufficiently heated, add to it some powdered charcoal; this will attract the oxygen from the salt, and be converted into carbonic acid—

Emily. But what occasions that crackling noise, and those vivid flashes that accompany it?

Mrs. B. The rapidity with which the carbonic acid gas is formed, occasions a succession of small detonations, which, together with the emission of flame, is called *deflagration.*

Nitrat of ammonia we have already noticed, on account of the gaseous oxyd of nitrogen which is obtained from it.

Nitrat of silver is the lunar caustic, so remarkable for its property of destroying animal fibre, for which purpose it is often used by surgeons.—We have said so much on a former occasion, on the mode in which caustics act on animal matter, that I shall not detain you any longer on this subject.

We now come to the CARBONIC ACID, which we have already had many opportunities of noticing. You recollect that this acid may be formed by the combustion of carbone whether in its imperfect state of charcoal, or in its purest form of diamond. And it is not necessary, for this purpose, to burn the carbone in pure oxygen gas, as we did in a preceding lecture; for you need only light a piece of charcoal and suspend it under the receiver on the water bath. The charcoal will soon be extinguished, and the air in the receiver will be found mixed with carbonic acid, the process, however, is much more expeditious if the combustion be performed in pure oxygen gas.

Caroline. But how can you separate the carbonic acid, obtained in this manner, from the air with which it is mixed.

Mrs. B. The readiest mode is to introduce under the receiver, a quantity of caustic lime, or caustic alkali, which soon attracts the whole of the carbonic acid to form a carbonat.—The alkali is found increased in weight, and the volume of the air is diminished by a quantity equal to that of the carbonic acid which was mixed with it.

Emily. Pray is there no method of obtaining pure carbone from carbonic acid?

Mrs. B. For a long time it was supposed that carbonic acid was not decomposable; but Mr. Tennant discovered, a few years ago, that this acid may be decomposed by burning phosphorus in a closed vessel with carbone of soda or carbonat of lime: the phosphorus absorbs the oxygen from the carbonat, whilst the carbone is separated in the form of a black powder.

Caroline. Cannot we make that experiment?

Mrs. B. Not easily; it requires being performed with extreme nicety, in order to obtain any sensible quantity of carbone, and the experiment is much too delicate for me to attempt it. But there can be no doubt of the accuracy of Mr. Tennant's results; and all chemists now agree, that 100 parts of carbonic acid gas consist of about 28 parts of carbone to 72 of oxygen gas.

Carbonic acid gas is found very abundantly in nature; it is supposed to form about a hundredth part of the atmosphere, and is constantly produced by the respiration of animals; it exists in a great variety of combinations, and is exhaled from many natural decompositions.

It is contained in a state of great purity in certain caves, such as the *Grotto del Cane*, near Naples.

Emily. I recollect having read an account of that grotto, and of the cruel experiments made on the poor dogs, to gratify the curiosity of strangers. But I understood that the vapour exhaled by this cave was called *fixed air*.

Mrs. B. That is the name by which carbonic acid was known before its chemical composition was discovered.—This gas is more destructive of life than any other; and if the poor animals that are submitted to its effects, are not plunged into cold water as soon as they become senseless, they do not recover. It extinguishes flame instantaneously. I have collected some in this glass, which I will pour over the candle.

Caroline. This is extremely singular—it seems to extinguish it as it were by enchantment, as the gas is invisible. I never should have imagined that a gas could have been poured like a liquid.

Mrs. B. It can be done with carbonic acid only, as no other gas is sufficiently heavy to be susceptible of being poured out in the atmospherical air, without mixing with it.

Emily. Pray by what means did you obtain this gas?

Mrs. B. I procured it from marble. Carbonic acid gas has so strong an attraction for all the alkalies and alkaline earths, that these are always found in nature in the state of carbonats. Combined with lime, this acid forms chalk, which may be considered as the basis of all kinds of marble, and calcareous stones. From these substances carbonic acid is easily separated, as it adheres so slightly to its combinations, that the carbonats are all decomposable by any of the other acids. I can easily shew you how I obtained this gas; I poured some diluted sulphuric acid over pulverized marble in this bottle (the same which we used the other day to prepare hydrogen gas), and the gas escaped through the tube connected with it; the operation still continues, as you may easily perceive—

Emily. Yes, it does; there is a great fermentation in the glass vessel. What singular commotion is excited by the sulphuric acid taking possession of the lime, and driving out the carbonic acid ?

Caroline. But did the carbonic acid exist in a gaseous state in the marble ?

Mrs. B. Of course not; the acid, when in a state of combination, is capable of existing in a solid form.

Caroline. Whence, then, does it obtain the caloric necessary to convert it into a gas ?

Mrs. B. It may be supplied in this case from the mixture of sulphuric acid and water, which produces an evolution of heat, even greater than is required for the purpose ; since, as you may perceive by touching the glass vessel, a considerable quantity of the caloric disengaged becomes sensible. But a supply of caloric may be obtained also from a diminution of capacity for heat, occasioned by the new combination which takes place ; and, indeed, this must be the case when other acids are employed for the disengagement of carbonic acid gas, which do not, like the sulphuric, produce heat on being mixed with water. Carbonic acid may likewise be disengaged from its combinations by heat alone, which restores it to its gaseous state.

Caroline. It appears to me very extraordinary that the same gas, which is produced by the burning of wood and coals, should exist also in stones, marble, and chalk, which are incombustible substances.

Mrs. B. I will not answer that objection, Caroline, because I think I can put you in a way of doing it yourself. Is carbonic acid combustible ?

Caroline. Why, no—because it is a body that has been already burnt, it is carbone only, and not the acid, that is combustible.

Mrs. B. Well, and what inference do you draw from this ?

Caroline. That carbonic acid cannot render the bodies in which it is contained combustible ; but that simple carbone does, and that it is in this elementary state that it exists in wood, coals, and a great variety of other combustible bodies.—Indeed, Mrs. B. you are very ungenerous ; you are not satisfied with convincing me that my objections are frivolous, but you oblige me to prove them so myself.

Mrs. B. You must confess, however, that I make ample amends for the detection of error, when I enable you to discover the truth. You understand, now, I hope, that carbonic acid is equally produced by the decomposition of chalk, or by the combustion of charcoal. These processes are certainly of a very different nature ; in the first case the acid is already formed, and requires nothing more than heat to restore it to its gaseous state ; whilst, in the latter, the acid is actually formed by the process of combustion.

Caroline. I understand it now perfectly. But I have just been thinking of another difficulty, which I hope you will excuse my not being able to remove myself. How does the immense quantity of calcareous earth, which is spread all over the globe, obtain the carbonic acid which is combined with it ?

Mrs. B. This question is, indeed, not very easy to answer ; but I conceive that the general carbonization of calcareous matter may have been the effect of a general combustion, occasioned by some revolution of our globe, and producing an immense supply of carbonic acid, with which the calcareous matter became impregnated ; or that this may have been effected by a gradual absorption of carbonic acid from the atmosphere.—But this subject would lead us to discussions which we cannot indulge in, without deviating too much from our subject.

Emily. How does it happen that we do not perceive the pernicious effects of the carbonic acid that is floating in the atmosphere ?

Mrs. B. Because of the state of very great dilution in which it exists there. But can you tell me, Emily, what are the sources which keep the atmosphere constantly supplied with this acid ?

Emily. I suppose the combustion of wood, coals, and other substances, that contain carbone.

Mrs. B. And also the breath of animals.

Caroline. The breath of animals ! I thought you said that this gas was not at all respirable, but, on the contrary, extremely poisonous.

Mrs. B. So it is; but although animals cannot breathe in carbonic acid gas, yet, in the process of respiration, they have the power of forming this gas in their lungs; so that the air which we *expire*, or reject from the lungs, always contains a greater proportion of carbonic acid, which is much greater than that which is commonly found in the atmosphere.

Caroline. But what is it that renders carbonic acid such a deadly poison?

Mrs. B. The manner in which this gas destroys life, seems to be merely by preventing the access of respirable air; for carbonic acid gas, unless very much diluted with common air, does not penetrate into the lungs, as the windpipe actually contracts, and refuses it admittance.—But we must dismiss this subject at present, as we shall have an opportunity of treating of respiration much more fully, when we come to the chemical functions of animals.

Emily. Is carbonic acid as destructive to the life of vegetables, as it is to that of animals?

Mrs. B. If a vegetable be completely immersed in it, I believe it generally proves fatal to it; but mixed in certain proportions with atmospheical air, it is on the contrary, very favourable to vegetation.

You remember, I suppose, our mentioning the mineral waters, both natural and artificial, which contain carbonic acid gas?

Caroline. You mean the Seltzer water?

Mrs. B. That is one of those which are most used; there are, however, a variety of others into which carbonic acid enters as an ingredient; all these waters are usually distinguished by the name of *acidulous* or *gaseous mineral waters.*

The class of salts called *carbonats* is the most numerous in nature; we must pass over them in a very cursory manner, as the subject is far too extensive for us to enter on in detail. The state of carbonat is the natural state of a vast number of minerals, and particularly of the alkalies and alkaline earths, as they have so great an attraction for the carbonic acid, that they are almost always found combined with it ; and you may recollect that it is only by separating them from this acid, that they acquire that causticity and those striking qualities which I have formerly described. All marbles, chalks, shells, calcareous spars, and lime-stones of every description, are neutral salts, in which *lime*, their common basis, has lost all its characteristic properties.

Emily. But if all these various substances are formed by the union of lime with carbonic acid, whence arises their diversity of form and appearance ?

Mrs. B. Both from the different proportions of their component parts, and from a variety of foreign ingredients which may be occasionally mixed with them : the veins and colours of marble, for instance, proceed from a mixture of metallic substances ; silex and alumine also frequently enter into these combinations. The various carbonats therefore, that I have enumerated, cannot be considered as pure unadulterated neutral salts, although they certainly belong to that class of bodies.

Conversation XVI.

On the muriatic and oxygenated muriatic acids ; and on muriats.

Mrs. B.

We come now to the undecompounded acids.—The MURIATIC, formerly called the MARINE ACID, is the only one that requires our particular attention.

The basis of this acid, as I have told you before, is unknown, all attempts to decompose it having hitherto proved fruitless ; it is, therefore, by analogy only, that we suppose it to consist of a certain substance or radical, combined with oxygen.

Caroline. It can then never be formed by the combination of simple bodies, but must always be drawn from its compounds.

Emily. Unless the acid should be found in nature uncombined with other substances.

Mrs. B. I believe that is never the case. Its principal combinations are with soda, lime, and magnesia. *Muriat of soda*, is the common sea salt, and from this substance the acid is usually disengaged by means of the sulphuric acid. The natural state of the muriatic acid, is that of an invisible permanent gas, at the common temperature of the atmosphere ; but it has an extremely strong attraction for water, and assumes the form of a whitish cloud, whenever it meets with any moisture to combine with. This acid is remarkable for its peculiar and very pungent smell, and possesses, in a powerful degree, most of the acid properties. Here is a bottle containing muriatic acid in a liquid state.

Caroline. And how is it liquified ?

Mrs. B. By impregnating water with it ; its strong attraction for water makes it very easy to obtain it in a liquid form. Now, if I open the phial, you may observe a kind of vapour rising from it, which is muriatic acid gas, of itself invisible, but made apparent by combining with the moisture of the atmosphere.

Emily. Have you not any of the pure muriatic acid gas ?

Mrs. B. This jar is full of that acid in its gaseous state—it is inverted over mercury instead of water, because, being absorbable by water, this gas cannot be confined by it.—I shall now raise the jar a little on one side, and suffer some of the gas to escape.—You see that it immediately becomes visible in the form of a cloud.

Emily. It must be, no doubt, from its uniting with the moisture of the atmosphere, that it is converted into this dewy vapour.

Mrs. B. Certainly; and for the same reason, that is to say, its extreme eagerness to unite with water, this gas will cause snow to melt as rapidly as an intense fire.

Emily. Since this acid cannot be decomposed, I suppose that it is not susceptible of different degrees of oxygenation?

Mrs. B. You are mistaken in your conclusion; for though we cannot deoxygenate this acid, yet we may add oxygen to it.

Caroline. Why then is not the least degree of oxygenation of the acid, called the *muriatous*, and the higher degree the *muriatic* acid?

Mrs. B. Because, instead of becoming, like other acids, more dense, and more acid by an addition of oxygen, it is rendered on the contrary more volatile, more pungent, but less acid, and less absorbable by water. These circumstances, therefore, seem to indicate the propriety of making an exception to the nomenclature. The highest degree of oxygenation of this acid has been distinguished by the additional epithet of *oxygenated*, or, for the sake of brevity, *oxy*, so that it is called the *oxygenated*, or *oxy-muriatic acid*. This likewise exists in a gaseous form, at the temperature of the atmosphere; it is also susceptible of being absorbed by water, and can be congealed, or solidified, by a certain degree of cold.

Emily. And how do you obtain the oxy-muriatic acid?

Mrs. B. By distilling liquid muriatic acid over oxyd of manganese, which supplies the acid with the additional oxygen. One part of the acid being put into a retort, with too parts of the oxyd of manganese, and the heat of a lamp applied, the gas is soon disengaged, and may be received over water, as it is but sparingly absorbed by it. I have collected some in this jar—

Caroline. It is not invisible, like the generality of gasses; for it is of a yellowish colour.

Mrs. B. The muriatic acid extinguishes flame, whilst, on the contrary, the oxy-muriatic makes the flame larger, and gives it a dark red colour. Can you account for this difference in the two acids?

Emily. Yes, I think so; the muriatic acid cannot be decomposed, and therefore will not supply the flame with the oxygen necessary for its support; but when this acid is farther oxygenated it will part with its additional quantity of oxygen, and in this way support combustion.

Mrs. B. That is exactly the case; indeed the oxygen, added to the muriatic acid, adheres so slightly to it, that it is separated by mere exposure to the sun's rays. This acid is decomposed also by combustible bodies, many of which it burns, and actually inflames, without any previous increase of temperature.

Caroline. That is extraordinary, indeed! I hope you mean to indulge us with some of these experiments?

Mrs. B. I have prepared several glass jars of oxymuriatic acid gas, for that purpose. In the first we shall introduce some Dutch gold leaf.—Do you observe that it takes fire?

Emily. Yes, indeed it does—how wonderful it is! it became immediately red hot, but was soon smothered in a thick vapour.

Caroline. Good heavens! what a disagreeable smell.

Mrs. B. We shall try the same experiment with phosphorus in another jar of this acid.—You had better keep your handkerchief to your nose when I open it—now let us drop into it this little piece of phosphorus—

Caroline. It burns really: and almost as brilliantly as in oxygen gas! But what is most extraordinary, these combustions take place without the metal or phosphorus being previously lighted, or even in the least heated.

Mrs. B. All these curious effects are owing to the very great facility with which this acid yields oxygen to such bodies as are strongly disposed to combine with it. It appears extraordinary indeed to see bodies, and metals in particular, melted down and inflamed, by a gas, without any increase of temperature, either of the gas or of the combustible. The phenomenon, however, is, you see, well accounted for.

Emily. Why did you burn a piece of Dutch gold-leaf rather than a piece of any other metal?

Mrs. B. Because, in the first place, it is a composition of metals consisting chiefly of copper, which burns readily; and I use a thin metallic leaf in preference to a lump of metal, because it offers to the action of the gas but a small quantity of matter under a large surface.—Filings, or shavings, would answer the purpose nearly as well; but a lump of metal, though the surface would oxydate with great rapidity, would not take fire. Pure gold is not inflamed by oxy-muriatic acid gas, but it is rapidly oxydated, and dissolved by it; indeed, this acid is the only one that will dissolve gold.

Emily. This, I suppose, is what is commonly called *aqua regia*, which you know, is the only thing that will act upon gold.

Mrs. B. That is not exactly the case either; for aqua regia is composed of a mixture of muriatic and nitric acid. But, in fact, the result of this mixture is nothing more than oxy-muriatic acid, as the muriatic acid oxygenates itself at the expense of the nitric; this mixture, therefore, though it bears the name of *nitro muriatic acid*, acts on gold merely in virtue of the oxy-muriatic acid which it contains.

Sulphur, volatile oils, and many other substances, will burn in the same manner in oxy-muriatic acid gas; but I have not prepared a sufficient quantity of it, to shew you the combustion of all these bodies.

Caroline. Yet there are several jars of the gas remaining.

Mrs. B. We must reserve these for other experiments. The oxy-muriatic acid does not, like other acids, redden the blue vegetable colours; but it totally destroys any colour, and turns all vegetables perfectly white. Let us collect some vegetable substances to put into this glass which is full of gas.

Emily. Here is a sprig of myrtle—

Caroline. And here some coloured paper—

Mrs. B. We shall also put in this piece of coquelicot ribbon, and a rose—

Emily. Their colours begin to fade immediately! But how does the gas produce this effect?

Mrs. B. The oxygen combines with the colouring matter of these substances, and destroys it; that is to say, destroys the property which these colours had of reflecting only one kind of rays, and renders them capable of reflecting them all, which, you know, will make them appear white. Old prints may be cleaned by this acid, for the paper will be whitened without injuring the impression, as printer's ink is made of materials (oil and lamp black) which are not acted upon by acids.

This property of the oxy-muriatic acid has lately been employed in manufactories in a variety of bleaching processes; but for these purposes the gas must be dissolved in water, as the acid is thus rendered much milder and less powerful in its effects; for, in a gaseous state, it would destroy the texture, as well as the colour, of the substance submitted to its action.

Caroline. Look at the things which we put into the gas; they have now entirely lost their colour!

Mrs. B. The effect of the acid is almost completed —and, and if we were to examine the quantity that remains, we should find it consist chiefly of muriatic acid.

The oxy-muriatic acid has been used to purify the air in fever hospitals and prisons, as it burns and destroys putrid effluvia of every kind. The infection of the small pox is likewise destroyed by this gas, and matter that has been submitted to its influence will no longer generate that disorder.

Caroline. Indeed, I think the remedy must be nearly as bad as the disease; the oxy-muriatic acid has such a dreadful suffocating smell.

Mrs. B. It is certainly extremely offensive; but, by keeping the mouth shut, and wetting the nostrils with liquid ammonia, in order to neutralize the vapour as it reaches the nose, its prejudicial effects may be in some degree prevented. At any rate, however, this mode of disinfection can hardly be used in places that are inhabited. And as the vapour of nitric acid, which is scarcely less efficacious for this purpose, is not at all prejudicial, it is usually preferred on such occasions.

Amongst the compound salts formed by muriatic acid, the *muriat of soda*, or common salt, is the most interesting. The uses and properties of this salt are too well known to require much comment. Besides the pleasant flavour it imparts to the food, it is very wholesome, when not used to excess, as it greatly assists the process of digestion.

Sea-water is the great source from which the muriat of soda is extracted by evaporation. But it is found also in large solid masses in the bowels of the earth, in England, and in many other parts of the world.

Emily. I thought that salts, when solid, were always in a state of crystals ; but the common table salt is in the form of a coarse white powder.

Mrs. B. Crystallization depends, as you may recollect, on the slow and regular reunion of particles dissolved in a fluid ; common sea salt is only in a state of imperfect crystallization, because the process by which it is prepared is not favorable to the formation of regular crystals. But, if you melt it, and afterwards evaporate the water slowly, you will obtain a regular crystallization.

Muriat of ammonia is another combination of this acid, which we have already mentioned as the principal source from which ammonia is derived.

I can at once shew you the formation of this salt by the immediate combination of muriatic acid with ammonia.—These two glass jars contain, the one muriatic acid gas, the other ammoniacal gas, both of which are perfectly invisible—now, if I mix them together, you see they immediately form an opaque white cloud like smoke. If a thermometer were placed in the jar in which these gasses are mixed, you would perceive that some heat is at the same time produced.

Emily. The effects of chemical combinations are, indeed, wonderful—how extraordinary it is that two invisible bodies should become visible by their union.

Mrs. B. This strikes you with wonder because it is a phenomenon which nature seldom exhibits to our view ; but the most common of her operations are as wonderful, and it is their frequency only that prevents our regarding them with equal admiration. What would be more surprising for instance, than combustion, were it not rendered so familiar by custom ?

Emily. That is true.—But pray, Mrs. B. is this white cloud the salt that produces ammonia ? How different it is from the solid muriat of ammonia which you once shewed us !

Mrs. B. It is the same substance which first appears in the state of vapour, but will soon be condensed, by cooling against the sides of the jar, in the form of very minute crystals.

We may now proceed to the *oxy-muriats*. In this class of salts the *oxy-muriat of potash* is the most worthy of our attention, for its striking properties. The acid, in this state of combination, contains a still greater proportion of oxygen than when alone.

Caroline. But how can the oxy-muriatic acid acquire an increase of oxygen by combining with potash ?

Mrs. B. It does not really acquire an additional quantity of oxygen, but it loses some of the muriatic acid, which produces the same effect, as the acid that remains is proportionably super-oxygenated.

If this salt be mixed, and merely rubbed together with sulphur, phosphorus, charcoal, or indeed any other combustible, it explodes strongly.

Caroline. Like gunpowder, I suppose, it is suddenly converted into elastic fluids ?

Mrs. B. Yes ; but with this remarkable difference, that no increase of temperature, any further than is produced by the gentle friction, is required in this instance. Can you tell me what gasses are generated by the detonation of this salt with charcoal ?

Emily. Let me consider. . . . . . The oxy muriatic acid parts with its excess of oxygen to the charcoal, by which means it is converted into muriatic acid gas ; whilst the charcoal, being burnt by the oxygen, is changed to carbonic acid gas—What becomes of the potash I cannot tell.

Mrs. B. That is a fixed product which remains in the vessel.

Caroline. But since the potash does not enter into the new combinations, I do not understand of what use it is in this operation. Would not the oxy-muriatic acid and the charcoal produce the same effect without it?

Mrs. B. No; because there would not be that very great concentration of oxygen which the combination with the potash produces, as I have just explained.

I mean to shew you this experiment, but I would advise you not to repeat it alone; for if care be not taken to mix only very small quantities at a time, the detonation will be extremely violent, and may be attended with dangerous effects. You see I mix an exceedingly small quantity of the salt with a little powdered charcoal, in this Wedgwood mortar, and rub them together with the pestle—

Caroline. Heavens! How can such a loud explosion be produced by so small a quantity of matter?

Mrs. B. You must consider that an extremely small quantity of solid substance may produce a very great volume of gasses; and it is the sudden evolution of these which occasions the sound.

Emily. Would not oxy-muriat of potash make stronger gunpowder than nitrat of potash?

Mrs. B. Yes; but the preparation as well as the use of this salt, is attended with so much danger, that it is never employed for that purpose.

Caroline. There is no cause to regret it, I think; for the common gunpowder is quite sufficiently destructive.

Mrs. B. I can shew you a very curious experiment with this salt; but it must again be on condition that you will never attempt to repeat it by yourselves. I throw a small piece of phosphorus into this glass of water; then a little oxy-muriat of potash; and, lastly, I pour in, by means of this funnel, so as to bring it in contact with the two other ingredients in the bottom of the glass, a small quantity of sulphuric acid—

Caroline. This is indeed, a beautiful experiment! the phosphorus takes fire and burns from the bottom of the water.

Emily. How wonderful it is to see flame bursting out under water, and rising through it! Pray, how is this accounted for?

Mrs. B. Cannot you find it out, Caroline?

Emily. Stop—I think I can explain it. Is it not because the sulphuric acid decomposes the salt by combining with the potash, so as to liberate the oxy-muriatic acid gas by which the phosphorus is set on fire?

Mrs. B. Very well, Emily; and with a little more reflection you would have discovered another concurring circumstance, which is, that an increase of temperature is produced by the mixture of the sulphuric acid and water, which assists in promoting the combustion of the phosphorus.

We have now examined such of the acids and salts as I conceived would appear to you most interesting.—I shall not enter into any particulars respecting the metallic acids, as they offer nothing sufficiently striking for our present purpose.

Conversation XVII.

On the nature and composition of vegetables.

Mrs. B.

We have hitherto treated only of the simplest combinations of elements, such as oxyds, acids, compound salts, stones, &c. all of which belong to the mineral kingdom. It is time now to turn our attention to a more complicated class of compounds, that of ORGANIZED BODIES, which will furnish us with a new source of instruction and amusement.

Emily. By organized bodies, I suppose you mean the vegetable and animal creation? I have, however, but a very vague idea of the word *organization*, and I have often wished to know more precisely what it means.

Mrs. B. Organized bodies are such as are endowed by nature with various parts, peculiarly constructed and adapted to perform certain functions connected with life. Thus you may observe, that mineral compounds are formed by the simple effect of mechanical or chemical attraction, and may appear to some to be, in a great measure, the productions of chance; whilst organized bodies bear the most striking marks of design, and are eminently distinguished by that unknown principle called *life*, from which the various organs derive the power of exercising their respective functions.

Caroline. But in what manner does life enable these organs to perform their several functions?

Mrs. B. That is a mystery which, I fear, is enveloped in too profound darkness for us to hope that we shall ever be able to unfold it. We must content ourselves with examining the effects of this principle; as for the cause, we have been able only to give it a name, without attaching any other meaning to it than the vague and unsatisfactory idea of an unknown agent.

Caroline. And yet I think I can form a very clear idea of life.

Mrs. B. Pray let us hear how you would define it.

Caroline. It is perhaps more easy to conceive than to express--let me consider--Is not life the power which enables both the animal and vegetable creation to perform the various functions which nature has assigned to them?

Mrs. B. I have nothing to object to you definition; but you will allow me to observe, that you have only mentioned the effects which the unknown cause produces, without giving us any notion of the cause itself.

Emily. Yes, Caroline, you have told us what life *does*, but you have not told us what it *is*.

Mrs. B. We may study its operations, but we should puzzle ourselves to no purpose by attempting to form an idea of its real nature.

We shall begin with examining its effects in the vegetable world, which constitutes the simplest class of organized bodies; these we shall find distinguished from the mineral creation, not only by their more complicated nature, but by the power which they possess within themselves, of forming new chemical arrangements of their constituent parts, by means of appropriate organs. Thus, though all vegetables are ultimately composed of hydrogen, carbone, and oxygen, (with a few other occasional ingredients), they separate and combine these principles by their various organs in a thousand ways, and form with them, different kinds of juices and solid parts, which exist ready made in vegetables, and may, therefore, be considered as their immediate materials.

These are:

Sap	*Resins,*
Mucilage	*Gum Resins,*
Sugar,	*Balsams,*
Fecula,	*Caoutchouc,*
Gluten,	*Extractive colouring matter,*
Fixed Oil,	*Tannin,*
Volatile Oil,	*Woody Fibre,*
Camphor,	*Vegetable Acids, &c.*

Caroline. What a long list of names! I did not suppose that a vegetable was composed of half so many ingredients.

Mrs. B. You must not imagine that every one of these materials is formed in each individual plant. I only mean to say, that they are all derived exclusively from the vegetable kingdom.

Emily. But does each particular part of the plant, such as the root, the bark, the stem, the seeds, the leaves, consist of one of these ingredients only, or of several of them combined together?

Mrs. B. I believe there is no part of a plant which can be said to consist solely of any one particular ingredient; a certain number of vegetable materials must always be combined for the formation of any particular part, (of a seed, for instance), and these combinations are carried on by sets of vessels, or minute organs, which select from other parts, and bring together, the several principles required for the developement and growth of those particular parts which they are intended to form and to maintain.

Emily. And are not these combinations always regulated by the laws of chemical attraction?

Mrs. B. No doubt; the organs of plants cannot force principles to combine that have no attraction for each other; nor can they compel superior attractions to yield to those of inferior power; they probably act rather mechanically, by bringing into contact such principles, and in such proportions, as will by their chemical combination, form the various vegetable products.

Caroline. We may then consider each of these organs as a curiously constructed apparatus, adapted for the performance of a variety of chemical processes.

Mrs. B. Exactly so. As long as the plant lives and thrives, the carbone, hydrogen, and oxygen, (the chief constituents of its immediate meterials), are so balanced and connected together, that they are not susceptible of entering into other combinations; but no sooner does death take place, than this state of equilibrium is destroyed, and new combinations produced.

Emily. But why should death destroy it; for these principles must remain in the same proportions, and consequently, I should suppose, in the same order of attractions?

Mrs. B. You must remember, that in the vegetable, as well as in the animal kingdom, it is by the principle of *life* that the organs are enabled to act; when deprived of that agent or stimulus, their power ceases, and an order of attractions succeeds similar to that which would take place in mineral or unorganized matter.

Emily. It is this new order of attractions, I suppose, that destroys the organization of the plant after death; for if the same combinations still continued to prevail, the plant would always remain in the state in which it died.

Mrs. B. And that you know is never the case; plants may be partially preserved for some time after death, by drying; but in the natural course of events they all return to the state of simple elements; a wise and admirable dispensation of Providence, by which dead plants are rendered fit to enrich the soil, and become subservient to the nourishment of living vegetables.

Caroline. But we are talking of the dissolution of plants, before we have examined them in their living state.

Mrs. B. That is true, my dear. But I wished to give you a general idea of the nature of vegetation, before we entered into particulars. Besides, it is not so irrelevant as you suppose to talk of vegetables in their dead state, since we cannot analyse them without destroying life; and it is only by hastening to submit them to examination, immediately after they have ceased to live, that we can anticipate their natural decomposition. There are two kinds of analysis of which vegetables are susceptible; first, that which separates them into their immediate materials, such as sap, resin, mucilage, &c. 2dly, that which decomposes them into their primitive elements, as carbone, hydrogen, and oxygen.

Emily. Is there not a third kind of analysis of plants which consists in separating their various parts, as the stem, the leaves, and the several organs of the flower?

Mrs. B. That, my dear, is rather the department of the botanist: we shall consider these different parts of plants, only as the organs by which the various secretions or separations are performed; but we must first examine the nature of these secretions.

The *sap* may be considered as the principal material of vegetables, since it contains the ingredients that nourish every part of the plant. The basis of this juice, which the roots suck up from the soil is water; this holds in solution the various other ingredients required by the several parts of the plant, which are gradually secreted from the sap by the different organs appropriated to that purpose, as it passes through them in circulating through the plant.

Mucus or *mucilage*, is a vegetable substance, which, like all the others, is secreted from the sap; when in excess, it exudes from trees in the form of gum.

Caroline. Is that the gum so frequently used instead of paste or glue?

Mrs. B. It is; almost all fruit-trees yield some sort of gum, but that most commonly used in the arts is obtained from a species of acacia-tree in Arabia, and is called *gum Arabic:* it forms the chief nourishment of the natives of those parts, who obtain it in great quantities from incisions which they make in the trees.

Caroline. I did not know that gum was eatable.

Mrs. B. I should not imagine that it would be either a pleasant or a particularly elegible diet to those who have not, from their birth, been accustomed to it. It is, however, frequently taken medicinally, and considered as very nourishing. Several kinds of vegetable acids may be obtained, by particular processes, from gum or mucilage, the principal of which is called the *mucous acid.*

Sugar is not found in its simple state in plants, but is always mixed with gum, sap, or other ingredients; it is to be found in every vegetable, but abounds most in roots, fruits, and particularly in the sugar-cane.

Emily. If all vegetables contain sugar, why is it extracted exclusively from the sugar cane?

Mrs. B. Because it it both most abundant in that plant, and most easily obtained from it.

During the late troubles in the West-Indies, when Europe was but imperfectly supplied with sugar, several attempts were made to extract it from other vegetables, and very good sugar was obtained from parsnips and from carrots; but the process was too expensive to carry this enterpize to any extent.

Caroline. I should think that sugar might be more easily obtained from sweet fruits, such as figs, dates, &c.

Mrs. B. Probably; but it would be still more expensive, from the high price of those fruits.

Emily. Pray in what manner is sugar obtained from the sugar-cane?

Mrs. B. The juice of this plant is first expressed by passing it between two cylinders of iron. It is then boiled with lime water, which makes a thick scum rise to the surface. The clarified liquor is let off below and evaporated to a very small quantity, after which it is suffered to crystalize by standing in a vessel, the bottom of which is perforated with holes, that are imperfectly stopped, in order that the syrup may drain off. The sugar obtained by this process is a coarse brown powder, commonly called raw or moist sugar; it undergoes another operation to be refined and converted into loaf sugar. For this purpose it is dissolved in water, and afterwards purified by an animal fluid, called albumen. White of eggs chiefly consist of this fluid, which is also one of the constituent parts of blood; and consequently eggs, or bullock's blood, are commonly used for this purpose.

The albuminous fluid being diffused through the syrup, combines with all the solid impurities contained in it, and rises with them to the surface, where it forms a thick scum; the clear liquor is then again evaporated to a proper consistence, and poured into moulds, in which, by a confused chrystallization, it forms loaf sugar. But an additional process is required to whiten it; to this effect the mould is inverted, and its open base is covered with clay, through which water is made to pass; the water slowly trickling through the sugar, combines with, and carries off the colouring matter.

Caroline. I am very glad to hear that the blood that is used to purify sugar does not remain in it, it would be a disgusting idea.

Emily. And pray how is sugar-candy and barley-sugar prepared?

Mrs. B. Candied sugar is nothing more than the regular crystals, obtained by slow evaporation from a solution of sugar. Barley sugar is sugar melted by heat, and afterwards cooled in moulds of a spiral form.

Sugar may be decomposed by a red heat; and, like all other vegetable substances, resolved into carbonic acid and hydrogen. The formation and the decomposition of sugar afford many very interesting particulars, which we shall fully examine after having gone through the other materials of vegetables.—We shall find there is reason to suppose that sugar is not, like the other materials, secreted from the sap by appropriate organs;

but that it is formed by a peculiar process with which you are not yet acquainted.

Caroline. Pray is not honey of the same nature as sugar?

Mrs. B. Honey is a mixture of sugar and gum.

Emily. I thought that honey was in some measure an animal substance, as it is prepared by the bees.

Mrs. B. It is rather collected by them from flowers, and conveyed to their storehouses, the hives.— It is the wax only that undergoes a real alteration in the body of the bee, and is thence converted into an animal substance.

Emily. Cannot sugar be obtained from honey, since it is so simple a compound?

Mrs. B. No mode has yet been discovered to effect this: it is supposed, however, to have been done by the ancients, who were unacquainted with the sugar cane, but the process is now unknown.

Manna is a compound of sugar, gum, and a nauseous extractive matter, to which last it owes its peculiar taste and colour. It exudes like gum from various trees in hot climates, some of which have their leaves glazed by it.

The next of the vegetable materials is *fecula*; this is the general name given to the farinaceous substance contained in all seeds, and in some roots, as the potato, parsnip, &c. It is intended by nature for the first aliment of the young vegetable; but that of one particular grain is become a favourite and most common food of a large part of mankind.

Emily. You allude, I suppose, to bread, which is made of wheat-flour?

Mrs. B. Yes. The fecula of wheat contains also another vegetable substance which seems peculiar to that seed, or at least has not as yet been obtained from any other. This is *gluten*, which is of a sticky, ropy, elastic nature; and it is supposed to be owing to the vicious qualities of this substance, that wheat flour forms a much better paste than any other.

Emily. Gluten, by your description, must be very like gum.

Mrs. B. In their sticky nature they certainly have some resemblance: but gluten is essentially different from gum in other points, and especially in its being insoluble in water, whilst gum you know is extremely soluble.

The *oils* contained in vegetables all consist of hydrogen and carbone in various proportions. They are of two kinds, *fixed* and *volatile*, both of which we formerly mentioned. Do you remember in what the difference between fixed and volatile oil consists?

Emily. If I recollect right, the former are decomposed by heat, whilst the latter are merely volatilized by it.

Mrs. B. Very well. Fixed oil is contained only in the seeds of plants, excepting in the olive, in which it is produced, and expressed from the fruit. We have already observed that seeds contain also fecula; these two substances, united with a little mucilage, form the white substance contained in the seeds or kernels of plants, and is destined for the nourishment of the young plant, to which the seed gives birth. The milk of almonds, which is expressed from the seed of that name, is composed of these three substances.

Emily. Pray of what nature is the linseed oil which is used in painting?

Mrs. B. It is a fixed oil obtained from the seed of flax. Nut oil, which is frequently used for the same purpose is expressed from walnuts.

Olive oil is that which is best adapted to culinary purposes.

Caroline. And what are the oils used for burning?

Mrs. B. Animal oils most commonly; but the preference given to them is owing to their being less expensive; for vegetable oils burn equally well, and are more pleasant, as their smell is not offensive.

Emily. Since oil is so good a combustible, what is the reason that lamps so frequently require trimming?

Mrs. B. This sometimes proceeds from the construction of the lamp, which may not be sufficiently favourable to a perfect combustion; but there is certainly a defect in the nature of oil itself, which renders it necessary for the best constructed lamps to be occasionally trimmed. This defect arises from a portion of mucilage which it is extremely difficult to separate from the oil, and which being a bad combustible, gathers round the wick, and thus impedes its combustion, and consequently dims the light.

Caroline. But will not oils burn without a wick?

Mrs. B. Not unless their temperature be elevated to 400°; the wick answers this purpose, as I think I once before explained to you. The oil rises between the fibres of the cotton by capillary attraction, and the heat of the burning wick volatilizes it, and brings it successively to the temperature at which it is combustible.

Emily. I suppose the explanation which you have given with regard to the necessity of trimming lamps, applies also to candles which so often require snuffing?

Mrs. B. I believe it does; at least in some degree. But beside the circumstance just explained, the common sort of oils are not very combustible, so that the heat produced by a candle, which is a coarse kind of animal oil, being insufficient to volatilize them completely, a quantity of soot is gradually deposited on the wick, which dims the light and retards the combustion.

Caroline. Wax candles then contain no incombustible matter, since they do not require snuffing?

Mrs. B. Wax is a much better combustible than tallow, but still not perfectly so, since it likewise contains some particles that are unfit for burning; but when these gather round the wick (which in a wax light is comparatively small) they weigh it down on one side, and fall off together with the burnt part of the wick.

Caroline. As oils are such good combustibles, I wonder that they should require so great an elevation of temperature before they begin to burn.

Mrs. B. Though fixed oils will not enter into actual combustion below the temperature of about 400°, yet they will slowly absorb oxygen at the common temperature of the atmosphere. Hence arises a variety of changes in oils which modify their properties and uses in the arts.

If oil simply absorbs, and combines with oxygen, it thickens and changes to a kind of wax. This change is observed to take place on the external parts of certain vegetables, even during their life. But it happens in many instances that the oil does not retain all the oxygen which it attracts, but that part of it combines with, or burns the hydrogen of the oil, thus forming a quantity of water which gradually goes off by evaporation. In this case the alteration of the oil consists not only in the addition of a certain quantity of oxygen, but in the diminution of the hydrogen. These oils are distinguished by the name of *drying oils*. Linseed, poppy, and nut-oils are of this descripiton.

Emily. I am well acquainted with drying oils, as I continually use them in painting. But I do not understand why the acquisition of oxygen on one hand, and loss of hydrogen on the other, should render them drying?

Mrs. B. This I conceive, may arise from two reasons; either from the oxygen which is added being less favourable to the state of fluidity than the hydrogen, which is subtracted; or from this additional quantity of oxygen giving rise to new combinations, in consequence of which the most fluid parts of the oil are liberated and volatilized.

For the purpose of painting, the drying quality of oil is farther increased by adding a quantity of oxyd of lead to it, by which means it is more rapidly oxygenated.

The rancidity of oils is likewise owing to their oxygenation. In this case a new order of attraction takes place, from which a peculiar acid is formed, called the *sebacic acid*.

Caroline. Since the nature and composition of oil is so well known, pray could not oil be actually *made*, by combining its principles?

Mrs. B. That is by no means a necessary consequence; for there are innumerable varieties of compound bodies which we can decompose, although we are unable to reunite their ingredients. This, however, is not the case with oil, as it has very lately been discovered, that it is possible to form oil, by a peculiar process, from the action of oxygenated muriatic acid gas on hydro-carbonate.

We now pass to the *volatile* or *essential oils*. These form the basis of all the vegetable perfumes, and are contained, more or less, in every part of the plant excepting the seed; they are, at least, never found in that part of the seed which contains the embrio plant.

Emily. The smell of flowers then, proceeds from volatile oil?

Mrs. B. Certainly; but this oil is often most abundant in the rind of fruits, as in oranges, lemons, &c. from which it may be extracted by the slightest pressure; it is found also in the leaves of plants, and even in the wood.

Caroline. Is it not very plentiful in the leaves of mint, and of thyme, and all the sweet-smelling herbs?

Mrs. B. Yes, remarkably so; and in geranium leaves also, which have a much more powerful odour than the flowers.

The perfume of sandal fans is an instance of its existence in wood. In short, all vegetable odours, or perfumes, are produced by the evaporation of particles of these volatile oils.

Emily. They are, I suppose, very light, and of very thin consistence, since they are so volatile?

Mrs. B. They vary very much in this respect, some of them being as thick as butter, whilst others are as fluid as water. In order to be prepared for perfumes, or essences, these oils are first properly purified, and then either distilled with alcohol, as is the case with lavender water, or simply mixed with a large proportion of water, as is often done with regard to peppermint. Frequently also, these odoriferous waters are prepared merely by soaking the plants in water, and distilling. The water then comes over impregnated with the volatile oil.

Caroline. Such waters are frequently used to take spots of grease out of cloth, or silk; how do they produce that effect?

Mrs. B. By combining with the substance that forms these stains; for volatile oils dissolve wax, tallow, spermaceti, and resins; if therefore the spot proceeds from any of these substances it will remove it.

Insects of all kinds have a great aversion to perfumes; so that volatile oils are employed with success in museums for the preservation of stuffed birds and other species of animals.

Caroline. Pray does not the powerful smell of camphor proceed from a volatile oil?

Mrs. B. Camphor seems to be a substance of its own kind, remarkable by many peculiarities. But if not exactly of the same nature as volatile oil, it is at least very analogous to it. It is obtained chiefly from the camphor tree, a species of laurel which grows in China, and the Indian isles, from the stem and roots of which it is extracted. Small quantities have also been distilled from thyme, sage, and other aromatic plants; and it is deposited in pretty large quantities by some volatile oils after long standing. It is extremely volatile and inflammable. It is insoluble in water, but is soluble in oils, in which state, as well as in its solid form, it is frequently applied to medicinal purposes. Amongst the particular properties of camphor, there is one too singular to be passed over in silence. If you take a small piece of camphor, and place it on the surface of a bason of pure water, it will immediately begin to move round and round with great rapidity; but if you pour into the bason a single drop of any odoriferous fluid, it will instantly put a stop to this motion. You can at any time try this very simple experiment; but you must not expect that I shall be able to account for this phenomenon, as nothing satisfactory has yet been advanced for its explanation.

Caroline. It is very singular indeed; and I will certainly try the experiment. Pray what are *resins*, which you just now mentioned?

Mrs. B. They are volatile oils, that have been acted on, and peculiarly modified, by oxygen.

Caroline. They are, therefore, oxygenated volatile oils.

Mrs. B. Not exactly; for the process does not appear to consist so much in the oxygenation of the oil, as in the combustion of a portion of its hydrogen, and a small portion of its carbone. For when resins are artificially made by the combination of volatile oils with oxygen, the vessel in which the process is performed is bedewed with water, and the air included within is loaded with carbonic acid.

Emily. This process must be, in some respects similar to that for preparing drying oils.

Mrs. B. Yes; and it is by this operation that both of them acquire a greater degree of consistence. Pitch, tar, and turpentine, are the most common resins; they exude from the pine and fir trees. Copal, mastic, and frankincense, are also of this class of vegetable substances.

Emily. Is it of these resins that the mastic and copal varnishes, so much used in painting, are made?

Mrs. B. Yes. Dissolved either in oil or in alcohol, resins form varnishes. From these solutions they may be precipitated by water, in which they are insoluble. This I can easily shew you. If you will pour some water into this glass of mastic varnish, it will combine with the alcohol in which the resin is dissolved, and the latter will be precipitated in the form of a white cloud—

Emily. It is so. And yet how is it that pictures or drawings, varnished with this solution, may safely be washed with water.

Mrs. B. As the varnish dries, the alcohol evaporates, and the dry varnish or resin which remains, not being soluble in water, will not be acted on by it.

There is a class of compound resins called *gum resins*, which are precisely what their name denotes, that is to say, resins combined with mucilage. Myrrh and assafœtida are of this description.

Caroline. Is it possible that a substance of so disagreeable a smell as assafœtida can be formed from a volatile oil?

Mrs. B. The odour of volatile oils is by no means always grateful. Onions and garlic derive their smell from volatile oils, as well as roses and lavender.

There is still another form under which volatile oils present themselves, which is that of *balsams.*—These consist of resinous juices combined with a peculiar acid, called the benzoic acid. Balsams appear to have been originally volatile oils, the oxygenation of which has converted one part into a resin and the other part into an acid, which, combined together, form a balsam; such are the balsams of Peru, Tolu, &c.

We shall now take leave of the oils and their various modifications, and proceed to the next vegetable substance, which is *caoutchouc*. This is a white milky glutinous fluid, which acquires consistence, and blackens in drying, in which state it forms the substance with which you are so well acquainted, under the name of gum-elastic.

Caroline. I am surprised to hear that gum-elastic was ever white, or ever fluid! And from what vegetable is it procured?

Mrs. B. It is obtained from two or three different species of trees in the East Indies, and South America, by making incisions in the stem. The juice is collected as it trickles from these incisions, and moulds of clay, in the form of little bottles of gum-elastic, are dipped into it. A layer of this juice adheres to the clay and dries on it; and several layers are successively added by repeating this till the bottle is of sufficient thickness. It is then beaten to break down the clay, which is easily shaken out.—The natives of the countries where this substance is produced, sometimes make shoes and boots of it by a similar process, and they are said to be extremely pleasant and serviceable, both from their elasticity, and from their being waterproof.

The substance which comes next in our enumeration of the immediate ingredients of vegetables, *is extractive matter*. This is a term, which, in a general sense, may be applied to any substance extracted from vegetables; but it is more particularly understood to relate to the extractive *colouring matter* of plants. A great variety of colours are prepared from the vegetable kingdom, both for the purposes of painting and of dying; all the colours called *lakes* are of this description: but they are less durable than mineral colours, for, by long exposure to the atmosphere, they either darken or turn yellow.

Emily. I know that in painting the lakes are reckoned far less durable colours than the ochres; but what is the reason of it?

Mrs. B. The change which takes place in vegetable colours is owing chiefly to the oxygen of the atmosphere slowly burning their hydrogen, and leaving in some measure the blackness of the carbone exposed. Such a change cannot take place in ochre which is altogether a mineral substance.

Vegetable colours have a stronger affinity for animal than for vegetable substances, and this is supposed to be owing to a small quantity of nitrogen which they contain. Thus, silk and worsted will take a much finer vegetable dye than linen and cotton.

Caroline. Dyeing, then, is quite a chemical process?

Mrs. B. Undoubtedly. The condition required to form a good dye is, that the colouring matter should be precipitated, or fixed, on the substance to be dyed, and should form a compound not soluble in the liquids to which it will probably be exposed. Thus, for instance, printed or dyed linens or cottons must be able to resist the action of soap and water, to which they must necessarily be subject in washing; and woolens and silks should withstand the action of grease and acids, to which they may accidentally be exposed.

Caroline. But if linen and cotton have not a sufficient affinity for colouring matter, how are they made to resist the action of washing, which they always do when they are well printed?

Mrs. B. When the substance to be dyed has either no affinity for the colouring matter, or not sufficient power to retain it, the combination is effected, or strengthened, by the intervention of a third substance, called a *mordant*, or basis. The mordant must have a strong affinity both for the colouring matter and the substance to be dyed, by which means it causes them to combine and adhere together.

Caroline. And what are the substances that perform the office of thus reconciling the two adverse parties?

Mrs. B. The most common mordant is sulphat of alumine, or alum. Oxyds of tin and iron, in the state of compound salts, are likewise used for that purpose.

Tannin is another vegetable ingredient of great importance in the arts. It is obtained chiefly from the bark of trees; but it is found also in nut-galls and in some other vegetables.

Emily. Is that the substance commonly called *tan* which is used in hot-houses?

Mrs. B. Tan is the prepared bark in which the peculiar substance, tannin, is contained. But the use of tan in hot-houses is of much less importance than in the operation of *tanning*, by which skin is converted into leather.

Emily. Pray, how is this operation performed?

Mrs. B. Various methods are employed for this purpose, which all consist in exposing skin to the action of the tannin, or of substances containing this principle, in sufficient quantities and disposed to yield it to the skin. The most usual way is to infuse coarsely powdered oak bark in water, and to keep the skin immersed in this infusion for a certain length of time. During this process, which is slow and gradual, the skin is found to have increased in weight, and to have acquired a considerable tenacity and impermeability to water. This effect may be much accelerated by using strong saturations of the tanning principle (which can be extracted from bark), instead of employing the bark itself. But this quick mode of preparation does not appear to make equally good leather.

Tannin is contained in a great variety of astringent vegetable substances, as galls, the rose-tree, and wine; but it is no where so plentiful as in bark. All these substances yield it to water, from which it may be precipitated by a solution of isinglass, or glue, with which it strongly unites and forms an insoluble compound. Hence its valuable property of combining with skin (which consists chiefly of glue), and of enabling it to resist the action of water.

Emily. Might we not see that effect by pouring a little melted isinglass into a glass of wine, which you say contains tannin?

Mrs. B. Yes. I have prepared a solution of isinglass for that very purpose.—Do you observe the thick muddy precipitate?—That is the tannin combined with the isinglass.

Caroline. This precipitate must then be of the same nature as leather?

Mrs. B. It is composed of the same ingredients; but the organization and the texture of the skin being wanting, it has neither the consistence nor the tenacity of leather.

Caroline. One might suppose that men who drink large quantities of red wine, stand a chance of having the coats of their stomachs converted into leather, since tannin has so strong an affinity for skin.

Mrs. B. It is not impossible but that the coats of their stomachs may be, in some measure, tanned, or hardened by the constant use of this liquor; but you must remember that where a number of other chemical agents are concerned, and, above all, where life exists, no certain chemical inference can be drawn.

I must not dismiss this subject, without mentioning a very recent discovery of Mr. Hatchett which relates to it. This gentleman found that a substance very similar to tannin, possessing all its leading properties, and actually capable of tanning leather, may be produced by exposing carbone, or any substance containing carbonaceous matter, whether vegetable, animal, or mineral, to the action of nitric acid.

Caroline. And is not this discovery very likely to be of great use to manufactures?

Mrs. B. That is very doubtful; because tannin, thus artificially prepared, must probably always be more expensive than that which is obtained from bark. But the fact is extremely curious, as it affords one of those very rare instances of chemistry being able to imitate the proximate principles of organized bodies.

The last of the vegetable materials is *woody fibre;* it is the hardest part of plants. The chief source from which this substance is derived is wood, but it is also contained, more or less, in every solid part of the plant. It forms a kind of skeleton of the part to which it belongs, and retains its shape after all the other materials have disappeared. It consists chiefly of carbone united with a small proportion of salts and the other constituents common to all vegetables.

Emily. It is of woody fibre, then, that the common charcoal is made?

Mrs. B. Yes. Charcoal, as you may recollect, is obtained from wood, by the separation of all its evaporable parts.

Before we take leave of the vegetable materials, it will be proper, at least, to enumerate the several vegetable acids which we either have had, or may have occasion to mention. I believe I have formerly told you that their basis, or radical, was uniformly composed of hydrogen and carbone, and that their difference consisted only in the various proportions of oxygen which they contained.

The following are the names of the vegetable acids:

The *Mucous Acid*,	obtained from gum, or mucilage;
Suberic, - -	from cork;
Camphoric, - - - -	from champhor;
Benzoic, - - - -	from balsams;
Gallic, - - - -	from galls, bark, &c.
Malic, - - - -	from ripe fruits;
Citric, - - - -	from lemon juice;
Oxalic, - - - -	from sorrel;
Succinic, - - - -	from amber;
Tartarous, - - -	from tartrit of potash;
Acetic, - - - -	from vinegar.

They are all decomposable by heat, soluble in water, and turn vegetable blue colours red. The *succinic*, the *tartarous*, and the *acetous acids*, are the products of the decomposition of vegetables; we shall, therefore, reserve their examination for a future period.

The *oxalic acid*, distilled from sorrel, is the highest term of vegetable acidification; for, if more oxygen be added to it, it loses its vegetable nature, and is resolved into carbonic acid and water; therefore, though all the other acids may be converted into the oxalic by an addition of oxygen, the oxalic itself is not susceptible of a farther degree of oxygenation ; nor can it be made, by any chemical process, to return to a state of lower acidification.

To conclude this subject, I have only to add a few words on the *gallic acid* . . . .

Caroline. Is not this the same acid before mentioned, which forms ink, by precipiating sulphat of iron from its solution ?

Mrs. B. Yes. Though it is usually extracted from galls, on account of its being most abundant in that vegetable substance, it may also be obtained from a great variety of plants. It constitutes what is called the *astringent principle* of vegetables ; it is generally combined with tannin, and you will find that an infusion of tea, coffee, bark, red wine, or any vegetable substance that contains the astringent principle, will make a black precipitate with a solution of sulphat of iron.

Caroline. But pray what are galls ?

Mrs. B. They are excrescences which grow on the bark of young oaks, and are occasioned by an insect which wounds the bark of trees, and lays its egg in the aperture. The lacerated vessels of the tree then discharge their contents, and form an excrescence which affords a defensive covering for these eggs. The insect, when come to life, first feeds on this excrescence, and some time afterwards eats its way out, as it appears from a hole found in all gall-nuts that no longer contain an insect. It is in hot climates only that strongly astringent gall-nuts are found ; those which are used for the purpose of making ink are brought from Aleppo.

Emily. But are not the oak-apples which grow on the leaves of the oak in this country, of a similar nature ?

Mrs. B. Yes ; only they are an inferior species of galls, containing less of the astringent principle, and therefore less applicable to useful purposes.

Caroline. Are the vegetable acids never found but in their pure uncombined state ?

Mrs. B. By no means ; on the contrary, they are frequently met with in the state of compound salts; these, however, are in general not fully saturated with the salifiable bases, so that the acid predominates, and in this state they are called *acidulous* salts. Of this kind is the salt called cream of tartar.

Caroline. Is not the salt of lemon commonly used to take out ink spots and stains, of this nature?

Mrs. B. No; that salt consists merely of the citric acid reduced to the state of crystals.

Caroline. And pray how does it take out ink spots?

Mrs. B. By decomposing the black precipitate, and rendering it soluble in water. But the display of attractions by which this is performed is, I believe, not exactly ascertained.

Besides the vegetable materials which we have enumerated, a variety of other substances, common to the three kingdoms, are found in vegetables, such as potash, which was formerly supposed to belong exclusively to plants, and was in consequence called the vegetable alkali.

Sulphur, phosphorus, earths, and a variety of metallic oxyds, are also found in vegetables, but only in small quantities. And we meet sometimes with neutral salts formed by the combination of these ingredients.

Conversation XVIII.

On the decomposition of Vegetables.

Caroline.

THE account which you have given us, Mrs. B. of the materials of vegetables, is doubtless, very instructive ; but it does not completely satisfy my curiosity.— I wish to know how plants obtain the principles from which their various materials are formed ; by what means these are converted into vegetable matter, and how they are connected with the life of the plant ?

Mrs. B. This implies nothing less than a complete history of the chemistry and physiology of vegetation, subjects on which we have yet but very imperfect notions. Still I hope that I shall be able, in some measure, to satisfy your curiosity. But in order to render the subject more intelligible, I must first make you acquainted with the various changes which vegetables undergo, when the vital power no longer enables them to resist the common laws of chemical attraction.

The composition of vegetables being more complicated than that of minerals, the former more readily undergo chemical changes than the latter : for the greater the variety of attractions, the more easily is the equilibrium destroyed, and a new order of combinations introduced.

Emily. I am surprised that vegetables should be so easily suceptible of decomposition ; for the preservation of the vegetable kingdom is certainly far more important than that of minerals.

Mrs. B. You must consider, on the other hand, how much more easily the former is renewed than the latter. The decomposition of the vegetable takes place only after the death of the plant, which, in the common course of nature, happens when it has yielded fruit and seeds to propagate its species. If instead of thus finishing its career, each plant was to retain its form and vegetable state, it would become an uesless burden to the earth and its inhabitants.—When vegetables, therefore, cease to be productive, they cease to live, and Nature then begins her process of decomposition, in order to dissolve them into their chemical constituents, hydrogen, carbone, and oxygen ; those simple and primitive ingredients which she keeps in store for all her combinations.

Emily. But since no system of combination can be destroyed, except by the establishment of another order of attractions, how can the decomposition of vegetables reduce them to their simple elements?

Mrs. B. It is a very long process, during which a variety of new combinations are successively established and successively destroyed; but, in each of these changes, the ingredients of vegetable matter tend to unite in a more simple order of compounds, till they are at length brought to their elementary state, or at least, to their most simple order of combinations. Thus you will find that vegetables are in the end almost entirely reduced to water and carbonic acid; the hydrogen and carbone dividing the oxygen between them, so as to form with it these two substances. But the variety of intermediate combinations that take place during the several stages of the decomposition of vegetables, present us with a new set of compounds, well worthy of our examination.

Caroline. How is it possible that vegetables, while putrefying, should produce any thing worthy of observation?

Mrs. B. They are susceptible of undergoing certain changes before they arrive at the state of putrefaction, which is the final term of decomposition; and of these changes we avail ourselves for particular and important purposes. But, in order to make you understand this subject, which is of considerable importance, I must explain it more in detail.

The decomposition of vegetables is always attended by a violent internal motion, produced by the disunion of one order of particles, and the combination of another. This is called *fermentation.*—There are several periods at which fermentation stops, so that a state of rest appears to be restored, and the new order of compounds fairly established. But, unless means be used to secure these new combinations in their actual state, their duration will be but transient, and a new fermentation will take place, by which the compound last formed will be destroyed; and another, and less complex order will succeed.

Emily. The fermentation, then, appears to be only the successive steps by which a vegetable descends to its final dissolution.

Mrs. B. Precisely so. Your definition is perfectly correct.

Caroline. And how many fermentations, or new arrangements, does a vegetable undergo before it is reduced to its simple ingredients?

Mrs. B. Chemists do not exactly agree in this point; but there are, I think, four distinct fermentations, or periods, at which the decomposition of vegetable matter stops and changes its course. But every kind of vegetable matter is not equally susceptible of undergoing all these fermentations.

There are likewise several circumstances required to produce fermentation. Water, and a certain degree of heat are both essential to this process, in order to separate the particles, and thus weaken their force of cohesion, that the new chemical affinities may be brought into action.

Caroline. In frozen climates, then, how can the spontaneous decomposition of vegetables take place?

Mrs. B. It certainly cannot; and, accordingly, we find scarcely any vestiges of vegetation where a constant frost prevails.

Caroline. One would imagine that, on the contrary, such spots would be covered with vegetables; for, since they cannot be decomposed, their numbers must always increase.

Mrs. B. But, my dear, heat and water are quite as essential to the formation of vegetables as they are to their decomposition. Besides, it is from the dead vegetables reduced to their elementary principles, that the rising generation is supplied with sustenance. No young plant, therefore, can grow, unless its predecessors contribute both to its formation and support; and these not only furnish the seed from which the new plant springs, but likewise the food by which it is nourished.

Caroline. Under the torrid zone, therefore, where water is never frozen, and the heat is very great, both the processes of vegetation and fermentation must, I suppose, be extremely rapid?

Mrs. B. Not so much as you imagine; for in such climates great part of the water which is requisite for these processes is in an aeriform state, which is scarcely more conducive either to the growth or formation of vegetables than that of ice. In those latitudes, therefore, it is only in low damp situations, sheltered by woods from the sun's rays, that the smaller tribes of vegetables can grow and thrive during the dry season, as dead vegetables seldom retain water enough to produce fermentation, but are, on the contrary, soon dried up by the heat of the sun, which enables them to resist that process; so that it is not till the fall of the autumnal rains (which are very violent in such climates), that spontaneous fermentation can take place.

The several fermentations derive their names from their principal products. The first is called the *saccharine fermentation*, because its product is *sugar*.

Caroline. But sugar, you have told us, is found in all vegetables; it cannot, therefore, be the product of their decomposition.

Mrs. B. It is true that this fermentation is not confined to the decomposition of vegetables, as it continually takes place during their life; and indeed this circumstance has, till lately prevented it from being considered as one of the fermentations. But the process appears so analogous to the other fermentations, and the formation of sugar, whether in living or dead vegetable matter, is so evidently a new compound, proceeding from the destruction of the previous order of combinations, and essential to the subsequent fermentations, that it is now esteemed the first step, or necessary preliminary, to decomposition, if not an actual commencement of that process.

Caroline. I recollect your hinting to us that sugar was supposed not to be secreted from the sap, in the same manner as mucilage, fecula, oil, and the other ingredients of vegetables.

Mrs. B. It is rather from these materials, than from the sap itself, that sugar is formed; and it is developed at particular periods, as you may observe in fruits, which become sweet in ripening, sometimes even after they have been gathered. Life, therefore, is not essential to the formation of sugar, whilst, on the contrary, mucilage, fecula, and the other vegetable materials that are secreted from the sap by appropriate organs, whose powers immediately depend on the vital principle, cannot be produced but during the existence of that principle.

Emily. The ripening of fruits is, then, their first step to destruction, as well as their last towards perfection?

Mrs. B. Exactly.—The saccharine fermentation frequently takes place also during the cooking of vegetables. This is the case with parsnips, carrots, potatoes, &c. in which, sweetness is developed by heat and moisture; and we know that if we carried the process a little farther, a more complete decomposition would ensue. The same process takes place also in seeds previous to their sprouting.

Caroline. How do you reconcile this to your theory, Mrs. B.? Can you suppose that a decomposition is the necessary precursor of life?

Mrs. B. That is indeed the case. The materials of the seed must be decomposed, and the seed disorganized, before a plant can sprout from it.—Seeds, besides the embryo plant, contain (as we have already observed), fecula, oil, and a little mucilage. These substances are destined for the nourishment of the future plant; but they must undergo some change before they can be fit for this function. The seeds, when buried in the earth, with a certain degree of moisture and of temperature, absorb water, which dilates them, separates their particles, and introduces a new order of attractions, of which sugar is the product. The substance of the seed is thus softened, sweetened, and converted into a sort of white milky pulp, fit for the nourishment of the embryo plant.

The saccharine fermentation of seeds is artificially produced, for the purpose of making *malt*, by the following process: A quantity of barley is first soaked in water for two or three days; the water being afterwards drained off, the grain heats spontaneously, swells, bursts, sweetens, shews a disposition to germinate, and would actually sprout, if the process was not stopped by putting it into a kiln, where it is well dried at a gentle heat. In this state it is crisp and friable, and constitutes the substance called *malt*, which is the principal ingredient of beer.

Emily. But I hope you will tell us how malt is made into beer?

Mrs. B. Certainly; but I must first explain to you the nature of the second fermentation, which is essential to that operation. This is called the *vinous fermentation*, because its product is *wine*.

Emily. How very different the decomposition of vegetables is from what I had imagined. The products of their disorganization appear almost superior to those which they yield during their state of life and perfection.

Mrs. B. And do you not at the same time, admire the beautiful economy of Nature, which, whether she creates, or whether she destroys, directs all her operations to some useful and benevolent purpose? It appears that the saccharine fermentation is essential, as a previous step, to the vinous fermentation; so that if sugar be not developed during the life of the plant, the sacharine fermentation must be artificially produced before the vinous fermentation can take place. This is the case with barley, which does not yield any sugar until it is made into malt; and it is in that state only that it is susceptible of undergoing the vinous fermentation by which it is converted into beer.

Caroline. But if the product of the vinous fermentation is always wine, beer cannot have undergone that process; for beer is certainly not wine.

Mrs. B. Chemically speaking, beer may be considered as the wine of grain. For it is the product of the fermentation of malt, just as wine is that of the fermentation of grapes, or other fruits.

The consequence of the vinous fermentation is the decomposition of the saccharine matter, and the formation of a spirituous liquor from the constituents of the sugar. But, in order to promote this fermentation, not only water and a certain degree of heat are necessary, but also some other vegetable ingredients, besides the sugar, as fecula, mucilage, acids, salts, extractive matter, &c. all of which seem to contribute to this process.

Emily. It is, perhaps, for this reason, that wine is not obtained from the fermentation of pure sugar; but that fruits are chosen for that purpose, as they contain not only sugar, but likewise the other vegetable ingredients which are requisite to promote the vinous fermentation.

Mrs. B. Certainly. And you must observe also, that the relative quantity of sugar is not the only circumstance to be considered in the choice of vegetable juices for the formation of wine; otherwise the sugar-cane would be best adapted for that purpose. It is rather the manner and proportion in which the sugar is mixed with other vegetable ingredients that influences the production and qualities of wine. And it is found that the juice of the grape not only yields the most considerable proportion of wine, but that it likewise affords it of the most grateful flavour.

Emily. I have seen a vintage in Switzerland, and I do not recollect that heat was applied, or water added, to produce the fermentation of the grapes.

Mrs. B. The common temperature of the atmosphere, in the cellars in which the juice of the grape is fermented, is sufficiently warm for this purpose; and, as the juice contains an ample supply of water, there is no occasion for any addition of it.—But when fermentation is produced in dry malt, a quantity of water must necessarily be added.

Emily. But what are precisely the changes that happen during the vinous fermentation?

Mrs. B. The sugar is decomposed, and its constituents are recombined into two new substances; the one a peculiar liquid substance, called *alcohol* or *spirit of wine*, which remains in the fluid; the other, carbonic acid gas, which escapes during the fermentation. Wine, therefore, in a general point of view, may be considered as a liquid of which alcohol constitutes the essential part. And the varieties of strength and flavour of the different kinds of wine are to be attributed to the different qualities of the fruits from which they are obtained, independently of the sugar, without which no wine can be produced.

Caroline. I am astonished to hear that so powerful a liquid as spirits of wine should be obtained from so mild a substance as sugar!

Mrs. B. Can you tell me in what the principal difference consists between alcohol and sugar?

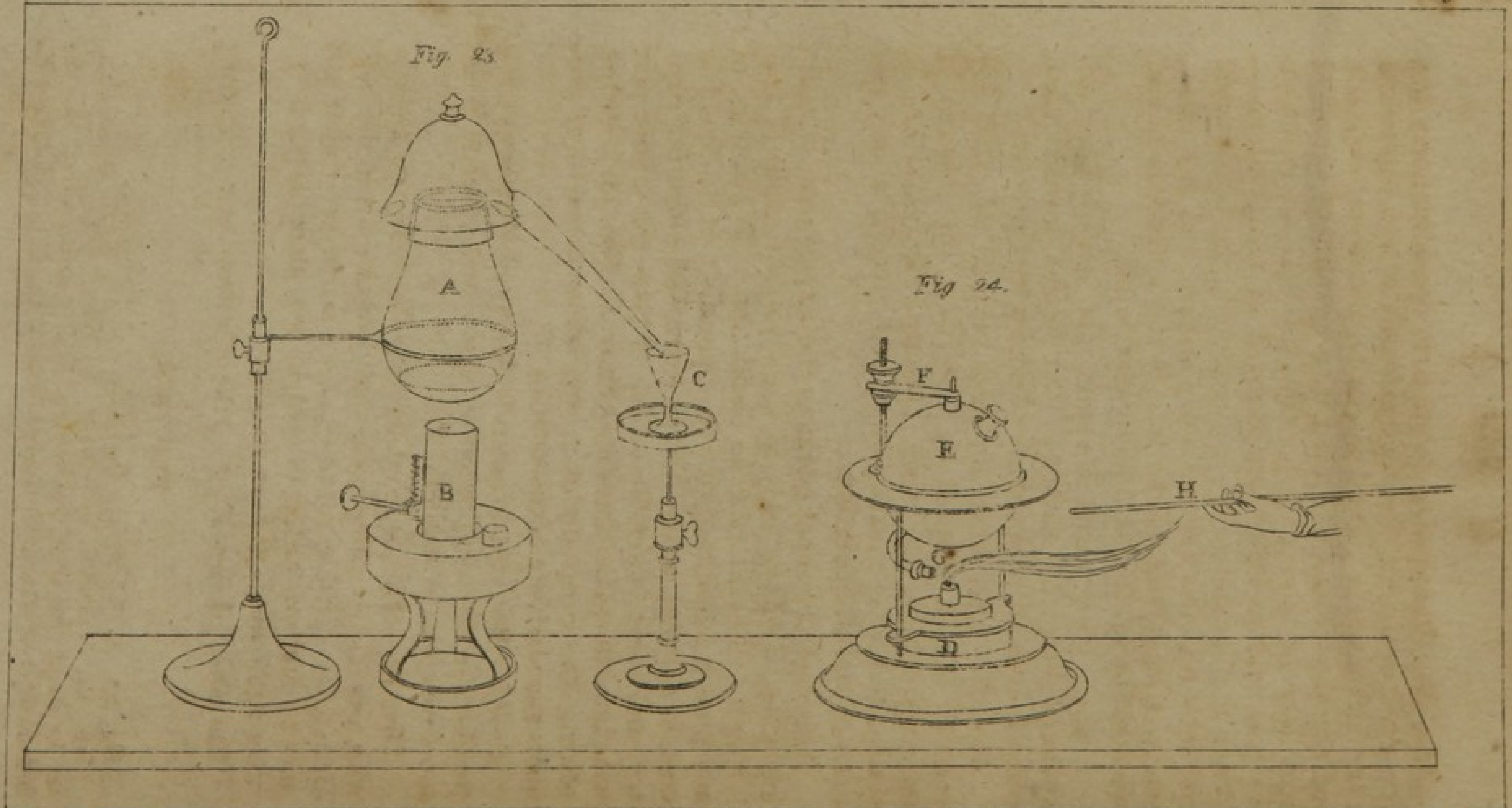
Caroline. Let me reflect . . . . Sugar consists of carbone, hydrogen, and oxygen. If carbonic acid be subtracted from it, during the formation of alcohol, the latter will contain less carbone and oxygen than sugar does; therefore hydrogen must be the prevailing principle of alcohol.

Mrs. B. It is exactly so. And this very large proportion of hydrogen accounts for the lightness and combustible property of alcohol, and of spirits in general, all of which consist of alcohol variously modified.

Emily. And can sugar be recomposed from the combination of alcohol and carbonic acid?

Mrs. B. Chemists have never been able to succeed in effecting this; but from analogy, I should suppose such a recomposition possible. Let us now observe more particularly the phenomena that take place during the vinous fermentation. At the commencement of this process, heat is evolved, and the liquor swells considerably from the formation of the carbonic acid, which is disengaged in such prodigious quantities as to be often prejudicial to the vintagers. If the fermentation be stopped by putting the liquor into barrels, before the whole of the carbonic acid is evolved, the wine is brisk, like Champagne, from the carbonic acid imprisoned in it, and it tastes sweet like cider, from the sugar not being completely decomposed.

Emily. But I do not understand why heat should be evolved during this operation. For, as there is a considerable formation of gas, in which a proportionable quantity of heat must become insensible, I should have imagined that cold, rather than heat, would have been produced.



Drawn by the Author Doolittle Sc.

Engraved for Increase Cooke & C.o New Haven.

Mrs. B. It appears so on first consideration; but you must recollect that fermentation is a complicated chemical process; and that, during the decompositions and recompositions attending it, a quantity of chemical heat may be disengaged, sufficient both to develope the gas, and to effect an increase of temperature.— When the fermentation is completed, the liquid cools and subsides, the effervescence ceases, and the thick, sweet, sticky juice of the fruit is converted into a clear transparent spirituous liquor called wine.

Emily. How much I regret not having been acquainted with the nature of the vinous fermentation, when I had an opportunity of seeing the process!

Mrs. B. You have an easy method of satisfying yourself in that respect by observing the process of brewing, which, in every essential circumstance, is similar to that of making wine, and is really a very curious chemical operation.

Although I cannot perform the experiment of making wine, it will be easy to shew you the mode of analyzing it. This is done by distillation. When wine of any kind is submitted to this operation, it is found to contain brandy, water, tartar, extractive colouring matter, and some vegetable acids. I have put a little port wine into this glass alembic (*Plate X. Fig.* 23.) and on placing the lamp under it, you will soon see these products successively come over—

Emily. But you do not mention alcohol amongst the products of the distillation of wine; and yet that is its most essential ingredient.

Mrs. B. The alcohol is contained in the brandy which is now coming over, and dropping from the still. Brandy is nothing more than a mixture of alcohol and water; and in order to obtain the alcohol pure, we must again distil it from brandy.

Caroline. I have just taken a drop on my finger;

PLATE X.

Fig. 23. A. Alembic. B. Lamp. C. Wine glass.

Fig 24 Alcohol blow-pipe. D. The Lamp. E. The vessel in which the alcohol is boiling. F. A safety valve. G. The inflamed jet or stream of alcohol directed towards a glass tube H.

it tastes like strong brandy, but it is without colour, whilst brandy is of a deep yellow.

Mrs. B. It is not so naturally ; in its pure state brandy is colourless, and it obtains the yellow tint you observe by extracting the colouring matter from the new oaken casks in which it is kept.

But if it does not acquire the usual tinge this way, it is the custom to colour the brandy used in this country artificially, in order to give it the appearance of having been long kept.

Caroline. And is rum also distilled from wine ?

Mrs. B. By no means ; it is distilled from the sugar-cane, a plant which contains so great a quantity of sugar, that it yields more alcohol than almost any other vegetable. Previous to the distillation of the spirit, the sugar-cane is made to undergo the vinous fermentation, which the other ingredients of the plant are just sufficient to promote.

The spirituous liquor called *arack*, is in a similar manner distilled from the product of the vinous fermentation of rice.

Emily. But rice has no sweetness ; does it contain any sugar ?

Mrs. B. Like barley and most other seeds, it is insipid until it has undergone the saccharine fermentation ; and this, you must recollect, is always a previous step to the vinous fermentation in those vegetables in which sugar is not already formed. Brandy may in the same manner be obtained from malt.

Caroline. You mean from beer, I suppose ; for the malt must have previously undergone the vinous fermentation.

Mrs. B. Beer is not precisely the product of the vinous fermentation of malt. For hops are a necessary ingredient for the formation of that liquor ; whilst brandy is distilled from pure fermented malt. But brandy might, no doubt, be distilled from beer as well as from any other liquor that has undergone the vinous fermentation ; for since the basis of brandy is alcohol, it may be obtained from any liquid that contains that spirituous substance.

Emily. And pray, from what vegetable is the favorite spirit of the lower orders of people, gin, extracted?

Mrs. B. The spirit (which is the same in all fermented liquors) may be obtained from any kind of grain; but the peculiar flavour which distinguishes gin, is that of juniper berries, which are distilled together with the grain—

I think the brandy contained in the wine which we are distilling, must, by this time, be all come over. Yes—taste the fluid that is now dropping from the alembic—

Caroline. It is perfectly insipid, like water.

Mrs. B. It is water, which, as I was telling you, is the second product of wine, and comes over after all the spirit, which is the lightest part, is distilled. The tartar and extractive colouring matter we shall find in a solid form at the bottom of the alembic.

Emily. they look very like the lees of wine.

Mrs. B. And in many respects they are of a similar nature; for lees of wine consist chiefly of tartrit of potash, a salt which exists in the juice of the grape, and in many other vegetables, and is developed only by the vinous fermentation. During this operation it is precipitated, and deposites itself on the internal surface of the cask in which the wine is contained. It is much used in medicine under the name of *cream of tartar*, and it is from this salt that the tartarous acid is obtained.

Caroline. But the medicinal cream of tartar is in appearance quite different from these dark coloured dregs; it is perfectly colourless.

Mrs. B. Because it consists of the pure salts only, in its crystallized form; whilst in the instance before us it is mixed with the deep-coloured extractive matter and other foreign ingredients.

Emily. Pray cannot we now obtain pure alcohol from the brandy which we have distilled?

Mrs. B. We might: but the process would be tedious: for in order to obtain alcohol perfectly free from water, it is necessary to distil, or as the distillers call it *rectify* it several times. You must therefore allow me to produce a bottle of alcohol that has been thus purified. This is a very important ingredient, which has many striking properties, besides its forming the basis of all spirituous liquors.

Emily. It is alcohol, I suppose, that produces intoxication ?

Mrs. B. Certainly ; but the stimulus and momentary energy it gives to the system, and the intoxication it occasions when taken in excess, are circumstances not yet accounted for.

Caroline. I thought that it produced these effects by increasing the rapidity of the circulation of the blood ; for drinking wine or spirits, I have heard always quickens the pulse.

Mrs. B. No doubt ; the spirit by stimulating the nerves, increases the action of the muscles ; and the heart, which is one of the strongest muscular organs, beats with augmented vigour and propels the blood with accelerated quickness. After such strong excitation the frame naturally suffers a proportional degree of depression, so that a state of debility and languor are the invarible consequences of intoxication. But though these circumstances are well ascertained, they are far from explaining why alcohol should produce such effects.

Emily. Liqueurs are the only kind of spirits which I think pleasant. Pray of what do they consist ?

Mrs. B. They are composed of alcohol, sweetened with syrup, and flavoured with volatile oil.

The different kinds of odoriferous spirituous waters are likewise solutions of volatile oil in alcohol, as lavender water, eau de Cologne, &c.

The chemical properties of alcohol are important and numerous. It is one of the most powerful chemical agents, and is particularly useful in dissolving a variety of substances which are soluble neither by water nor heat.

Emily. We have seen it dissolve copal and mastic to form varnishes ; and these resins are certainly not soluble in water, since water precipitates them from their solution in alcohol.

Mrs. B. I am happy to find that you recollect these circumstances so well. The same experiment affords also an instance of another property of alcohol, its tendency to unite with water; for the resin is precipitated in consequence of losing the alcohol, which abandons it from its preference for water. We do not, however, consider the union of alcohol and water, as the effect of chemical combination, but rather as a simple solution, similar to that of sulphuric acid and water; it is attended also, as you may recollect, with the same peculiar circumstance of a disengagement of heat and consequent diminution of bulk, which we have supposed to be produced by a mechanical penetration of particles by which latent heat is forced out.

Alcohol unites thus readily not only with resins and with water, but with oils and balsams; these compounds form the extensive class of elixirs, tinctures, quintescences. &c.

Emily. I suppose that alcohol must be highly combustible, since it contains so large a proportion of hydrogen?

Mrs. B. Extremely so; and it will burn at a very moderate temperature.

Caroline. I have often seen both brandy and spirit of wine burnt; they produce a great deal of flame, but not a proportional quantity of heat, and no smoke whatever.

Mrs. B. The last circumstance arises from their combustion being complete; and the disproportion between the flame and heat shows you that these are by no means synonimous.

The great quantity of flame proceeds from the combustion of the hydrogen, to which, you know, that manner of burning is peculiar.—Have you not remarked also, that brandy and alcohol will burn without a wick? They take fire at so low a temperature, that this assistance is not required to concentrate the heat and volatilize the fluid.

Caroline. I have sometimes seen brandy burnt by merely heating it in a spoon.

Mrs. B. The rapidity of the combustion of alcohol may, however, be prodigiously increased by volatilizing it. An ingenious instrument has been constructed on this principle to answer the purpose of a blow-pipe, which may be used for melting glass or other chemical purposes. It consists of a small metallic vessel (*Plate* X. *Fig.* 24.) of a spherical shape, which contains the alcohol, and is heated by the lamp beneath it; as soon as the alcohol is volatilized, it passes through the spout of the vessel, and issues just above the wick of the lamp, which immediately sets fire to the stream of vapour, as I shall shew you—

Emily. With what amazing violence it burns! The flame of alcohol in the state of vapour, is, I fancy, much hotter than when the spirit is merely burnt in a spoon?

Mrs. B. Yes; because in this way the combustion goes on much quicker, and, of course, the heat is proportionally increased.—Observe its effect on this small glass tube, the middle of which I present to the exremity of the flame, where the heat is greatest.

Caroline. The glass, in that spot, is become red hot, and bends from its own weight.

Mrs. B. I have now drawn it asunder, and am going to blow a ball at one of the heated ends; but I must previously close it up, and flatten it with a little metallic instrument, otherwise the breath would pass through the tube without dilating any part of it. Now, Caroline, will you blow strongly into the tube whilst the closed end is red hot?

Emily. You blowed too hard; for the ball suddenly dilated to a great size, and then burst in pieces.

Mrs. B. You will be more expert another time; but I must caution you, should you ever use this blow-pipe, to be very careful that the combustion of the alcohol does not go on with too great violence, for I have seen the flame sometimes dart out with such force as to reach the opposite wall of the room, and set the paint on fire. There is, however, no danger of the vessel bursting, as it is provided with a safety tube, which affords an additional vent for the vapour of alcohol when required.

The products of the combustion of alcohol consist in a great proportion of water, and a small quantity of carbonic acid. There is no smoke or fixed remains whatever. How do you account for that, Emily?

Emily. I suppose that the oxygen which the alcohol absorbs in burning, converts its hydrogen into water, and its carbone into carbonic acid gas; and thus it is completely consumed.

Mrs. B. Very well.—*Ether*, the lighest of all fluids, and with which you are well acquainted, is obtained from alcohol, of which it forms the lightest and most volatile part.

Emily. Ether, then, is to alcohol, what alcohol is to brandy?

Mrs. B. No: there is an essential difference. In order to obtain alcohol from brandy, you need only deprive the latter of its water; but for the formation of ether, the alcohol must be decomposed, and one of its constituents partly subtracted. I leave you to guess which of them it is—

Emily. It cannot be hydrogen, as ether is more volatile than alcohol, and hydrogen is the lightest of all its ingredients: nor do I suppose that it can be oxygen, as alcohol contains so small a proportion of that principle; it is therefore, most probably carbone, a diminution of which would not fail to render the new compound more volatile.

Mrs. B. You are perfectly right. The formation of ether consists simply in subtracting from the alcohol a certain proportion of carbone; this is effected by the action of the sulphuric, nitric, or muriatic acids on alcohol. The acid and carbone remain at the bottom of the vessel, whilst the decarbonized alcohol flies off in the form of a condensable vapour, which is ether.

Ether is the most inflamable of all fluids, and burns at so low a temperature that the heat evolved during its combustion is more than is required for its support, so that a quantity of ether is volatilized, which takes fire, and gradually increases the violence of the combustion.

This spirituous fluid is so light that it evaporates at the common temperature of the atmosphere, it is therefore necessary to keep it confined by a well ground glass stopper. No degree of cold known has ever frozen it.

Caroline. Is it not often taken medicinally ?

Mrs. B. Yes ; it is one of the most effectual antispasmodic medicines, and the quickness of its effects, as such, probably depends on its being instantly converted into vapour by the heat of the stomach, through the intervention of which it acts on the nervous system. But the frequent use of ether, like that of spirituous liquors, becomes prejudicial, and, if taken to excess, it produces effects similar to those of intoxication.

We may now take our leave of the vinous fermentation, of which I hope, you have acquired a clear idea ; as well as of the several products that are derived from it.

Caroline. Though this process appears at first sight so much complicated, it may, I think, be summed up in few words, as it consists simply in the conversion of sugar into alcohol and carbonic acid, which gives rise both to the formation of wine, and of all kinds of spirituous liquors.

Mrs. B. We shall now proceed to the *acetous fermentation*, which is thus called, because it converts wine into vinegar, by the formation of the acetous acid, which is the basis or radical of vinegar.

Caroline. But is not the acidifying principle of the acetous acid the same as that of all other acids, oxygen ?

Mrs. B. Certainly ; and on that account the contact of air is essential to this fermentation, as it affords the necessary supply of oxygen. Vinegar, in order to obtain pure acetous acid from it, must be distilled and rectified by certain processes ; and the more frequently this operation is repeated, the more perfect the acid will be.

Emily. But pray, Mrs B. is not the acetous acid frequently formed without this fermentation taking place ? Is it not, for instance, contained in acid fruits, and in every substance that becomes sour ?

Mrs. B. No, not in fruits ; you confound it with the citric, the malic, the oxalic, and other vegetable acids, to which living vegetables owe their acidity. But whenever a vegetable substance turns sour, after it has ceased to live, the acetous acid is developed by means of the acetous fermentation, in which the substance advances a step towards its final decomposition.

Amongst the various instances of acetous fermentation, that of bread is usually classed.

Caroline. But the fermentation of bread is produced by yeast; how does that effect it?

Mrs. B. It is found by experience that any substance that has already undergone a fermentation, will readily excite it in one that is susceptible of that process. If, for instance, you mix a little vinegar with wine that is intended to be acidified, it will absorb oxygen more rapidly, and the process be completed much sooner that if left to ferment spontaneously. Thus, yeast, which is a product of the fermentation of beer, is used to excite and accelerate the fermentation of malt, which is to be converted into beer, as well as that of paste that is to be made into bread.

Caroline. But if bread undergoes the acetous fermentation, why is it not sour?

Mrs. B. It acquires a certain savour which corrects the heavy insipidity of flour, and may be reckoned a first degree of acidification; for if the process was carried farther, the bread would become decidedly acid.

There are, however, some chemists who do not consider the fermentation of bread as being of the acetous kind, but suppose that it is a process of fermentation peculiar to that substance.

The *putrid fermentation* is the final operation of Nature, and her last step towards reducing organized bodies to their simplest combinations. All vegetables spontaneously undergo this fermentation after death, provided there be a sufficient degree of heat and moisture, together with access of air; for it is well known that dead plants may be preserved by drying, or by the total exclusion of air.

Caroline. But do dead plants undergo the other fermentations previous to this last; or do they immediately suffer the putrid fermentation?

Mrs. B. That depends on a variety of circumstances, such as the degrees of temperature and of moisture, the nature of the plant itself, &c. But, if you were carefully to follow and examine the decomposition of plants from their death to their final dissolution, you would generally find a sweetness developed in the seeds, and a spirituous flavour in the fruits, (which have undergone the saccharine fermentation), previous to the total disorganization and separation of the parts.

Emily. I have sometimes remarked a kind of spirituous taste in fruits that were over ripe, especially oranges ; and this was just before they became rotten.

Mrs. B. It was then the vinous fermentation which had succeeded the saccarine, and had you followed up these changes attentively, you would probably have found the spirituous taste followed by acidity, previous to the fruit passing to the state of putrefaction.

When the leaves fall from the trees in autumn, they do not (if there is no great moisture in the atmosphere) immediately undergo a decomposition, but are first dried and withered ; as soon, however, as the rain sets in, fermentation commences, their gaseous products are impercepibly evolved into the atmosphere, and their fixed remains mixed with their kindred earth.

Wood, when exposed to moisture, also undergoes the putrid fermentation and becomes rotten.

Emily. But I have heard that the *dry rot*, which is so liable to destroy the beams of houses, is prevented by a current of air ; and yet you said that air was essential to the putrid fermentation ?

Mrs. B. True ; but it must not be in such a proportion to the moisture as to dissolve the latter, and this is generally the case when the rotting of wood is prevented or stopped by the free access of air.—What is commonly dry rot, however, is not, I believe, a true process of putrefaction. It is supposed to depend on a peculiar kind of vegetation, which, by feeding on the wood, gradually destroys it.

Straw and all other kinds of vegetable matter undergo the putrid fermentation much more rapidly when mixed with animal matter. Much heat is evolved during this process, and a variety of volatile products are disengaged, as carbonic acid and hydrogen gas, the latter of which is frequently either sulphurated or phosphorated. When all these gasses have been evolved, the fixed products consisting of carbone, salts, potash, &c. form a kind of vegetable earth, which makes very fine manure, as it is composed of those elements which form the immediate materials of plants.

Caroline. Pray are not vegetables sometimes preserved from decomposition be petrifaction ? I have seen very curious specimens of petrified vegetables, in which state they perfectly preserve their form and organization, though in appearance they are changed to stone.

Mrs. B. That is a kind of metamorphosis, which, now that you are tolerably well versed in history of mineral and vegetable substances, I leave to your judgment to explain. Do you imagine that vegetables can be converted into stone ?

Emily. No certainly ; but they might perhaps be changed to a substance in appearance resembling stone.

Mrs. B. It is not so, however, with the substances that are called petrified vegetables ; for these are really stone, and generally of the hardest kind, consisting chiefly of silex. The case is this : when a vegetable is buried under water, or in wet earth, it is slowly and gradually decomposed. As each successive particle of the vegetable is destroyed, its place is supplied by a particle of silicious earth, conveyed thither by the water. In the course of time the vegetable is entirely destoyed, but the silex has completely replaced it, having assumed its form and apparent texture, as if the vegetable itself were changed to stone.

Caroline. That is very curious ! and I suppose that petrified animal substances are of the same nature ?

Mrs. B. Precisely. It is equally impossible for either animal or vegetable substances to be converted into stone. They may be reduced, as we find they are, by decomposition, to their constituent elements, but cannot be changed to elements, which do not enter into their composition.

There are, however, circumstances which frequently prevent the regular and final decomposition of vegetables; as, for instance, when they are buried either in the sea, or in the earth, where they cannot undergo the putrid fermentation for want of air. In these cases they are subject to a peculiar change, by which they are converted into a new class of compounds, called *bitumens.*

Caroline. These are substances I never heard of before.

Mrs. B. You will find, however, that some of them are very familiar to you. Bitumens are vegetables so far decomposed as to retain no organic appearance; but their origin is easily detected by their oily nature, their combustibility, the products of their analysis, and the impressions of the forms of leaves, grains fibres of wood, and even of animals, which they frequently bear.

They are sometimes of an oily liquid consistence, as the substance called *naphtha,* which is a fine transparent colourless fluid, that issues out of clays in some parts of Persia. But more frequently they are solid as *asphaltum,* a smooth hard brittle substance, which easily melts, and forms, in its liquid state, a beautiful dark brown colour for oil painting. *Jet,* which is of a still harder texture, is a peculiar *bitumen,* susceptible of so fine a polish that it is used for many ornamental purposes.

Coal is also a bituminous substance, to the composition of which both the mineral and animal kingdoms seem to concur. This most useful mineral appears to consist chiefly of vegetable matter, mixed with remains of marine animals and marine salts, and occasionally containing a quantity of sulphuret of iron, commonly called pyrites.

Emily. It is, I suppose, the earthy, the metallic, and the saline parts of coals, that compose the cinders or fixed products of their combustion; whilst the hydrogen and the carbone, which they derive from vegetables, constitute their volatile products.

Caroline. Pray is not *coak* (which I have heard is much used in some manufactures) also a bituminous substance?

Mrs. B. It is a kind of fuel artificially prepared from coals. It consists of coals reduced to a substance analogous to charcoal, by the evaporation of their volatile parts. Coak, therefore, is composed of carbone, with some earthy and saline ingredients.

Succin, or *yellow amber*, is a bitumen which the ancients called *electrum*, from whence the word electricity is derived, as that substance is peculiarly, and was once supposed to be exclusively electric. It is found either deeply buried in the bowels of the earth, or floating on the sea, and is supposed to be a resinous body which has been acted on by sulphuric acid, as its analysis shews it to consist of an oil and an acid. The oil is called *oil of amber*, the acid the *succinic*.

Emily. That oil I have sometimes used in painting, as it is reckoned to change less than the other kinds of oils.

Mrs. B. The last class of vegetable substances that have changed their nature are *fossil wood*, *peat*, and *turf*. These are composed of wood and roots of shrubs, that are partly decomposed by being exposed to moisture under ground, and yet, in some measure, preserve their form and organic appearance. The peat, or black earth of the moors, retains but few vestiges of the roots to which it owes its richness and combustibility, these substances being in the course of time reduced to the state of vegetable earth. But in turf the roots of plants are still discernable, and it equally answers the purpose of fuel. It is the combustible used by the poor in heathy countries, which supply it abundantly.

It is too late this morning to enter upon the history of vegetation. We shall reserve this subject, therefore, for our next interview, when I expect that it will furnish us with ample matter for another conversation.

Conversation XIX.

History of Vegetation.

Mrs. B.

The Vegetable Kingdom may be considered as the link which unites the mineral and animal creation into one common chain of beings; for it is through the means of vegetation alone that mineral substances are introduced into the animal system, since generally speaking it is from vegetables that all animals ultimately derive their sustenance.

Caroline. I do not understand that; the human species subsists as much on animal as on vegetable food, and there are some carnivorous animals that will eat only animal food.

Mrs. B. That is true; but you do not consider that those that live on animal food derive their sustenance equally, though not so immediately, from vegetables. The meat that we eat is formed from the herbs of the field, and the prey of carnivorous animals proceeds, either directly or indirectly, from the same source. It is therefore through this channel that the simple elements become a part of the animal frame. We should in vain attempt to derive nourishment from carbone, hydrogen, and oxygen, either in their separate state, or combined in the mineral kingdom; for it is only by being united in the form of vegetable combination, that they become capable of conveying nourishment.

Emily. Vegetation then, seems to be the method which nature employs to prepare the food of animals?

Mrs. B. That is certainly its principal object.—The vegetable creation does not exhibit more wisdom in that admirable system of organization, by which it is enabled to answer its own immediate ends of preservation, nutrition, and propagation, than in its grand and ulimate object of forming those arrangements and combinations of principles, which are so well adapted for the nourishment of animals.

Emily. But I am very curious to know whence vegetables obtain those principles, which form their immediate materials ?

Mrs. B. This is a point on which we are yet so much in the dark, that I cannot hope fully to satisfy your curiosity ; but what little I know on this subject, I will endeavour to explain to you.

The soil, which, at first view, appears to be the aliment of vegetables, is found, on a closer investigation, to be little more than the channel through which they receive their nourishment ; so that it is very possible to rear plants without any earth or soil.

Caroline. Of that we have an instance in the hyacinth and other bulbous roots, which will grow and blossom beautifully in glasses of water. But I confess I should think it would be difficult to rear trees in a similar manner.

Mrs. B. No doubt it would, as it is the burying of the roots in the earth that supports the stem of the tree. But this office, besides that of affording a vehicle for food, is far the most important part which the earthy portions of the soil perform in the process of vegetation ; for we can discover by analysis but an extremely small proportion of earth in vegetable compounds.

Caroline. But if earths do not afford nourishment, why is it necessary to be so attentive to the preparation of the soil ?

Mrs. B. In order to impart to it those qualities which render it a proper vehicle for the food of the plant. Water is the chief nourishment of vegetables ; if, therefore, the soil be too sandy, it will not retain a quantity of water sufficient to supply the roots of the plants. If, on the contrary, it abounds too much with clay, the water will lodge in such quantities as to threaten a decomposition of the roots.—Calcareous soils are upon the whole, the most favourable to the growth of plants, from their containing in great abundance carbonic acid, which is one of the most essential ingredients of vegetation. Soils are, therefore, usually improved by chalk, which you may recollect is a carbonat of lime. Different vegetables, however, require different kinds of soils. Thus rice demands a moist, retentive soil; potatoes a soft sandy soil; wheat a firm and rich soil. Forest trees grow better in fine sand than in a stiff clay; and a light feruginous soil is best suited to fruit trees.

Caroline. But pray what is the use of manuring the soil?

Mrs. B. Manure consists of all kinds of substances, whether of vegetable or animal origin, which have undergone the putrid fermentation and are consequently decomposed, or nearly so, into their elementary principles. Now, I ask you what is the utility of supplying the soil with these decomposed substances?

Caroline. It is, I suppose, in order to furnish vegetables with the principles which enter into their composition. For manures not only contain carbone, hydrogen, and oxygen, but by their decomposition supply the soil with these principles in their elementary form.

Mrs. B. Undoubtedly; and it is for this reason that the finest crops are produced in fields that were formerly covered with woods, because their soil is composed of a rich mould, a kind of vegetable earth which abounds in those principles.

Emily. This accounts for the plentifulness of the crops produced in America, where the country was but a few years since covered with wood.

Caroline. But how is it that animal substances are reckoned to produce the best manure? Does it not appear much more natural that the decomposed elements of vegetables should be the most appropriate to the formation of new vegetables?

Mrs. B. The addition of a much greater proportion of nitrogen, which constitutes the chief difference between animal and vegetable matter, renders the composition of the former more complicated, and consequently more favourable to decomposition. The use of animal substances is chiefly to give the first impulse to the fermentation of the vegetable ingredients that enter into the composition of manures. The manure of a farm-yard is of that description; but there is scarcely any substance susceptible of undergoing the putrid fermentation that will not make good manure. The heat produced by the fermentation of manure is another circumstance which is extremely favourable to vegetation; yet this heat would be too great if the manure was laid on the ground in the height of fermentation; it is used in this state only for hot-beds, to produce melons, cucumbers, and such vegetables as require a very high temperature.

Caroline. A difficulty has just occurred to me which I do not know how to remove.—Since all organized bodies are, in the common course of nature, ultimately reduced to their elementary state, they must necessarily in that state enrich the soil, and afford food for vegetation. How is it then that agriculture, which cannot increase the quantity of those elements that are required to manure the earth, can increase its produce so wonderfully, as is found to be the case in all cultivated countries?

Mrs. B. It is by suffering none of these principles to remain inactive, and by employing them to the best advantage. This object is attained by a judicious preparation of the soil, which consists in fitting it either for the general purposes of vegetation, or for that of the particular seed which is to be sown. Thus, if the soil be too cold, it may be warmed by slakeing lime upon it; if too loose and sandy, it may be rendered more consistent and retentive of water by the addition of clay or loam; if too poor, it may be enriched by chalk or any kind of calcareous earth. On soils thus improved, manures will act with double efficacy, and if attention be paid to spread them on the ground at a proper season of the year, to mix them with the soil so that they may be generally diffused through it, to destroy the weeds that might apropriate these nutritive principles to their own use, to remove the stones which would impede the growth of the plant, &c. we may obtain a produce an hundred fold more abundant than the earth would spontaneously supply.

Emily. We have a very striking instance of this in the scanty produce of uncultivated commons, compared to the rich crops of meadows which are occasionally manured.

Caroline. But, Mrs. B. though experience daily proves the advantages of cultivation, there is still a difficulty which I cannot get over. A certain quantity of elementary principles exist in nature, which it is not in the power of man either to augment or diminish. Of these principles you have taught us that both the animal and vegetable creation are composed. Now the more of them is taken up by the vegetable kingdom, the less, it would seem, will remain for animals; and therefore the more populous the earth becomes, the less it will produce.

Mrs. B. Your reasoning is very plausible; but experience every where contradicts the inference you would draw from it: for we find that the animal and vegetable kingdoms, instead of thriving as you would suppose, at each other's expense, always increase and multiply together. Indeed, you must allow that your conclusion would be valid only if every particle of the several principles that could possibly be spared from other purposes were employed in the animal and vegetable creations. Now we have reason to believe, that a much greater proportion of these principles than is required for such purposes remains, either in an elementary state, or engaged in a less useful mode of combination in the mineral kingdom. Possessed of such immense resources as the atmosphere and the waters afford us, for oxygen, hydrogen, and carbone, so far from being in danger of working up all our simple materials, we cannot suppose that we shall ever bring agriculture to such a degree of perfection as to require the whole of what these resources could supply.

Nature, however, in thus furnishing us with an inexhaustible stock of raw materials, leaves it in some measure to the ingenuity of man to appropriate them to his own purposes. But, like a kind parent, she stimules him to exertion, by setting the example and pointing out the way. For it is on the operations of nature that all the improvements of art are founded.—

The art of agriculture consists, therefore, in discovering the readiest method of obtaining the several principles, either from their grand sources, air and water, or from the decomposition of organized bodies; and in appropriating them in the best manner to the purposes of vegetation.

Emily. But, among the sources of nutritive principles, I am surprised that you do not mention the earth itself, as it contains abundance of coals which are chiefly composed of carbone.

Mrs. B. You must recollect that coals are, principally, if not entirely, of vegetable origin; and therefore, the earth should be considered rather as the vehicle thro' which decayed organized matter is gradually brought to the state of coals, than as the original source of that valuable combustible. Besides, you know, that tho' coals abound in carbone, they cannot on account of their hardness and impermeable texture, be immediately subservient to the purposes of vegetation.

Emily. No; but by their combustion carbonic acid is produced; and this entering into various combinations on the surface of the earth, may perhaps assist in promoting vegetation.

Mrs. B. Prebably it may in some degree; but at any rate the quantity of nourishment, which vegetables may derive from that source, can be but very trifling, and must entirely depend on local circumstances.

Caroline. Porhaps the smoky atmosphere of London is the reason why vegetation is so forward and so rich in its vicinity?

Mrs. B. I rather believe that this circumstance proceeds from the very ample supply of manure, assisted perhaps by the warmth and shelter which the town affords. Far from attributing any good to the smoky atmosphere of London, I confess, I like to anticipate the time when we shall have made such progress in the art of managing combustion, that every particle of carbone will be consumed, and the smoke destroyed at the moment of its production. We may then expect to have the satisfaction of seeing the atmosphere of London as clear as that of the country.—But to return to our subject: I hope that you are now convinced that we shall not easily experience a deficiency of nutritive elements to fertilize the earth, and that, provided we are but industrious in applying them to the best advantage by improving the art of agriculture, no limits can be assigned to the fruits that we may expect to reap from our labours!

Caroline. Yes; I am perfectly satisfied in that respect, and can assure you that I feel already much more interested in the progress and improvement of agriculture.

Emily. I have often thought that the culture of the land was not considered as a concern of sufficient importance. Manufactures always take the lead; and health and innocence are frequently sacrificed to the prospect of a more profitable employment. It has often grieved me to see the poor manufacturers crowded together in close rooms, and confined for the whole day to the most uniform and sedantary employment, instead of being engaged in that innocent and salutary kind of labour, which nature seems to have assigned to man for the immediate acquirement of comfort, and for the preservation of his existence. I am sure that you agree with me in thinking so, Mrs. B?

Mrs. B. I am entirely of your opinion, my dear, in regard to the importance of agriculture; but I am far from wishing to depreciate manufactures; for as the labour of one man is sufficient to produce food for several, those whose industry is not required in tillage must do something in return for the food that is provided for them. They exchange, consequently, the accommodations for the necessaries of life. Thus the carpenter and the weaver lodge and clothe the peasant, who supplies them with their daily bread. The greater stock of provisions, therefore, which the husbandman produces, the greater is the quantity of accommodation which the artificer prepares. Such are the happy effects which naturally result from civilized society. It would be wiser, therefore, to endeavour to improve the situation of those who are engaged in manufactures, than to indulge in vain declamations on the hardships to which they are often exposed.

But we must not yet take our leave of the subject of agriculture ; we have prepared the soil, it remains for us now to sow the seed. In this operation we must be careful not to bury it too deep in the ground, as the access of air is absolutely necessary to its germination ; the earth therefore must lie loose and light over it, in order that the air may penetrate.—Hence the use of ploughing and digging, harrowing and raking, &c. A certain degree of heat and moisture, such as usually takes place in the spring, is likewise necessary.

Caroline. One would imagine you were going to describe the decomposition of an old plant, rather than the formation of a new one ; for you have enumerated all the requisites of fermentation.

Mrs. B. Do you forget, my dear, that the young plant derives its existence from the destruction of the seed, and that it is actually by the saccharine fermentation that the latter is decomposed ?

Caroline. True ; I wonder that I did not recollect that. The temperature and moisture required for the germination of the seed, is then employed in producing the saccharine fermentation within it.

Mrs. B. Certainly. But, in order to understand the nature of germination, you should be acquainted with the different parts of which the seed is composed. The external covering or envelope contains, besides the germ of the future plant, the substance which is to constitute its first nourishment ; this substance, which is called the *parenchyma*, consists of fecula, mucilage, and oil, as we formerly observed.

The seed is generally divided into two compartments, called *lobes*, or *cotyledons*, as is exemplified by the bean, (*Plate* XI. *Fig.* 25.)—the dark coloured kind of string which divides the lobes, is called the *rad-*

PLATE XI.

Fig. 25. Bean.
Fig. 26. AB. Cotyledons. C. Envelope. D. Radicle.
Fig. 27. AB. Cotyledons. C. Plumula. D. Radicle.
Fig. 28. AB. Cotyledons. C. Plumula. D. Radicle.
Fig. 29. AA. Glass bell. B. Bladder representing the lungs. C. Bladder representing the diaphragm.

icle, as it forms the root of the plant, and it is from a contiguous substance called *plumula*, which is enclosed within the lobes, that the stem arises. The figure and size of the seed depend very much upon the cotyledons; these vary in number in different seeds; some have only one, as wheat, oats, barley, and all the grasses; some have three, others six. But most seeds, as for instance, all the varieties of beans, have two cotyledons. When the seed is buried in the earth, at any temperature above 40° it imbibes water, which softens and swells the lobes; it then absorbs oxygen which combines with some of its carbone, and is returned in the form of carbonic acid. This loss of carbone increases the comparative proportion of hydrogen and oxygen in the seed, and excites the saccharine fermentation, by which the parenchymatoas matter is converted into a kind of sweet emulsion. In this form it is carried into the radicle by vessels for that purpose; and in the mean time, the fermentation having caused the seed to burst, the cotyledons are rent asunder, the radicle strikes into the ground and becomes the root of the plant, and hence the fermented liquid is conveyed to the plumula, whose vessels have been previously distended by the heat of the fermentation. The plumula being thus swelled, as it were, by the emulsive fluid, raises itself and springs up to the surface of the earth, bearing with it the cotyledons, which as soon as they come in contact with the air, spread themselves, and are transformed into leaves— If we go into the garden, we shall probably find some seeds in the state which I have described—

Emily. Here are some lupines that are just making their appearance above ground.

Mrs. B. We will take up several of them to observe their different degrees of progress in vegetation. Here is one that has but recently burst its envelope—do you see the little radicle striking downwards? (*Plate* XI. *Fig.* 26.) In this the plumula is not yet visible. But here is another in a greater state of forwardness—the plumula, or stem, has risen out of the ground, and the cotyledons are converted into seed leaves, (*Plate* XI. *Fig.* 27.)

Caroline. These leaves are very thick and clumsy, and unlike the other leaves which I perceive are just beginning to appear.

Mrs. B. It is because they retain the remains of the parenchyma, with which they still continue to nourish the young plant, as it has not yet sufficient roots and strength to provide for its sustenance from the soil.—But, in this third lupine, *(Plate* XI. *Fig.* 28.*)* the radicle had sunk deep into the earth, and sent out several shoots, each of which is furnished with a mouth to suck up nourishment from the soil ; the function of the original leaves, therefore, being no longer required, they are gradually decaying, and the plumula is become a regular stem, shooting out small branches and spreading its foliage.

Emily. There seems to be a very striking analogy between a seed and an egg ; both require an elevation of temperature to be brought to life ; both at first supply with aliment the organized being which they produce ; and as soon as this has attained sufficient strength to procure its own nourishment, the egg-shell breaks, whilst in the plant the seed-leaves fall off.

Mrs. B. There is certainly some resemblance between these processes ; and when you become acquainted with animal chemistry, you will frequently be struck with its analogy to that of the vegetable kingdom.

As soon as the young plant feeds from the soil, it requires the assistance of leaves, which are the organs by which the plant throws off its superabundant fluid ; this secretion is much more plentiful in the vegetable than in the animal creation, and the great extent of surface of the foliage of plants is admirably calculated for carrying it on in sufficient quantities. This transpired fluid consists of little more than water. The sap, by this process, is converted into a liquid of greater consistence, which is fit to be assimilated to its several parts.

Emily. Vegetation, then, must be essentially injured by destroying the leaves of the plant ?

Mrs. B. Undoubtedly ; it not only diminishes the transpiration, but also the absorption by the roots ; for the quantity of sap absorbed, is always in proportion to the quantity of fluid thrown off by transpiration. You see therefore the necessity that a young plant should unfold its leaves as soon as it begins to derive its nourishment from the soil; and accordingly, you will find that those lupines which have dropped their seed leaves, and are no longer fed by the parenchyma, have spread their foliage, in order to perform the office just described.

But I should inform you that this function of transpiration seems to be conbined to the upper surface of the leaves, whilst, on the contrary, the lower surface, which is more rough and uneven, and furnished with a kind of hair or down, is destined to absorb moisture, or such other ingredients as the plant derives from the atmosphere.

As soon as a young plant makes its appearance above ground, light as well as air becomes necessary to its preservation. Light is essential to the developement of the colours and to the thriving of the plant. You may have often observed what a predilection vegetables have for the light. If you make any plants grow in a room, they all spread their leaves and extend their branches towards the windows.

Caroline. And many plants close up their flowers as soon as it is dark.

Emily. But may not this be owing to the cold and dampness of the evening air?

Mrs. B. That does not appear to be the case; for in a course of curious experiments, made by Mr. Senebier, of Geneva, on plants which he reared by lamp light, he found that the flowers closed their petals whenever the lamps were extinguished.

Emily. But pray, why is air essential to vegetation; plants do not breathe it like animals?

Mrs. B. At least not in the same manner; but they certainly derive some principles from the atmosphere, and yield others to it. Indeed, it is chiefly owing to the action of the atmosphere and the vegetable kingdom on each other, that the air continues always fit for respiration. But you will understand this better when I have explained the effect of water on plants.

I have said that water forms the chief nourishment of plants; it is the basis not only of the sap, but of all the vegetable juices. Water is the vehicle which carries into the plant the various salts and other ingredients required for the formation and support of the vegetable system. Nor is this all; great part of the water itself is decomposed by the organs of the plant; the hydrogen becomes a constituent part of oil, of extract, of colouring matter, &c. whilst a portion of the oxygen enters into the formation of mucilage, of fecula, of sugar, and of vegetable acids. But the greater part of the oxygen, proceeding from the decomposition of the water, is converted into a gaseous state by the caloric, disengaged from the hydrogen during its condensation in the formation of the vegetable materials. In this state the oxygen is transpired by the leaves of plants when exposed to the sun's rays. Thus you find that the decomposition of water, by the organs of the plant, is not only a means of supplying it with its chief ingredient, hydrogen, but at the same time of replenishing the atmosphere with oxygen, a principle which requires continual renovation, to make up for the great consumption of it occasioned by the numerous oxygenations, combustions, and respirations, that are constantly taking place on the surface of the globe.

Emily. What a striking instance of the harmony of nature!

Mrs. B. And how admirable the design of Providence, who makes every different part of the creation thus contribute to the support and renovation of each other!

But the intercourse of the vegetable and animal kingdoms through the medium of the atmosphere extends still farther. Animals, in breathing, not only consume the oxygen of the air, but load it with carbonic acid, which, if accumulated in the atmosphere, would, in a short time, render it totally unfit for respiration. Here the vegetable kingdom again interferes; it attracts and decomposes the carbonic acid, retains the carbone for its own purposes, and returns the oxygen for ours. This process, however, is only carried on during the day, and a contrary one seems to take place during the night; for the leaves then absorb oxygen and emit carbonic acid. The absorption of carbonic acid during the day, is, however, far from balanced by the quantity emitted during the night.

Caroline. How interesting this is! I do not know a more beautiful illustration of the wisdom which is displayed in the laws of nature.

Mrs. B. Faint and imperfect as are the ideas which our limited perceptions enable us to form of Divine Wisdom, still they cannot fail to inspire us with awe and admiration. What then would be our feelings were the complete system of nature at once displayed before us! So magnificent a scene would probably be too great for our limited and imperfect comprehension, and it is, no doubt, amongst the wise dispensations of Providence, to veil the splendour of a glory with which we should be overpowered.—But it is well suited to the nature of a rational being to explore, step by step, the works of the creation; to endeavour to connect them into harmonious systems; and, in a word, to trace, in the chain of beings, the kindred ties and benevolent desings which unite its various links, and secure its preservation.

Caroline. But of what nature are these organs of plants which are endued with such wonderful powers?

Mrs. B. They are so minute, that their structure, as well as the mode in which they perform their functions, generally elude our examination; but we may consider them as so many vessels or apparatus appropriated to perform, with the assistance of the principle of life, certain chemical processes, by means of which these vegetable compounds are generated. We may, however, trace the tannin, resins, gum, mucilage, and some other vegetable materials in the organized arrangement of plants, in which they form the bark, the wood, the leaves, flowers, and seeds.

The *bark* is composed of the *epidermis*, the *parenchyma* and the *cortical layers*.

The epidermis is the external covering of the plant. It is a thin transparent membrane consisting of a number of slender fibres crossing each other, and forming a kind of net-work. When of a white glossy nature, as in several species of trees, in the stems of corn and of seeds, it is composed of a thin coating of silicious earth, which accounts for the strength and hardness of those long and slender stems. Mr. Davy was led to the discovery of the silicious nature of the epidermis of such plants, by observing the singular phenomenon of sparks of fire emitted by the collision of rattan canes with which two boys were fighting in a dark room.—On analysing the epidermis of the cane, he found it to be almost entirely silicious.

Caroline. With iron then, a cane I suppose, will strike fire very easily?

Mrs. B. I understand that it will.—In evergreens the epidermis is mostly resinous, and in some few plants is formed of wax. The resin, from its want of affinity for water, tends to preserve the plant from the destructive effects of violent rains, severe climates, or inclement seasons, to which this species of vegetables is peculiarly exposed.

Emily. Resin must preserve wood just like a varnish, as it is the essential ingredient of varnishes.

Mrs. B. Yes, and by this means it prevents likewise all unnecessary expenditure of moisture.

The parenchyma is immediately beneath the epidermis; it is that green rind which appears when you strip a branch of any tree or shrub of its external coat of bark. The parenchyma is not confined to the stem or branches, but extends over every part of the plant. It forms the green matter of the leaves, and is composed of tubes filled with a peculiar juice.

The cortical layers are immediately in contact with the wood; they abound with tannin and gallic acid, and consist of small vessels, through which the sap descends after being elaborated in the leaves. The cortical layers are annually renewed, the old bark being converted into wood.

Emily. But through what vessels does the sap ascend?

Mrs. B. That function is performed by the tubes of the alburnum or wood, which is immediately beneath the cortical layers. The wood is composed of woody fibres, musilage, and resin. The fibres are disposed in two ways; some of them longitudinally, and these form what is called the silver grain of the wood. The others, which are concentric, are called the spurious grain. These last are disposed in layers, from the number of which the age of the tree may be computed, a new one being produced annually by the conversion of the bark into wood. The oldest, and consequently most internal part of the alburnum, is called heart-wood; it appears to be dead, at least no vital functions are discernible in it. It is through the tubes of the living alburnum that the sap rises. These, therefore, spread into the leaves, and there communicate with the extremities of the vessels of the cortical layers, into which they pour their contents.

Caroline. Of what use then are the tubes of the parenchyma, since neither the ascending nor descending sap passes through them?

Mrs. B. They are supposed to perform the important function of secreting from the sap the peculiar juices from which the plant more immediately derives its nourishment. These juices are very conspicuous, as the vessels which contain them are much larger than those through which the sap circulates. The peculiar juices of plants differ much in their nature, not only in different species of vegetablss, but frequently in different parts of the same individual plant. They are sometimes saccharine as in the sugar-cane, sometimes resinous, as in firs and evergreens, sometimes of a milky appearance, as in the laurel.

Emily. I have often observed, that in breaking a young shoot, or in bruising a leaf of laurel, a milky juice will ooze out in great abundance.

Mrs. B. And it is by making incissions in the bark, that pitch, tar, and turpentine are obtained from fir trees. The durability of this species of wood is chiefly owing to the resinous nature of its peculiar juices. The volatile oils have in a great measure, the same preservative effects, as they defend the parts with which they are connected, from the attack of insects. This tribe seems to have as great an aversion to perfumes, as the human species take delight in them. They scarcely ever attack any odoriferous parts of plants, and it is not uncommon to see every leaf of a tree destroyed by a blight, whilst the blossoms remain untouched. Cedar, sandal, and all aromatic woods, are on this account of great durability.

Emily. But the wood of the oak, which is so much esteemed for its durability 'has I believe, no smell.—Does it derive this quality from its hardness alone?

Mrs. B. Not entirely; for the chesnut, though considerably harder and firmer than the oak, is not so lasting. The durability of the oak is, I believe, in a great measure owing to its having very little heart-wood, the alburnum preserving its vital functions longer than in other trees.

Caroline. If incisions are made into the alburnum and cortical layers, may not the ascending and descending sap be procured in the same manner as the peculiar juice is from the vessels of the parenchyma?

Mrs. B. Yes; but in order to obtain specimens of these fluids, in any quantity, the experiment must be made in the spring, when the sap circulates with the greatest energy. For this purpose a small bent glass tube should be introduced into the incision, through which the sap may flow without mixing with any of the other juices of the tree. From the bark the sap will flow much more plentifully than from the wood, as the ascending sap is much more liquid, more abundant, and more rapid in its motion than that which descends; for the latter having been deprived by the operation of the leaves of a consiberable part of its moisture, contains a much greater proportion of solid matter which retards its motion. It does not appear that there is any of descending sap, as none ever exudes from the roots of plants; this process, therefore, seems to be carried on only in proportion to the wants of the plant, and the sap descends no further and in no greater quantity than is required to nourish the several organs.—Therefore, though the sap rises and descends in the plant, it does not appear to undergo a real circulation.

The last of the organs of plants is the *flower* or *blossom*, which produces the *fruits* and *seed.* These may be considered as the ultimate purpose of nature in the vegetable creation. From fruits and seeds animals derive both a plentiful source of immediate nourishment, and an ample provision for the reproduction of the same means of subsistence.

The *seed*, which forms the final product of mature plants we have already examined, as constituting the first rudiments of future vegetation.

These are the principal organs of vegetation, by means of which the several chemical processes, which are carried on during the life of the plant, are performed.

Emily. But how are the several principles which enter into the composition of vegetables, so combined by the organs of the plant as to be converted into vegetable matter?

Mrs. B. By chemical processes, no doubt, but the apparatus in which they are performed is so extremely minute as completely to elude our examination. We can form an opinion, therefore, only by the result of these operations. The sap is evidently composed of water absorbed by the roots, and holding in solution the various principles which it derives from the soil. From the roots the sap ascends through the tubes of the alburnum into the stem, and thence branches out to every extremity of the plant. Together with the sap circulates a certain quantity of carbonic acid, which is gradually disengaged from the former by the internal heat of the plant.

Caroline. What! have vegetables a peculiar heat analogous to animal heat?

Mrs. B. It is a circumstance that has long been suspected; but late experiments have decided beyond a doubt, that vegetable heat is considerably above that of unorganized matter in winter, and below it in summer. The wood of a tree is about 60° when the thermometer is 70° or 80°. And the bark, though so much exposed, is seldom below 40 in winter.

It is from the sap, after it has been elaborated by the leaves, that vegetables derive their nourishment; in its progress through the plant, from the leaves to the roots, it deposites in the several sets of vessels with which it communicates, the materials on which the growth and nourishment of each part depends. It is thus that the various peculiar juices, saccharine, oily, mucous, acid, and colouring, are formed; as also the more solid parts of fecula, woody fibre, tannin, resins, concrete salts: in a word, all the immediate materials of vegetables, as well as the organized parts of plants, which latter, besides the power of secreting these from the sap, for the general purpose of the plant have also that of applying them to their own particular nourishment.

Emily. But why should the process of vegetation take place only at one season of the year, whilst a total inaction prevails during the other?

Mrs. B. Heat is such an important chemical agent, that its effect, as such, might perhaps alone account for the impulse which the spring gives to vegetation. But, in order to explain the mechanism of that operation, it has been supposed that the warmth of the spring dilates the vessels of plants, and produces a kind of vacuum, into which the sap (which had remained in a state of inaction in the trunk during the winter) rises; this is followed by the ascent of the sap contained in the roots, and room is thus made for fresh sap, which the roots, in their turn pump up from the soil. This process goes on till the plant blossoms and bears fruit, which terminates its summer career; but when the cold weather sets in, the fibres and vessels contract, the leaves wither, and are no longer able to perform their office of transpiration; and, as this secretion stops, the roots cease to absorb sap from the soil.—If the plant be an annual, its life then terminates; if not, it remains in a state of torpid inaction during the winter; or the only internal motion that takes place is that of a small quantity of resinous juice, which slowly rises from the stem into the branches, and enlarges their buds during the winter.

Caroline. Yet, in evergreens, vegetation must continue throughout the year.

Mrs. B. Yes; but in winter it goes on in a very imperfect manner, compared to the vegetation of spring and summer.

We have dwelt much longer on the history of vegetable chemistry than I had intended; but we have at length, I think brought the subject to a conclusion.

Caroline. I rather wonder that you did not reserve the account of the fermentations for the conclusion; for the decomposition of vegetables naturally follows their death, and can hardly, it seems, be introduced with so much propriety at any other period.

Mrs. B. It is difficult to determine at what point precisely it may be most eligible to enter on the history of vegetation; every part of the subject is so closely connected, and forms such an uninterrupted chain, that it is by no means easy to divide it. Had I begun with a germination of the seed, which, at first view, seems to be the most proper arrangement, I could not have explained the nature and fermentation of the seed, or have described the changes which manure must undergo, in order to yield the vegetable elements. To understand the nature of germination, it is necessary, I think, previously to decompose the parent plant, in order to become acquainted with the materials required for that purpose. I hope, therefore, that, upon second consideration, you will find that the order which I have adopted, though apparently less correct, is in fact the best calculated for the elucidation of the subject.

Conversation XX.

On the Composition of Animals.

Mrs. B.

WE are now come to the last branch of chemistry, which comprehends the most camplicated order of compound beings. This is the animal creation, the history of which cannot but excite the highest degree of curiosity and interest, though we often fail in attempting to explain the laws by which it is governed.

Emily. But since all animals ultimately derive their nourishment from vegetables, the chemistry of this order of beings must consist merely in the conversion of vegetable into animal matter?

Mrs. B. Very true; but the manner in which this is effected, is, in a great measure, concealed from our observation. This process is called *animalization*, and is performed by peculiar organs. The difference of the animal and vegetable kingdoms does not, however, depend merely on a different arrangement of combinations. A new principle abounds in the animal kingdom, which is but rarely and in very small quantities found in vegetables; this is nitrogen. There is likewise in animal substances a greater and more constant proportion of phosphoric acid, and other saline matters. But these are not essential to the formation of animal matter.

Caroline. Animal compounds contain then four fundamental principles, oxygen, hydrogen, carbone, and nitrogen.

Mrs. B. Yes; and these form the immediate materials of animals, which are *gelatine*, *albumen*, and *fibrine*.

Emily. Are those all? I am surprised that animals should be composed of fewer kinds of materials than vegetables; for they appear much more complicated in their organization.

Mrs. B. Their organization is certainly more perfect and intricate, and the ingredients that occasionally enter into their composition are more numerous. But notwithstanding the wonderful variety observable in the texture of the animal organs, we find that the original compounds, from which all the varieties of animal matter are derived, may be reduced to the three heads just mentioned. Animal substances being the most complicated of all natural compounds, are most easily susceptible of decomposition, as the scale of attractions increases in proportion to the number of constituents. Their analysis is, however, both difficult and imperfect; for as they cannot be examined in their living state, and are liable to alteration immediately after death, it is probable that, when submitted to the investigation of a chemist, they are always more or less altered in combinations and properties, from what they were whilst they made part of the living animal.

Emily. The mere diminution of temperature, which they experience by the privation of animal heat, must, I should suppose, be sufficient to derange the order of attractions that existed during life.

Mrs. B. That is one of the causes, no doubt : but there are many other circumstances which prevent us from studying the nature of living animal substances. We must therefore, in a considerable degree, confine our researches to the phenomena of these compounds in their inanimate state.

These three kinds of animal matter, gelatine, albumen, and fibrine, form the basis of all the various parts of the animal system ; either solid, as the *skin*, *flesh*, *nerves*, *membranes*, *cartilages*, and *bones* ; or fluids, as *blood*, *chyle*, *milk*, the *gastric* and *pancreatic juices*, *bile*, *perspiration*, *saliva*, *tears*, *&c.*

Caroline. Is it not surprising that so great a variety of substances, and so different in their nature, should yet all arise from so few materials, and from the same original elements ?

Mrs. B. The difference in the nature of various bodies depends, as I have often observed to you, rather on their state of combination, than on the materials of which they are composed. Thus, in considering the chemical nature of the creation in a general point of view, we observe that it is throughout composed of a very small number of elements. But when we divide it into the three kingdoms, we find that, in the mineral, the combinations seem to result from the union of elements casually brought together ; whilst in the vegetable and animal kingdoms, the attractions are peculiarly and regularly produced by appropriate organs, whose action depends on the vital principle. And we may further observe, that by means of certain spontaneous changes and decompositions, the elements of one kind of matter become subservient to the production of another ; so that the three kingdoms are intimately connected, and constantly contributing to the preservation of each other.

Emily. There is, however, one very considerable class of elements, which seems to be confined to the mineral kingdom : I mean metals.

Mrs. B. Not entirely ; they are found, though in very minute quantities, both in the vegetable and animal kingdoms. A small portion of earth and sulphur enters also into the composition of organized bodies. Phosphorus, however, is almost entirely confined to the animal kingdom ; and nitrogen, but with few exceptions, is extremely scarce in vegetables.

Let us now proceed to examine the nature of the three principal materials of the animal system.

Gelatine, or *jelly*, is the chief ingredient of skin, and of all the membranous parts of animals. It may be obtained from these substances under the forms of glue, size, isinglass, and transparent jelly.

Caroline. But these are of a very different nature ; they cannot therefore be all pure gelatine.

Mrs. B. Not entirely, but very nearly so. Glue is extracted from the skin of animals. Size is obtained either from skin in its natural state, or from leather. Isinglass is gelatine procured from a particular species of fish ; it is, you know, of this substance that the finest jelly is made, and this is done by merely dissolving the isinglass in boiling water, and allowing the solution to congeal.

Emily. The wine, lemon, and spices, are, I suppose, added only to flavour the jelly ?

Mrs. B. Exactly so.

Caroline. But jelly is often made of hartshorn shavings, and of calves' feet ; does these substances contain gelatine ?

Mrs. B. Yes. Gelatine may be obtained from almost any animal substance, as it enters more or less into the composition of all of them. The process of obtaining it is extremely simple, as it consists merely in boiling the substance that contains it with water. The gelatine dissolves in water, and may be obtained of any degree of consistence or strength, by evaporating this solution. Bones in particular produce it very plentifully, as they consist of phosphat of lime combined or cemented by gelatine. Horns which are a species of bone, will yield abundance of gelatine. The horns of the hart are reckoned to produce gelatine of the finest quality; they are reduced to the state of shavings in order that the jelly may be more easily extracted by the water. It is of hartshorn shavings that the jellies for invalids are usually made, as they are of very easy digestion.

Caroline. It appears singular that hartshorn, which yields such a powerful ingredient as ammonia, should at the same time produce so mild and insipid a substance as jelly?

Mrs. B. And, what is more surprising, it is from the gelatine of bones that ammonia is produced.—You must observe, however, that the processes by which these two substances are obtained from bones are very different. By the simple action of water, and heat, the gelatine is separated; but in order to procure the ammonia, or what is commonly called hartshorn, the bones must be distilled, by which means the gelatine is decomposed, and hydrogen and nitrogen combined in the form of ammonia. So that the first operation is a mere separation of ingredients, whilst the second requires a chemical decomposition.

Caroline. But when jelly is made from hartshorn shavings, what becomes of the phosphat of lime which constitutes the other part of bones?

Mrs. B. It is easily separated by straining. But the jelly is afterwards more perfectly purified, and rendered transparent by adding white of egg, which being coagulated by heat, rises to the surface along with any impurities.

Emily. I wonder that bones are not used by the common people to make jelly; a great deal of wholesome nourishment might, I should suppose, be procured from them, though the jelly would perhaps not be quite so good as if made from hartshorn shavings?

Mrs. B. There is a kind of prejudice among the poor against a species of food that is usually thrown to the dogs ; and as we cannot expect them to enter into chemical considerations, it is in some degree excusable. Besides, it requires a prodigious quantity of fuel to dissolve bones and obtain the gelatine from them.

The solution of bones in water is greatly promoted by an accumulation of heat. This may be effected by means of an extremely strong metallic vessel, called *Papin's digester*, in which the bones and water are enclosed, without any possibility of the steam making its escape. A heat can thus be applied much superior to that of boiling water ; and bones, by this means, are completely reduced to a pulp. But the process still consumes too much fuel to be generally adopted among the lower classes.

Caroline. And why should not a manufacture be established for grinding or macerating bones, or at least for reducing them to the state of shavings, when I suppose they would dissolve as readily as hartshorn shavings?

Mrs. B. Indeed I see no objection to this plan, if the prejudices of the vulgar could be overcome ; but this would be a difficult matter, for I have even heard it objected to Papin's digester, that by the use of food thus prepared, the flesh of those feeding upon it would become ossified.

Caroline. But these prejudiced people might easily see that the flesh of dogs, who feed chiefly on bones, is not ossified. Besides it would not be difficult to convince them that the real bony matter, the phosphat of lime, is deposited and forms no part of the jelly.

Emily. And when jelly is made of isinglass, does it leave no sediment ?

Mrs. B. No ; nor does it so much require clarifying, as it consists almost entirely of pure gelatine, and any foreign matter that is mixed with it, is thrown off during the boiling in the form of scum. These are processes which you may see performed in great perfection in the culinary labratory, by that very able and most useful chemist the cook.

Caroline. To what an immense variety of purposes chemistry is subservient !

Emily. It appears, in that respect, to have an advantage over most other arts and sciences; for these very often have a tendency to confine the imagination to their own particular object, whilst the pursuit of chemistry is so extensive and diversified, that it inspires a general curiosity, and a desire of inquiring into the nature of every object.

Caroline. I suppose that soup is likewise composed of gelatine; for when cold, it often assumes the consistence of jelly?

Mrs. B. Yes; all soups contain a quantity of gelatine obtained from meat, and dissolved in water. And the various kinds of portable soups consist almost entirely of concentrated jelly, which, in order to be made into soup, requires only to be dissolved in water.

Gelatine, in its solid state, is a semiductile transparent substance, without either taste or smell.—When exposed to heat, in contact with air and water, it first swells, then fuses, and finally burns. You may have seen the first part of this operation performed in the carpenter's glue-pot.

Caroline. But you said that gelatine had no smell, and glue has a very disagreeable one.

Mrs. B. Glue is not purely gelatine; but like size, the smell of which is still more offensive, it retains some other particles of animal matter.

Gelatine may be precipitated from its solution in water by alcohol.—We shall try this experiment with a glass of warm jelly.—You see that the gelatine subsides by the union of the alcohol and the water.—

Emily. How is it, then, that jelly is flavoured with wine, without producing any precipitation?

Mrs. B. Because the alcohol contained in wine is already combined with water and other ingredients, and is therefore not at liberty to act upon the jelly as when in its separate state. Gelatine is soluble both in acids and in alkalies; the former, you know, are frequently used to season jellies.

Caroline. Among the combinations of gelatine we must not forget one which you formerly mentioned: that with tannin, to form leather.

Mrs. B. True; but you must observe that leather can be produced only by gelatine in a membraneous state; for though pure gelatine and tannin will produce a substance chemically similar to leather, yet the texture of the skin is requisite to make it answer the useful purposes of that substance.

The next animal substance we are to examine is *albumen:* this, although constituting part of most of the animal compounds, is frequently found insulated in the animal system; the white of egg, for instance, consists almost entirely of albumen; the substance that composes the nerves, the serum, or white part of the blood, and the curds of milk, are little else than albumen variously modified.

In its most simple state, albumen appears in the form of a transparent viscous fluid, possessed of no distinct taste or smell; it coagulates at the low temperature of 165°, and when once solidified, it will never return to its fluid state.

Sulphuric acid and alcohol are each of them capable of coagulating albumen in the same manner as heat, as I am going to shew you—

Emily. Exactly so.—Pray, Mrs. B. what kind of action is there between albumen and water? I have sometimes observed, that if the spoon with which I eat an egg happens to be wetted, it becomes tarnished.

It is because the white of egg (and indeed albumen in general) contains a little sulphur, which, at the temperature of an egg just boiled, will decompose the drop of water that wets the spoon, and produce sulphurated hydrogen gas, which has the property of tarnishing silver.

We may now proceed to *Fibrine.* This is an insipid and inodorous substance, having somewhat the appearance of fine white threads adhering together; it is the essential constituent of muscles or flesh, in which it is mixed with and softened by gelatine. It is insoluble both in water and alcohol, but sulphuric acid converts it into a substance very analagous to gelatine.

These are the essential and general ingredients of animal matter; but there are other substances, which, though not peculiar to the animal system, usually enter into its composition, such as oils, acids, salts, &c.

Animal Oil is the chief constituent of fat; it is contained in abundance in the cream of milk, whence it is obtained in the form of butter.

Emily. Is animal oil the same in its composition as vegetable oils?

Mrs. B. Not the same, but very analagous. The chief difference is that animal oil contains nitrogen, a principle that seldom enters into the composition of vegetable oils, and never in so large a proportion.

There are a few animal acids, that is to say, acids peculiar to animal matter, from which they are almost exclusively obtained.

The animal acids have triple bases of hydrogen, carbone, and nitrogen. Some of them are found native in animal matter; others are produced during its decomposition.

Those that we find ready formed are:

The *bombic acid*, which is obtained from silkworms.

The *formic acid*, from ants.

The *lactic acid*, from the whey of milk.

The *sebacic* from oil or fat.

Those produced during the decomposition of animal substances by heat, are the *prussic* and *zoonic* acids.— This last is produced by the roasting of meat, and gives it a brisk flavour.

Caroline. The class of animal acids is not very extensive.

Mrs. B. No; nor are they, generally speaking, of great importance. The prussic acid is, I think, the only one sufficiently interesting to require any further comment. It can be formed by an artificial process, without the presence of any animal matter; and it may likewise be obtained from a variety of vegetables, particularly those of the narcotic kind, such as poppies, laurel, &c. But it is commonly obtained from blood, by strongly heating that substance with caustic potash; the alkali attracts the acid from the blood, and forms with it a *prussiat of potash.* From this state of combination the prussic acid can be obtained pure by means of other substances which have the power of separating it from the alkali.

Emily. But if this acid does not exist ready formed in blood, how can the alkali attract it from it?

Mrs. B. It is the triple bases only of this acid that exists in the blood; and this is developed and brought to the state of acid, during the combustion. The acid therefore is first formed, and it afterwards combines with the potash.

Emily. Now I comprehend it. But how can the prussic acid be artificially made?

Mrs. B. By passing ammoniacal gas over red hot charcoal; and hence we learn that the constituents of this acid are hydrogen, nitrogen, and carbone. The two first are derived from the volatile alkali, the last from the combustion of the charcoal.

Caroline. But this does not accord with the system of oxygen being the indispensable principle of acidity?

Mrs. B. It is true; and this circumstance, together with some others of the same kind, has led several chemists to suspect that oxygen may not be the sole generator of acids, and that acidity may possibly depend rather on the arrangement than on the presence of any particular principles.

Caroline. I do not like that idea. For if it were founded, all our theory of chemistry must be erroneous.

Mrs. B. The objection is yet so new and unconfirmed by common experience, that I confess I do not feel inclined to distrust the general doctrine of acidification which we have hitherto adopted. But we have not yet done with the prussic acid. It has a strong affinity for metallic oxyds, and precipitates the solution of iron in acids of a blue colour. This is the prussian blue, or prussiat of iron, so much used in the arts, and with which I think you must be acquainted.

Emily. Yes, I am; it is much used in painting, both in oil and in water colours; but it is not reckoned a permanet oil colour.

Mrs. B. That defect arises, I believe, in general, from its being badly prepared, which is the case when the iron is not so fully oxydated as to form a red oxyd. For a solution of green oxyd of iron (in which the metal is more slightly oxydated) makes only a pale green, or even a white precipitate, with prussiat of potash; and this gradually changes to blue by being exposed to the air, as I can immediately shew you.

Caroline. It already begins to assume a pale blue colour. But how does the air produce this change?

Mrs. B. By oxydating the iron more perfectly. If we pour some nitrous acid on it, the prussian blue colour will be immediately produced, as the acid will yield its oxygen to the precipitate, and fully saturate it with this principle—as you shall see—

Caroline. It is very curious to see a colour change so instantaneously.

Mrs. B. Hence you perceive that prussian blue cannot be a permanent colour unless prepared with red oxyd of iron, since by exposure to the atmosphere it gradually darkens, and in a short time is no longer in harmony with the other colours of the painting.

Caroline. But it can never become darker, by exposure to the atmosphere, than the true prussian blue, in which the oxyd is perfectly saturated?

Mrs. B. Certainly not. But in painting, the artist not reckoning upon partial alterations in his colours, gives his blue tints that particular shade which harmonizes with the rest of the picture. If, afterwards those tints become darker, the harmony of the colouring must necessarily be destroyed.

Caroline. Pray, of what nature is the paint called *carmine?*

Mrs. B. It is an animal colour, prepared from *cochineal,* an insect, the infusion of which produces a very beautiful red.

Caroline. Whilst we are on the subject of colours, I should like to learn what *ivory black* is?

Mrs. B. It is a carbonaceous substance obtained by the combustion of ivory. A more common species of black is obtained from the burning of bone.

Caroline. But during the combustion of ivory or bone, the carbone I should have imagined, must be converted into carbonic acid gas, instead of this black substance!

Mrs. B. In this, as in most combustions, a considerable part of the carbone is simply volatilized by the heat, and again obtained concrete on cooling.—This colour, therefore, may be called the soot produced by the burning of ivory or bone.

Conversation XXI.

On the Animal Economy.

Mrs. B.

We have now acquired some idea of the various materials that compose the animal system; but if you are curious to know in what manner these substances are formed by the animal organs, from vegetable, as well as from animal substances, it will be necessary to have some previous knowledge of the nature and functions of these organs, without which it is impossible to form any distinct idea of the processes of *animalization* and *nutrition*.

Caroline. I do not exactly understand the meaning of the word animalization?

Mrs. B. Animalization is the process by which the food is *assimilated*, that is to say, converted into animal matter; and nutrition is that by which the food thus assimilated is rendered subservient to the purposes of nourishing and maintaining the animal system.

Emily. This, I am sure, must be the most interesting of all the branches of chemistry.

Caroline. So I think; particularly as I expect that we shall hear something of the nature of respiration, and of the circulation of the blood?

Mrs. B. These functions undoubtedly occupy a most important place in the history of the animal economy.—But I must previously give you a very short account of the principal organs by which the various operations of the animal system are performed.—These are:

The *Bones*,
Muscles,
Blood vessels,
Lymphatic vessels,
Glands, and
Nerves.

The *bones* are the most solid part of the animal frame, and in a great measure determine its form and dimensions. You recollect, I suppose, what are the ingredients which enter into their composition?

Caroline. Yes; phosphat of lime, cemented by gelatine.

Mrs. B. During the earliest period of animal life they consist almost entirely of a gelatinous membrane of the form of the bones, but of a loose spongy texture, the cells or cavities of which are destined to be filled with phosphat of lime; it is the gradual acquisition of this salt which gives to the bones their subsequent hardness and durability. Infants first receive it from their mother's milk, and afterwards derive it from all animal and from most vegetable food, especially farinaceous substances, such as wheat flour, which contain it in sensible quantities. A portion of the phosphat after the bones of the infant have been sufficiently expanded and solidified, is deposited in the teeth, which consist at first of only a gelatinous membrane or case, fitted for the reception of this salt; and which, after acquiring hardness within the gum, gradually protrude from it.

Caroline. How very curious this is: and how ingeniously nature has first provided for the solidification of such bones as are immediately wanted, and afterwards for the formation of the teeth, which would not only be useless, but detrimental in infancy!

Mrs. B. In quadrupeds the phosphat of lime is deposited likewise in their horns, and in the hair or wool with which they are generally clothed.

In birds it serves also to harden the beaks and the quills of their feathers.

When animals are arrived at a state of maturity, and their bones have acquired a sufficient degree of solidity, the phosphat of lime which is taken with the food is seldom assimilated, excepting when the female nourishes her young; it is then all secreted into the milk, as a provision for the tender bones of the nursling.

Emily. So that whatever becomes superfluous to one being, is immediately wanted by another; and the child acquires strength precisely by the species of nourishment which is no longer necessary to the mother. Nature is, indeed, an admirable economist!

Caroline. Pray, Mrs. B. does not the disease in the bones of children, called the rickets, proceed from a deficiency of phosphat of lime?

Mrs. B. I have heard that this disease may arise from two causes; it is sometimes occasioned by the growth of the muscles being too rapid in proportion to that of the bones. In this case the weight of the flesh is greater than the bones can support, and presses upon them so as to produce a swelling of the joints which is the great indication of the rickets. The other cause of this disorder is an imperfect digestion and assimilation of the food, attended with an excess of acid, which counteracts the formation of phosphat of lime. In both instances, therefore, care should be taken to alter the child's diet, not merely by increasing the quantity of aliment containing phosphat of lime, but also by avoiding all food that is apt to turn acid on the stomach and produce indigestion. But the best preservative against complaints of this kind is, no doubt, good nursing; when a child has plenty of air and exercise, the digestion and assimilation will be properly performed, no acid will be produced to interrupt these functions, and the muscles and bones will grow together in just proportions.

Caroline. I have often heard the rickets attributed to bad nursing, but I never could have guessed what connection there was between exercise and the formation of the bones.

Mrs. B. Exercise is generally beneficial to all the animal functions. If man is destined to labour for his subsistence, the bread which he earns is scarcely more essential to his health and preservation than the exertions by which he obtains it. Those whom the gift of fortune have placed above the necessity of bodily labour, are compelled to take exercise in some mode or other, and when they cannot convert it into an amusement, they must submit to it as a task, or their health will soon experience the effects of their indolence.

Emily. That will never be my case: for exercise, unless it becomes fatigue, always gives me pleasure; and, so far from being a task, is to me a source of daily enjoyment. I often think what a blessing it is, that exercise which is so conducive to health, should be so delightful, whilst fatigue which is rather hurtful, instead of pleasure occasions painful sensations. So that fatigue, no doubt, was intended to moderate our bodily exertions, as satiety puts a limit to our appetites?

Mrs. B. Certainly.—But let us not deviate too far from our subject.—The bones are connected together by ligaments, which consist of a white thick flexible substance, adhering to their extremities, so far as to secure the joints firmly, though without impeding their motion. And the joints are moreover covered by a solid smooth, elastic, white substance, called *cartilage*, the use of which is to allow, by its smoothness and elasticity, the bones to slide easily over one another, so that the joints may perform their office without difficulty or detriment.

Over the bones the *muscles* are placed; they consist of bundles of fibres which terminate in a kind of string, or ligament, by which they are fastened to the bones. The muscles are the organs of motion; by their power of dilatation and contraction they put into action the bones, which act as leavers in all the motions of the body, and form the solid support of its various parts. The muscles are of various degrees of strength or consistence in different species of animals. The mammiferous tribe, or those that suckle their young, seem in this respect to occupy an intermediate place between birds and cold-blooded animals, such as reptiles and fishes.

Emily. The different degrees of firmness and solidity in the muscles of these several species of animals proceed, I imagine, from the different nature of the food on which they subsist?

Mrs. B. No; that is not supposed to be the case: for the human species, who are of the mammiferous tribe, live on more substantial food than birds, and yet the latter exceed them in muscular strength.—We shall hereafter attempt to account for this difference; but let us now proceed in the examination of the animal functions.

The next class of organs is that of the *vessels* of the body, the office of which is to convey the various fluids throughout the frame. These vessels are innumerable. The most considerable of them are those thro' which the blood circulates, which are of two kinds: the *arteries*, which convey it from the heart to the extremities of the body, and the *veins*, which bring it back into the heart.

Besides these, there are a numerous set of small transparent vessels, destined to absorb and convey different fluids into the blood; they are generally called the *absorbent* or *lymphatic* vessels: but it is to a portion of them only that the function of conveying into the blood the fluid called *lymph* is assigned.

Emily. Pray what is the nature of that fluid?

Mrs. B. The nature and use of the lymph have, I believe, never been perfectly ascertained; but it is supposed to consist of matter that has been previously animalized, and which, after answering the purpose for which it was intended, must in regular rotation make way for the fresh supplies produced by nourishment. The lymphatic vessels pump up this fluid from every part of the system, and convey it into the veins to be mixed with the blood which runs through them, and which is commonly called venous blood.

Caroline. But does it not again enter into the animal system through that channel?

Mrs. B. Not entirely; for the venous blood does not return into the circulation until it has undergone a peculiar change, in which it throws off whatever is become useless.

Another set of absorbent vessels pump up the *chyle* from the stomach and intestines, and convey it, after many circumvolutions, into the great vein near the heart.

Emily. Pray what is chyle?

Mrs. B. It is the substance into which food is converted by digestion.

Caroline. One set of the absorbent vessels, then, is employed in bringing away the old materials that are no longer fit for use; whilst the other set is busy in conveying into the blood the new materials that are to replace them.

Emily. What a great variety of ingredients must enter into the composition of the blood!

Mrs. B. You must observe that there is also a great variety of substances to be secreted from it. We may compare the blood to a general receptacle or storehouse for all kinds of commodities which are afterwards fashioned, arranged, and disposed of as circumstances require.

There is another set of absorbent vessels in females which is destined to secrete milk for the nourishment of the young.

Emily. Pray is not milk very analogous in its composition to blood; for, since the nursling derives its nourishment from that source only, it must contain every principle which the animal system requires?

Mrs. B. Very true. Milk is found, by its analysis, to contain all the principal materials of animal matter, gelatine, albumen, oil, and phosphat of lime; so that the suckling has but little trouble to digest and assimilate this nourishment. But we shall examine the composition of milk more fully afterwards.

In many parts of the body numbers of small vessels are collected together in little bundles called *glands*, from a Latin word meaning *acorn*, on account of the resemblance which some of them bear in shape to that fruit. The function of the glands is to *secrete*, or separate certain matters from the blood.

The secretions are not only mechanical, but chemical separations from the blood; for the substances thus formed, though contained in the blood, are not ready combined in that fluid. The secretions are of two kinds, those which form peculiar animal fluids, as bile, tears, saliva, &c. and those which produce the general materials of the animal system, for the purpose of recruiting and nourishing the several organs of the body; such as albumen, gelatine, and fibrine; the latter may be distinguished by the name of *nutritive secretions*.

Caroline. I am quite astonished to hear that all the secretions should be derived from the blood.

Emily. I thought that the bile was produced by the liver?

Mrs. B. So it is; but the liver is nothing more than a very large gland, which secretes the bile from the blood.

The last of the animal organs which we have mentioned are the *nerves*; these are the vehicles of sensation, every other part of the body being, of itself totally insensible.

Caroline. They must then be spread throughout every part of the frame, for we are every where susceptible of feeling.

Emily. Excepting the nails and the hair.

Mrs. B. And those are almost the only parts in which nerves cannot be discovered. The common source of all the nerves is the brain; thence they descend, some of them through different holes of the skull, but the greatest part through the back bone, and extend themselves by innumerable ramifications throughout the whole body. They spread themselves over the muscles, penetrate the glands, wind round the vascular system, and even pierce into the interior of the bones. It is most probably through them that the communication is carried on between the mind and the other parts of the body ; but in what manner they are acted upon by the mind, and made to re-act on the body, is still a profound secret. Many hypotheses have been formed on this very obscure subject, but they are all equally improbable, and it would be useless for us to waste our time in conjectures on an inquiry which in all probability, is beyond the reach of human capacity.

Caroline. But you have not mentioned those particular nerves that form the senses of hearing, seeing, smelling, and tasting ?

Mrs. B. They are considered as being of the same nature as those which are dispersed over every part of the body, and constitute the general sense of feeling. The different sensations which they produce arise from their peculiar situation and connection with the several organs of taste, smell, and hearing.

Emily. But these senses appear totally different from that of feeling ?

Mrs. B. They are, all of them sensations, but variously modified according to the nature of the different organs in which the nerves are situated. For, as we have formerly observed, it is by contact only that the nerves are affected. Thus odoriferous particles must strike upon the nerves of the nose in order to excite the sense of smelling, in the same manner that taste is produced by the particular substance coming in contact with the nerves of the palate. It is thus also that the sensation of sound is produced by the concussion of the air striking against the auditory nerve ; and sight is the effect of the light falling upon the optic nerve. These various senses, therefore, are affected only by the actual contact of particles of matter, in the same manner as that of feeling.

The different organs of the animal body, though easily separable and perfectly distinct, are loosely connected together by a kind of spongy substance, in texture somewhat resembling net-work, called the cellular membrane ; and the whole is covered by the skin.

The *skin*, as well as the bark of vegetables, is formed of three coats. The external one is called the *cuticle*, or *epidermis ;* the second, which is called the *mucous membrane*, is of a thin soft texture, and consists of a mucous substance, which in negroes is black, and is the cause of their skin appearing of that colour.

Caroline. Is then the external skin of negroes white like ours?

Mrs. B. Yes; but as the cuticle is transparent, as well as porus, the blackness of the mucous membrane is visible through it. The extremities of the nerves are spread over the skin, so that the sensation of feeling is transmitted through the cuticle. The internal covering of the muscles, which is properly the skin, is the thickest, the toughest, and most resisting of the whole —it is this membrane that is so essential in the arts, by forming leather when combined with tannin.

The skin which covers the animal body, as well as those membranes that form the coats of the vessels, consist almost exclusively of gelatine; and are capable of being converted into glue, size, or jelly.

The cavities between the muscles and the skin are usually filled with fat, which lodges in the cells of the membranous net before mentioned, and gives to the external form (especially in the human figure) that roundness, smoothness, and softness, so essential to beauty.

Emily. And the skin itself is, I think, a very ornamental part of the human frame, both from the finess of its texture, and the variety and delicacy of its tints.

Mrs. B. This variety and harmonious gradation of colours, proceed, not so much from the skin itself, as from the internal organs which transmit their several colours through it, these being only softened and blended by the colour of the skin, which is uniformly of a yellowish white.

Thus modified, the darkness of the veins appears of a pale blue colour, and the floridness of the arteries is changed to a delicate pink. In the most transparent parts, the skin exhibits the bloom of the rose, whilst where it is more opaque its own colour predominates; and at the joints, where the bones are most prominent, their whiteness is often discernible. In a word, every part of the human frame seems to contribute to its external grace; and this not merely by producing a pleasing variety of tints, but by a peculiar kind of beauty which belongs to each individual part. Thus it is to the solidity and arrangement of the bones that the human figure owes the grandeur of its stature, and its firm and dignified deportment. The muscles delineate the form, and stamp it with energy and grace; and the soft substance which is spread over them smooths their ruggedness, and gives to the contours the gentle undulations of the line of beauty. Every organ of sense is a peculiar and separate ornament; and the skin, which polishes the surface and gives it that charm of colouring so inimitable by art, finally conspires to render the whole the fairest work of the creation.

But now that we have seen in what manner the animal frame is formed, let us observe how it provides for its support, and how the several organs, which form so complete a whole, are nourished and maintained.

This will lead us to a more particular explanation of the internal organs: here we shall not meet with so much apparent beauty, because these parts were not intended by nature to be exhibited to view; but the beauty of design, in the internal organization of the animal frame, is, if possible, still more striking than that of the external part.

We shall defer this subject until our next interview.

Conversation XXII.

On Animalization, Nutrition, and Respiration.

Mrs. B.

We have now learnt of what materials the animal system is composed, and have formed some idea of the nature of its organization. In order to complete the subject, it remains for us to examine in what manner it is nourished and supported.

Vegetables we have observed, obtain their nourishment from various substances, either in their elementaary state, or in a very simple state of combination; as carbone, water, and salts, which they pump up from the soil; and carbonic acid and oxygen, which they absorb from the atmosphere.

Animals, on the contrary, feed on substances of the most complicated kind: for they derive their sustenance, some from the animal creation, others from the vegetable kingdom, and some from both.

Caroline. And there is one species of animals, which, not satisfied with enjoying either kind of food in its simple state, has invented the art of combining them together in a thousand ways, and of rendering even the mineral kingdom subservient to their refinements.

Emily. Nor is this all; for our delicacies are collected from the various climates of the earth, so that the four quarters of the globe are often obliged to contribute to the preparation of our simplest dishes.

Caroline. But the very complicated substances which constitute the nourishment of animals, do not, I suppose, enter into their system in their actual state of combination.

Mrs. B. So far from it, that they not only undergo a new arrangement of their parts, but a selection is made of such as are most proper for the nourishment of the body, and those only enter into the system and are animalized.

Emily. And by what organs is this process performed?

Mrs. B. Chiefly by the stomach, which is the organ of digestion, and the prime regulator of the animal frame.

Digestion is the first step towards nutrition. It consists in reducing into one homogenous mass the various substances that are taken as nourishment; it is performed by first chewing and mixing the solid aliment with the saliva, which reduces it to a soft mass, in which state it is conveyed into the stomach, where it is more completely dissolved by the *gastric juice.*

This fluid (which is secreted into the stomach by appropriate glands) is so powerful a solvent that scarcely any substances will resist its action.

Emily. The coats of the stomach however, cannot be attacked by it, otherwise we should be in danger of having them destroyed when the stomach was empty.

Mrs. B. They are probably not subject to its action; as long at least as life continues. But it appears, that when the gastric juice has no foreign substance to act upon, it is capable of occasioning a degree of irritation in the coats of the stomach, which produces the sensation of hunger. The gastric juice together with the heat and muscular action of the stomach, converts the aliment into a uniform pulpy mass called chyme. This passes into the intestines, where it meets with the bile and some other fluids, by the agency of which, and by the operation of other causes hitherto unknown, the chyme is changed into chyle, a much thinner substance, somewhat resembling milk, which is pumped up by immense numbers of small absorbent vessels spread over the internal surface of the intestines. These, after many circumvolutions, gradually meet and unite into large branches, till they at length collect the chyle into one vessel, which pours its contents into the great vein near the heart, by which means the food, thus prepared, enters into the circulation.

Caroline. But I do not yet clearly understand how the blood, thus formed, nourishes the body and supplies all the secretions.

Mrs. B. Before this can be explained to you, you must first allow me to complete the formation of the blood. The chyle may indeed be considered as forming the chief ingredient of blood; but this fluid is not perfect until it has passed through the lungs, and undergone (together with the blood that has already circulated) certain necessary changes that are effected by RESPIRATION.

Caroline. I am very glad that you are going to explain the nature of respiration: I have often longed to understand it, for though we talk incessantly of breathing, I never knew precisely what purpose it answered.

Mrs. B. It is indeed one of the most interesting processes imaginable; but in order to understand this function well, it will be necessary to enter into some previous explanations. Tell me, Emily, what do you understand by respiration?

Emily. Respiration, I conceive, consists simply in alternately *inspiring* air into the lungs, and *expiring* it from them.

Mrs. B. Your answer will do very well as a general definition. But, in order to form a tolerably clear notion of the various phenomena of respiration, there are many circumstances to be taken into consideration.

In the first place, there are two things to be distinguished in respiration, the *mechanical* and the *chemical* part of the process.

The mechanism of breathing depends on the alternate expansions and contractions of the chest, in which the lungs are contained. When the chest dilates the cavity is enlarged, and the air rushes in at the mouth, to fill up the vacuum formed by this dilatation; when it contracts, the cavity is diminished, and the air forced out again.

Caroline. I thought that it was the lungs that contracted and expanded in breathing?

Mrs. B. They do likewise; but their action is only the consequence of that of the chest. The lungs, together with the heart and the largest blood vessels, in a manner fill up the cavity of the chest; they could not, therefore, dilate if the chest did not previously expand; and, on the other hand, when the chest contracts, it compresses the lungs and forces the air out of them.

Caroline. The lungs, then, are like bellows, and the chest is the power that works them.

Mrs. B. Precisely so. Here is a curious little figure (*Plate* XI. *Fig* 29), that will assist me in explaining the mechanism of breathing.

Caroline. What a droll figure! a little head fixed upon a glass bell, with a bladder tied over the bottom of it!

Mrs. B. You must observe that there is another bladder within the glass, the neck of which communicates with the mouth of the figure—this represents the lungs contained within the chest; the other bladder, which you see is tied loose, represents a muscular membrane, called the *diaphragm*, which separates the chest from the lower part of the body. By the chest, therefore, I mean that large cavity in the upper part of the body contained within the ribs, the neck, and the diaphragm; this membrane is muscular and capable of contraction and dilatation. The contraction may be imitated by drawing the bladder tight over the bottom of the receiver, when the air, in the bladder which represents the lungs, will be forced out through the mouth of the figure—

Emily. See, Caroline, how it blows the flame of the candle in breathing!

Mrs. B. By letting the bladder loose again, we imitate the dilatation of the diaphragm, and the cavity of the chest being enlarged, the lungs expand, and the air rushes in to fill them.

Emily. This figure, I think, gives a very clear idea of the process of breathing.

Mrs. B. It illustrates tolerably well the action of the lungs and diaphragm; but those are not the only powers that are concerned in enlarging or diminishing the cavity of the chest; the ribs are also possessed of a muscular motion for the same purpose; they are alternately drawn in edgeways to assist the contraction, and stretched out, like the hoops of a barrel, to contribute to the dilatation of the chest.

Emily. I always supposed that the elevation and depression of the ribs were the consequence, not the cause, of breathing.

Mrs. B. It is exactly the reverse. The muscular action of the diaphragm, together with that of the ribs, are the *causes* of the contraction and expansion of the chest; and the air rushing into, and being expelled from the lungs, are only *consequences* of those actions.

Caroline. I confess that I thought the act of breathing began by opening the mouth for the air to rush in, and that it was the air alone, which, by alternately rushing in and out, occasioned the dilatations and contractions of the lungs and chest.

Mrs. B. Try the experiment of merely opening your mouth; the air will not rush in, till by an interior muscular action you produce a vacuum—yes, just so, your diaphragm is now dilated, and the ribs expanded. But you will not be able to keep them long in that state. Your lungs and chest are already resuming their former state, and expelling the air with which they had just been filled. This mechanism goes on more or less rapidly, but in general, a person at rest and in health will breathe between fifteen and twenty-five times in a minute.

We may now proceed to the chemical effects of respiration; but, for this purpose, it is necessary that you should previously have some notion of the *circulation* of the blood. Tell me, Caroline, what do you understand by the circulation of the blood?

Caroline. I am delighted that you come to that subject, for it is one that has long excited my curiosity.—But I cannot conceive how it is connected with respiration. The idea I have of the circulation is, that the blood runs from the heart through the veins all over the body, and back again to the heart.

Mrs. B. I could hardly have expected a better definition from you; it is, however, not quite correct;

for you do not distinguish the *arteries* from the *veins*, which, as we have already observed, are two distinct sets of vessels, each having its own particular functions. The arteries convey the blood from the heart to the extremities of the body ; and the veins bring it back to the heart.

This sketch will give you an idea of the manner in which some of the principal veins and arteries of the human body branch out of the heart, which may be considered as a common centre to both sets of vessels. The heart is a kind of strong elastic bag, or muscular cavity, which possesses a power of dilating and contracting itself, for the purpose of alternately receiving and expelling the blood, in order to carry on the process of circulation.

Emily. Why are the arteries in this drawing painted red, and the veins purple ?

Mrs. B. It is to point out the difference of the colour of the blood in these two sets of vessels.

Caroline. But if it is the same blood that flows from the arteries into the veins, how can its colour be changed ?

Mrs. B. This change arises from various circumstances. In the first place, during its passage through the arteries, the blood undergoes a considerable alteration, some of its constituent parts being gradually separated from it for the purpose of nourishing the body, and of supplying the various secretions. The consequence of this is, that the florid arterial colour of the blood changes by degrees to a deep purple, which is its constant colour in the veins. On the other hand, the blood is recruited during its return through the veins by the fresh chyle, or imperfect blood, which has been produced by food ; and it receives also lymph from the absorbent vessels, as we have before mentioned. In consequence of these several changes, the blood returns to the heart in a state very different from that in which it left it. It is loaded with a greater proportion of hydrogen and carbone, and is no longer fit for the nourishment of the body or other purposes of circulation.

Emily. And in this state does it mix in the heart with the pure florid blood that runs into the arteries?

Mrs. B. No. The heart is divided into two cavities or compartitions, called the *right* and *left ventricles.* The left ventricle is the recepticle for the pure arterial blood previous to its circulation; whilst the venous, or impure blood, which returns to the heart after having circulated, is received into the right ventricle, previous to its purification, which I shall presently explain.

Caroline. For my part, I always thought that the same blood circulated again and again through the body, without undergoing any change.

Mrs. B. Yet you must have supposed that the blood circulated for some purpose?

Caroline. I knew that it was indispensable to life, but had no idea of its real functions.

Mrs. B. But now that you understand that the blood conveys nourishment to every part of the body, and supplies the various secretions, you must be sensible that it cannot constantly answer these objects without being renovated and purified.

Caroline. But does not the chyle answer this purpose?

Mrs. B. Only in part. It renovates the nutritive principles of the blood, but does not relieve it from the superabundance of hydrogen and carbone with which it is incumbered.

Emily. How then is this effected?

Mrs. B. By Respiration. This is one of the grand mysteries which modern chemistry has disclosed. When the venous blood enters the left ventricle of the heart, it contracts by its muscular power, and throws the blood through a large vessel into the lungs, which are contiguous, and through which it circulates by millions of small ramifications. Here it comes in contact with the air which we breathe. The action of the air on the blood in the lungs is indeed concealed from our immediate observation; but we are able to form a tolerably accurate judgment of it from the changes which it effects not only in the blood, but also on the air expired.

This air is found to contain all the nitrogen inspired, but to have lost part of its oxygen, and to have acquired a portion of watery vapour. Hence it is inferred, that when the air comes in contact with the venous blood in the lungs, the oxygen attracts from it the superabundant quantity of hydrogen and carbone with which it has impregnated itself during the circulation; and that one part of that oxygen combines with the hydrogen, in the form of watery vapour, whilst another part combines with the carbone, which it converts into carbonic acid. The whole of these products being then expired, the blood is restored to its former purity, that is, to the state of arterial blood, and is thus again enabled to perform its various functions.

Caroline. This is truly wonderful! Of all that we have yet learned, I do not recollect any thing that has appeared to me so curious and interesting. I almost believe that I should like to study anatomy now, though I have hitherto had so disgusting an idea of it. Pray, to whom are we indebted for these beautiful discoveries?

Mrs. B. Crawford, in this country, and Lavoisier, in France, are the principal inventors of the theory of respiration. But the still more important and more admirable discovery of the circulation of the blood was made long before by our immortal countryman, Hervey.

Emily. Indeed I never heard any thing that delighted me so much as this theory of respiration. But I hope, Mrs. B. that you will enter a little more into particulars before you dismiss so interesting a subject. We left the blood in the lungs to undergo the salutary change. But how does it thence spread to all the parts of the body?

Mrs. B. After circulating through the lungs, the blood is collected into four large vessels, by which it is conveyed into the left ventricle of the heart, whence it is propelled to all the different parts of the body by a large artery which gradually ramifies into millions of small arteries through the whole frame. From the extremities of these little ramifications the blood is transmitted to the veins, which bring it back to the heart and lungs, to go round again and again in the manner we have just described. You see, therefore, that the blood actually undergoes two circulations; the one, through the lungs, by which it is converted into pure arterial blood; the other, or general circulation, by which nourishment is conveyed to every part of the body; and these are both equally indispensable to the support of animal life.

Caroline. Do we expire all the air that we inspire, besides the addition of hydrogen and carbone which are taken up from the blood?

Mrs. B. Yes, excepting small portions of the oxygen, and of the nytrogen, which, as they do not reappear, are supposed to be absorbed by the blood for some purposes which have not yet been clearly ascertained. The general opinion, however, with regard to oxygen, is, that it serves to stimulate the heart and keep up its muscular action. As to the nitrogen, it was supposed to be expired from the lungs, without any change or diminution. But it was proved a few years ago, by some of Mr. Davy's experiments, which have been since confirmed by those of professor Plaff of Kiel, that a small quantity of nitrogen disappears in respiration, and combines with the system in a manner which is not yet well understood.

Emily. But whence proceeds the hydrogen and carbone with which the blood is impregnated when it comes into the lungs?

Mrs. B. Both hydrogen and carbone exist in a greater proportion in blood than in organized animal matter. The blood, therefore, after supplying its various secretions, becomes loaded with an excess of these principles, which is carried off by respiration. But, besides this, the formation of new chyle affords a constant supply of carbone and hydrogen.

Caroline. Pray, how does the air come in contact with the blood in the lungs?

Mrs. B. I cannot answer this question without entering into an explanation of the nature and structure of the lungs. You recollect that the venous blood on being expelled from the right ventricle, enters the lungs to go through what we may call the lesser circulation; the large trunk or vessel that conveys it, branches out, at its entrance into the lungs, into an infinite number of very fine ramifications.—The windpipe, which conveys the air from the mouth into the lungs, likewise spreads out into a corresponding number of air vessels, which follow the same course as the blood vessels, forming millions of very minute air cells.—These two setts of vessels are so interwoven as to form a sort of net-work, connected into a kind of spongy mass, in which every particle of blood must necessarily come in contact with a particle of air.

Caroline. But since the blood and the air are contained in different vessels, how can they come into contact?

Mrs. B. They act on each other through the membrane which forms the coats of these vessels; for although this membrane prevents the blood and the air from mixing together in the lungs, yet it is no impediment to their chemical action on each other.

Emily. Are the lungs composed entirely of blood vessels and air vessels?

Mrs. B. I believe they are with the addition only of nerves and of a small quantity of the cellular substance before mentioned, which connects the whole into an uniform mass.

Emily. Pray, why are the lungs always spoken of in the plural number? is there more than one?

Mrs. B. Yes; for though they form but one organ, they really consist of two compartments called *lobes*, which are enclosed in separate membranes or bags, each occupying one side of the chest, and being in close contact with each other, but without communicating together. This is a beautiful provision of nature, in consequence of which, if one of the lobes be wounded, the other performs the whole process of respiration till the first is healed.

But, before we proceed further, I must inform you that the chemical theory of respiration, with which you have just been made acquainted, simple and beautiful as it is, has appeared to many philosphers insufficient to explain all the phenomena of respiration. Amongst the various modifications proposed, with a view to improve this theory, that suggested by La Grange, Hassenfratz, and some other eminent chemist, appears to be the most important. These philosophers suppose that the oxygen, which disappears in respiration, is absorbed by the blood, and carried with it into the circulation, during which it gradually combines with the hydrogen and carbone that are successively added to the circulation, forming the water and carbonic acid which are expelled from the lungs at each expiration. Thus the process, instead of being completed in the lungs, as the former theory supposes, only begins in that organ, and cotninues throughout the circulation.

According to this theory, the florid colour of arterial blood depends upon the addition of oxygen, so that this colour gradually vanishes as the blood passes from the arterial to the venous state, that is to say, as the oxygen enters into combination with the hydrogen and carbone during circulation.

Caroline. There does not appear to me to be any very essential difference in these two theories, since in both the oxygen purifies the blood by combining with and carrying off the matter which had accumulated in it during circulation.

Mrs. B. Yes; but, in medical, or rather phisiological science, it must be a question of great importance, whether the oxygen actually enters the circulation, or whether it proceeds no further than the lungs.

The blood thus completed, forms the most complex of all animal compounds, since it contains not only the numerous materials necessary to form the various secretions, as saliva, tears, &c. but likewise all those that are required to nourish the several parts of the frame, as the muscles, bones, nerves, glands, &c.

Emily. There seems to be a singular analogy between the blood of animals, and the sap of vegetables; for each of these fluids contain the several materials destined for the nutrition of the numerous class of bodies to which they respectively belong.

Mrs. B. Nor is the production of these fluids in the animal and vegetable systems entirely different; for the absorbent vessels, which pump up the chyle from the stomach and intestines, may be compared to the absorbents of the roots of plants, which suck up the nourishment from the soil. And the analogy between the sap and the blood may be still further traced, if we follow the latter in the course of its circulation; for in the living animal, we find every where organs which are possessed of a power to secrete from the blood and appropriate to themselves the ingredients requisite for their support.

Caroline. But whence does these organs derive their respective powers?

Mrs. B. From peculiar organization, the secret of which no one has yet ever been able to unfold. But it must be ultimately by means of the vital principle that both their mechanical and chemical powers are brought into action.

I cannot dismiss the subject of circulation without mentioning *perspiration*, a secretion which is immediately connected with it, and acts a most important part in the animal economy.

Caroline. Is not this secretion likewise made by appropriate glands?

Mrs. B. No; it is performed by the extremities of the arteries, which penetrate through the skin and terminate under the cuticle, through the pores of which the perspiration issues. When this fluid is not secreted in excess, it is *insensible*, because it is dissolved by the air as it exudes from the pores: but when it is secreted faster than it can be dissolved, it becomes *sensible*, as it assumes its liquid state.

Emily. This secretion bears a striking resemblance to the transpiration of the sap of plants. They both consist of the most fluid parts, and both exude from the surface by the extremities of the vessels through which they circulate.

Mrs. B. And the analogy does not stop there; for, since it has been ascertained that the sap returns into the roots of the plants, the resemblance between the animal and vegetable circulation is become still more obvious. The latter, however, is far from being complete, since, as we observed before, it consists only in a rising and descending of the sap, whilst in animals the blood actually *circulates* through every part of the system.

We have now, I think, traced the process of nutrition from the introduction of the food into the stomach to its finally becoming a constituent part of the animal frame. This will, therefore, be a fit period to conclude our present conversation. What further remarks we have to make on the animal economy shall be reserved for our next interview.

Conversation XXIII.

On Animal Heat: and on various Animal Products.

Emily.

SINCE our last interview, I have been thinking much of the theory of respiration; and I cannot help being struck with the resemblance which it appears to bear to the process of combustion. For in respiration, as in most cases of combustion, the air suffers a change, and a portion of its oxygen combines with hydrogen and carbone, producing carbonic acid and water.

Mrs. B. I am much pleased that this idea has occurred to you: these two processes appear so very analogous, that it has been supposed that a kind of combustion actually takes place in the lungs; not of the blood, but of the superfluous hydrogen and carbone which the oxygen attracts from it.

Caroline. A combustion in our lungs! that is a curious idea indeed! But, Mrs. B. how can you call the action of the air on the blood in the lungs, combustion, when neither light nor heat are produced by it?

Emily. I was going to make the same objection. Yet I do not conceive how the oxygen can combine with the hydrogen and carbone, and produce water and carbonic acid, without disengaging heat?

Mrs. B. The fact is, that heat is disengaged. Whether any light be evolved, I cannot pretend to determine; but that heat is produced in considerable and very sensible quantities is certain, and this is the prinpal, if not the only source of ANIMAL HEAT.

Emily. How wonderful! that the very process which purifies and elaborates the blood, should afford an inexhaustible supply of internal heat!

Mrs. B. This is the theory of animal heat in its original simplicity, such as it was first proposed by Black and Lavoisier. It is equally clear and ingenious; and was at first generally adopted. But it was objected, on second consideration, that if the whole of the animal heat was evolved in the lungs, it would necessarily be much less in the extremities of the body, than immediately at its source; which is not found to be the case. This objection, however, which was by no means frivolous, is now satisfactorily answered by means of the improved theory of respiration which I mentioned last. According to this hypothesis, you recollect, the changes which the blood undergoes in consequence of respiration only begin in the lungs and gradually continue during circulation. Therefore the animal heat, which is the consequence of those changes, likewise begins in the lungs, and afterwards continues during the whole circulation; and heat is thus uniformly diffused throughout every part of the body.

Caroline. More and more admirable!

Mrs. B. Now let me hear whether you can explain how animal heat is produced. You, Caroline, tell me in what manner it is first evolved in the lungs?

Caroline. Part of the oxygen gas inspired, immediately combines in the lungs with the loose carbone and hydrogen of the venous blood ; and the caloric evolved during this combination, becomes animal heat.

Mrs. B. Very well ; but you must observe, that the whole of the oxygen inspired at a breath is not consumed by one respiration : a considerable part of it is expired, so that we may breathe the same portion of air several times before the whole of the oxygen is expended.—Now, Emily, will you explain to me in what manner an uniform degree of heat is kept up throughout the body ?

Emily. A quantity of oxygen enters into the circulation during which it gradually combines with the hydrogen and carbone of the blood, thus producing a constant disengagement of heat throughout every part of the body.

Mrs. B. Very well, indeed. You have in a few words stated nearly all that can be said on the subject. I must, however, mention another circumstance which may contribute to account for the gradual evolution of animal heat. It appears, from some experiments, that the blood, in consequence of the successive changes it undergoes during circulation (by which it is gradually converted from arterial into venous blood), has its capacity for caloric diminished. What must be the consequence of this ?

Emily. That heat, of course, must be disengaged.

Mrs. B. Exactly so ; and thus an additional quantity of animal heat must be generated. However, the heat produced in this way is but trifling, and could only account for a very small portion of the animal temperature.

Caroline. The cause of animal heat was always a perfect mystery to me, and I am delighted with its explanation.—But pray, Mrs. B. can you tell me what is the reason of the increase of heat that takes place in a fever ?

Emily. Is it not because we then breathe quicker, and therefore more heat is disengaged in the system ?

Mrs. B. That may be one reason: but I should think that the principal cause of the heat experienced in fevers, is, that there is no vent for the caloric which is generated in the body. One of the most considerable secretions is the insensible perspiration; this is constantly carrying off caloric in a latent state; but during the hot stage of a fever, the pores are so contracted that all perspiration ceases, and the accumulation of caloric in the body occasions those burning sensations that are so painful.

Emily. This is, no doubt, the reason why the perspiration that often succeeds the hot stage of a fever affords so much relief. If I had known this theory of animal heat when I had a fever last summer, I think I should have found some amusement in watching the chemical processes that were going on within me.

Caroline. But exercise likewise produces animal heat, and that must be quite in a different manner.

Mrs. B. Not so much so as you think; for the more exercise you take, the more the body is stimulated, and requires recruiting. For this purpose the circulation of the blood is quickened, the breath proportionably accelerated, and consequently a greater quantity of caloric evolved.

Caroline. True; after running very fast, I gasp for breath, my respiration is quick and hard, and it is just then that I begin to feel hot.

Emily. It would seem, then, that violent exercise should produce fever.

Mrs. B. Not if the person is in a good state of health; for the additional caloric is then carried off by the perspiration which succeeds.

Emily. What admirable resources nature has provided for us! By the production of animal heat she has enabled us to keep up the temperature of our bodies above that of inanimate objects; and whenever this source becomes too abundant, the excess is carried off by perspiration.

Mrs. B. It is by the same law of nature that we are enabled, in all climates, and in all seasons, to preserve our bodies of an equal temperature, or at least very nearly so.

Caroline. You cannot mean to say that our bodies are of the same temperature in summer and in winter, in England and in the West Indies?

Mrs. B. Yes, I do; at least if you speak of the temperature of the blood, and the internal parts of the body; for those parts that are immediately in contact with the atmosphere, such as the hands and face, will occasionally get warmer, or colder, than the internal or more sheltered parts. But if you put the bulb of a thermometer in your mouth, which is the best way of ascertaining the real temperature of your body, you will scarcely perceive any difference in its indication, whatever may be the difference of temperature of the atmosphere.

Caroline. And when I feel overcome by heat, I am really not hotter than when I am shivering with cold?

Mrs. B. When a person in health feels very hot, whether from internal heat, from violent exercise, or from the temperature of the atmosphere, his body is certainly a little warmer than when he feels very cold; but this difference is much smaller than our sensations would make us believe; and the natural standard is soon restored by rest and perspiration. I am sure you will be surprised to hear that the internal temperature of the body scarcely ever descends below 95° or 96°, and hardly ever attains 104° or 105°, even in the most violent fevers.

Emily. The greater quantity of caloric, therefore, that we receive from the atmosphere in summer, cannot raise the temperature of our bodies, beyond certain limits, as it does that of inanimate bodies, because an excess of caloric is carried off by perspiration.

Caroline. But the temperature of the atmosphere, and consequently that of inanimate bodies, is surely never so high as that of animal heat?

Mrs. B. I beg your pardon. Frequently in the East and West Indies, and sometimes, in the southern parts of Europe, the atmosphere is above 98°, which is the common temperature of animal heat.—Indeed, even in this country, it occasionally happens that the sun's rays, setting full on an object, elevate its temperature above that point.

In illustration of the power which our bodies have to resist the effects of external heat, Sir Charles Blagden, with some other gentlemen, made several very curious experiments. He remained for some time in an oven heated to a temperature not much inferior to that of boiling water, without suffering any other inconvenience than a profuse perspiration, which he supported by drinking plentifully.

Emily. He could scarcely consider the perspiration as an inconvenience, since it saved him from being baked, by giving vent to the exess of caloric.

Caroline. I always thought, I confess, that it was from the heat of the perspiration that we suffered in summer.

Mrs. B. You now find that you were quite mistaken. Whenever evaporation takes place, cold, you know, is produced in consequence of a quantity of caloric being carried off in a latent state; this is the case with perspiration, and it is in this way that it affords relief. It is for the same reason that tea is often refreshing in summer, though it appears to heat you at the moment you drink it.

Emily. And in winter, on the contrary, tea is pleasant on account of its heat.

Mrs. B. Yes; for we have then rather to guard against a deficiency than an excess of caloric, and you do not find that tea will excite perspiration in winter, unless after dancing, or any other violent exercise.

Caroline. What is the reason that it is dangerous to eat ice after dancing, or to drink any thing cold when one is very hot?

Mrs. B. Because the loss of heat arising from the perspiration, conjointly with the chill occasioned by the cold draught, produces more cold than can be borne with safety, unless you continue to use the same exercise after drinking that you did before; for the heat occasioned by the exercise will counteract the effects of the cold drink, and the danger will be removed. You may, however, contrary to the common notion, consider it as a rule, that cold liquids may at all times, be drunk with perfect safety, however hot you may feel, provided you are not at the moment in a state of great perspiration, and on condition that you keep yourself in gentle exercise afterwards.

Emily. But since we are furnished with such resources against the extremes of heat or cold, I should have thought that all climates would have been equally wholesome.

Mrs. B. That is true, in a certain degree, with regard to those who have been accustomed to them from birth; for we find that the natives of those climates, which we consider as the most deleterious, are as healthy as ourselves; and if such climates are unwholesome to those who are habituated to a more moderate temperature, it is because the animal economy does not easily accustom itself to considerable changes.

Caroline. But pray, Mrs. B. if the circulation preserves the body of an uniform temperature, how does it happen, that animals are sometimes frozen?

Mrs. B. Because if more heat is carried off by the atmosphere than the circulation can supply, the cold will finally prevail, the heart will cease to beat, and the animal will be frozen. And likewise, if the body remained long exposed to a degree of heat, greater than the perspiration could carry off, it would at last lose the power of resisting its destructive influence.

Caroline. Fish, I suppose, have no animal heat, but partake of the temperature of inanimate objects?

Emily. And their coldness, no doubt, proceeds from their not breathing?

Mrs. B. All kinds of fish, I believe, breathe more or less, though in a much smaller degree than land animals. Nor are they entirely destitute of animal heat, though for the same reason they are much colder than other creatures. They have comparatively but a very small quantity of blood, therefore but little oxygen is required, and a proportionally small quantity of animal heat is generated.

Caroline. But how can fish breathe under water?

Mrs. B. Some of them raise their heads above the water to breathe; and others are supposed to be endowed by nature with the power of decomposing water and absorbing oxygen from it. Besides, water always contains air mixed with it, which the fish may possibly apply to the purposes of respiration. Whatever the case may be, it is certain that several kinds of fish have reservoirs of air, or air bags, from which they have probably the means of supplying the gills, an organ which, in the respiration of fish, answers the double purpose of mouth and lungs.

Caroline. Are there any species of animals that breathe more than we do?

Mrs. B. Yes; birds, of all animals, breathe the greatest quantity of air in proportion to their size; and it is to this that they are supposed to owe the peculiar firmness and strength of their muscles, by which they are enabled to support the violent exertion of flying.

This difference between birds and fish, which may be considered as the two extremes of the scale of muscular strength, is well worth observing. Birds residing constantly in the atmosphere, surrounded by oxygen, and respiring it in greater proportions than any other species of animals, are endowed with a superior degree of muscular strength, whilst the muscles of fish, on the contrary, are flaccid and oily; these animals are comparitively slow and feeble in their motions, and their temperature is scarcely above that of the water in which they live. This is, in all probability, owing to their imperfect respiration; the quantity of hydrogen and carbone, that is in consequence accumulated in their bodies, forms the oil which is so strongly characteristic of that species of animals, and which relaxes and softens the small quantity of fibrine which their muscles contain.

Caroline. But, Mrs. B. there are some species of birds that frequent both elements, as, for instance, ducks and other water fowl. Of what nature is the flesh of these?

Mrs. B. Such birds, in general, make but little use of their wings; if they fly, it is but feebly, and only to a short distance. Their flesh too partakes of the oily nature, and even in taste sometimes resembles that of fish. This is the case not only with the various kinds of water fowls, but with all other amphibious animals, as the otter, the crocodile, the lizard, &c.

Caroline. And what is the reason that reptiles are so deficient in muscular strength?

Mrs. B. It is because they usually live under ground, and seldom come into the atmosphere.—They have imperfect, and sometimes no discernible organs of respiration, they partake therefore of the soft oily nature of fish; indeed, many of them are amphibious, as frogs, toads, and snakes, and very few of them find any difficulty in remaining a length of time under water. Whilst, on the contrary, the insect tribe that are so strong in proportion to their size, and alert in their motions, partake of the nature of birds, air being their peculiar element, and their organs of respiration being comparatively larger than in other classes of animals.

I have now given you a short account of the principal animal functions. However interesting the subject may appear to you, a fuller investigation of it would, I fear, lead us too far from our object.

Emily. Yet I shall not quit it without much regret; for of all the branches of chemistry, it is certainly the most curious and most interesting.

Caroline. But, Mrs. B. I must remind you that you promised to give us some account of the nature of *milk*.

Mrs. B. True. There are several other animal productions that deserve likewise to be mentioned. We shall begin with milk, which is certainly the most important and most interesting of all the animal secretions.

Milk, like all other animal substances, ultimately yields by analysis, oxygen, hydrogen, carbone, and nitrogen. These are combined in it under the forms of albumen, gelatine, oil, and water. But milk contains, besides, a considerable portion of phosphat of lime, the purposes of which, I have already pointed out.

Caroline. Yes; it is the salt which serves to nourish the tender bones of the suckling?

Mrs. B. To reduce milk to its elements would be a very complicated, as well as useless operation; but this fluid, without any chemical assistance, may be decomposed into three parts, *cream*, *curds*, and *whey*.— These constituents of milk have but a very slight affinity to each other, and you find accordingly that cream separates from milk by mere standing. It consists chiefly of oil, which being lighter than the other parts of the milk, gradually rises to the surface. It is of this, you know, that butter is made, which is nothing more than oxygenated cream.

Caroline. Butter, then, is somewhat analogous to the waxy substance formed by the oxygenation of vegetable oils.

Mrs. B. Very much so.

Emily. But is the cream oxygenated by churning?

Mrs. B. Its oxygenation commences previous to churning, merely by standing exposed to the atmosphere, from which it absorbs oxygen. The process is afterwards completed by churning; the violent motion which this operation occasions, brings every particle of cream in contact with the atmosphere, and thus facilitates its oxygenation.

Caroline. But the effect of churning, I have often observed in the dairy, is to separate the cream into two substances, butter, and butter-milk?

Mrs. B. That is to say, in proportion as the oily particles of the cream become oxygenated, they separate from the other constituent parts of the cream in the form of butter. So by churning you produce, on the one hand, butter, or oxygenated oil; and, on the other, butter-milk, or cream deprived of oil.—But if you make butter by churning new milk instead of cream, the butter-milk will then be exactly similar in its properties to creamed or skimmed milk.

Caroline. Yet butter-milk is very different from common skimmed milk.

Mrs. B. Because you know it is customary, in order to save time and labour, to make butter from cream alone. In this case, therefore, the butter-milk is deprived of the creamed milk, which contains both the curd and the whey. Besides, in consequence of the milk remaining exposed to the atmosphere during the separation of the cream, the latter becomes more or less acid, as well as the butter-milk which it yields in churning.

Emily. Why should not the butter be equally acidified by oxygenation?

Mrs. B. Animal oil is not so easily acidified as the other ingredients of milk. Butter, therefore, though usually made of sour cream, is not sour itself, because the oily part of the cream had not been acidified. Butter, however, is susceptible of becoming acid by an excess of oxygen ; it is then said to be rancid, and produces the sebacic acid, the same which is obtained from fat.

Emily. If that be the case, might not rancid butter be sweetened by mixing with it some substance that would take the acid from it ?

Mrs. B. This idea has been suggested by Mr. Davy, who supposes, that if rancid butter were well washed in an alkaline solution, the alkali would separate the acid from the butter.

Caroline. You said just now that creamed milk consisted of curd and whey. Pray how are these separated ?

Mrs. B. They may be separated by standing for a certain length of time exposed to the atmosphere ; but this decomposition may be almost instantaneously effected by the chemical agency of a variety of substances. Alkalies, rennet,* and indeed almost all animal substances, decompose milk by combining with the curds.

Acids and spirituous liquors, on the other hand, produce a decomposition by combining with the whey. In order therefore to obtain the whey pure, rennet, or alkaline substances, must be used to attract the curds from it.

But if it be wished to obtain the curds pure, the whey must be separated by acids, wine, or other spirituous liquors.

Emily. This is a very useful piece of information ; for I find white wine whey, which I sometimes take when I have a cold, extremely heating ; now, if the whey were separated by means of an alkali instead of wine, it could not produce that effect.

* *Rennet is the name given to a watery infusion of the coats of the stomach of a sucking calf. Its remarkable efficacy in promoting coagulation is supposed to depend on the gastric juice with which it is impregnated.*

Mrs. B. Perhaps not. But I would strenuously advise you not to place too much reliance on your slight chemical knowledge in medical matters. I do not know why whey is not separated from curd by rennet, or by an alkali, for the purpose which you mention ; but I strongly suspect there must be some good reason why the preparation by means of wine is generally preferred. I can, however, safely point out to you a method of obtaining whey without either alkali, rennet, or wine ; it is by substituting lemon juice, a very small quantity of which will separate it from the curds.

Whey, as an article of diet, is very wholesome ; it is the most nutritive part of the milk, and the lightest of digestion. But its effect, taken medicinally, is chiefly, I believe, to excite perspiration, by being drunk warm on going to bed.

It appears that the nutritive particles of whey may be obtained in crystals by evaporation ; in this state they are called salts, or more commonly *sugar of milk*. This salt is sweet to the taste, and in its composition is so analogous to sugar, that it is susceptible of undergoing the vinous fermentation.

Caroline. Why then is not wine, or alcohol, made from whey ?

Mrs. B. The quantity of sugar contained in milk is so trifling that it can hardly answer for that purpose. I have heard of only one instance of its being used for the production of a spirituous liquor, and this is by the Arabs ; their abundance of horses as well as their scarcity of fruits, has introduced the fermentation of mares' milk, by which they produce a liquor called *koumiss*. Whey is likewise susceptible of being acidified by combining with oxygen from the atmosphere. It then produces the *lactic acid*, which you may recollect is mentioned amongst the animal acids, as the acid of milk.

Let us now see what are the properties of curds.

Emily. I know that they are made into cheese ; but I have heard that for that purpose they are separated from the whey by rennet, and yet this you have just told us is not the method of obtaining pure curds ?

Mrs. B. Nor are pure curds so well adapted for the formation of cheese. For the nature and flavour of the cheese depends, in a great measure, upon the cream or oily matter which is left in the curds; so that if every particle of cream be removed from the curds, the cheese is scarcely eatable. Rich cheeses, such as cream and Stilton cheeses, derive their excellence from the quantity, as well as the quality of the cream that enters into their composition.

Caroline. I had no idea that milk was such an interesting compound. In many respects there appears to me to be a very striking analogy between milk and the contents of an egg, both in respect to their nature and their use. They are, each of them, composed of the various substances necessary for the nourishment of the young animal, and equally destined for that purpose.

Mrs. B. There is, however, a very essential difference. The young animal is formed, as well as nourished by the contents of the egg-shell; whilst milk serves as nutriment to the suckling, only after it is born.

There are several peculiar animal substances which do not enter into the general enumeration of animal compounds, and which, however, deserve to be mentioned.

Spermaceti is of this class; it is a kind of oily substance obtained from the head of the whale, which, however, must undergo a certain preparation before it is in a fit state to be made into candles. It is not much more combustible than tallow, but it is more pleasant to burn, as it is less fusible and less greasy.

Ambergris is another peculiar substance derived from a species of whale. It is, however, seldom obtained from the animal itself, but is generally found floating on the surface of the sea.

Wax, you know, is a concrete oil, the peculiar product of the bee, part of the constituents of which may probably be derived from flowers, but so prepared by the organs of the bee, and so mixed with its own substance, as to be decidedly an animal product. Bees'-wax is naturally of a yellow colour, but it is bleached by long exposure to the atmosphere, or may be instantaneously whitened by the oxy-muriatic acid. The combustion of wax is far more perfect than that of tallow, and consequently produces a greater quantity of light and heat.

Lac is a substance very similar to wax in the manner of its formation; it is the product of an insect which collects its ingredients from flowers, apparently for the purpose of protecting its eggs from injury. It is formed into cells fabricated with as much skill as those of the honey-comb, but differently arranged. The principal use of lac is in the manufacture of sealing-wax, and in dying scarlet.

Musk, *civet*, and *castor*, are other particular productions, from different species of quadrupeds. The two first are very powerful perfumes; the latter has a nauseous smell and taste, and is only used medicinally.

Caroline. Is it from this substance that castor oil is obtained?

Mrs. B. No. Far from it, for castor oil is a vegetable oil, expressed from the seeds of a particular plant; and has not the least resemblance to the medicinal substance obtained from the castor.

Silk is a peculiar secretion of the silk worm, with which it builds its nest or cocoon. This insect was originally brought to Europe fiom China. Silk, in its chemical nature, is very similar to the hair and wool of animals. The moth of the silk worm ejects a liquor which appears to contain a particular acid, called *bombic*, the properties of which are very little known.

Emily. Before we conclude the subject of the animal economy, shall we not learn by what steps animals return to their elementary state?

Mrs. B. Animal matter, although the most complicated of all natural substances, returns to its elementary state by one single spontaneous process, the *putrid fermentation*. By this, the gelatine, albumen, and fibrine, are slowly reduced to the state of oxygen, hydrogen, nitrogen, and carbone; and thus the circle of changes through which these principles have passed is finally completed. They first quitted their elementary form, or their combination with unorganized matter, to enter into the vegetable system.—Hence they were transmitted to the animal kingdom; and from this they return again to their primitive simplicity, soon to re-enter the sphere of organized existence.

When all the circumstances necessary to produce fermentation do not take place, animal, like vegetable matter, is liable to a partial or imperfect decomposition, which converts it into a combustible substance very like spermaceti. I dare say that Caroline, who is so fond of analogies, will consider this as a kind of animal bitumen.

Caroline. And why should I not, since the processes, that produce these substances are so similar.

Mrs. B. There is, however, one considerable difference; the state of bitumen seems permanent, whilst that of animal substances, thus imperfectly decomposed, is only transient; and, unless precautions be taken to preserve them in that state, a total dissolution infallibly ensues. This circumstance, of the occasional conversion of animal matter into a kind of spermaceti, is of late discovery. A manufacture has in consequence been established near Bristol, in which, by exposing the carcases of horses and other animals for a length of time under water, the muscular parts are converted into this spermaceti-like substance. The bones afterwards undergo a different process to produce hartshorn, or, more properly, ammonia, and phosphorous; and the skin is prepared for leather.

Thus art contrives to enlarge the sphere of useful purposes, to which the elements were intended by nature; and the productions of the several kingdoms are frequently arrested in their course, and variously modified, by human skill, which compels them to contribute, under new forms, to the necessities or luxuries of man.

But all that we enjoy, whether produced by the spontaneous operations of nature, or the ingenious efforts of art, proceed alike from the goodness of Providence.—To GOD alone man owes the admirable faculties which enable him to improve and modify the productions of nature, no less than those productions themselves. In contemplating the works of the creation, or studying the inventions of art, let us, therefore, never forget the Divine Source from which they proceed; and thus every acquisition of knowledge will prove a lesson of piety and virtue.

END OF THE LONDON COPY.

An abridgement of the Bakerian Lecture on the decomposition of the fixed alkalies and the exhibition of the new substances which constitute their bases: by Humphrey Davy, esq. secretary of the Royal Society.

THE researches I had made on the decomposition of acids, and of alkaline and earthly neutral compounds, proved that the powers of electrical decomposition were proportional to the strength of the opposite electricities in the circuit, and to the conducting power and degree of concentration of the materials employed. In the first attempts I made on the decomposition of the fixed alkalies, I acted upon aqueous solutions of potash and soda, saturated at common temperatures, by the highest electrical power I could command, and which was produced by a combination of voltaic batteries, belonging to the Royal Institution, containing 24 plates of copper and zinc of 12 inches square, 100 plates of 6 inches, and 150 of 4 inches square, charged with solutions of alum and nitrous acid; but in these cases, though there was a high intensity of action, the water of the solutions alone was effected, and hydrogen and oxygen disengaged with the production of much heat and violent effervescence. The presence of water appearing thus to prevent any decomposition, I used potash in igneous fusion. By means of a stream of oxygen gas from a gasometer applied to the flame of a spirit lamp, which was thrown on a platina spoon containing potash, this alkali was kept for some minutes in a strong red heat, and in a state of perfect fluidity. The spoon was preserved in communication with the positive side of the battery, of the power of 100 of inches, highly charged; and the connection from the negative side was made by a platina wire. By this arrangement some brilliant phenomena were produced. The potash appeared a conductor, in a high degree, and as long as the communication was preserved, a most intense light was exhibited at the negative wire, and a column of flame, which seemed to be owing to the developement of combustible matter, arose from the point of contact. When the order was changed, so that the platina spoon was made negative, a vivid, constant light appeared at the opposite point. There was no effect of inflammation round it, but æriform globules, which inflamed in the atmosphere, rose through the potash. The platina, as might have been expected, was considerably acted upon; and in the cases when it had been negative in the highest degree.

. The alkali was apparently dry in this experiment; and it seemed probable, that the inflammable matter arose from its decomposition. The residual potash was unaltered; it contained, indeed, a number of dark grey metallic particles, but these proved to be derived from the platina.

I tried several experiments on the electrization of potash, rendered fluid by heat, with the hopes of being able to collect the combustible matter, but without success; and I only attained my object, by employing electricity, as the common agent for fusion and decomposition. Though potash, perfectly dried by ignition, is a non-conductor, yet it is rendered a conductor by a very slight addition of moisture, which does not perceptibly destroy its aggregation; and in this state it readily fuses and decomposes by strong electrical powers.

A small piece of pure potash, which had qeen exposed for a few seconds to the atmosphere, so as to give conducting power to the surface, was placed upon an insulated disc of platina, connected with the negative side of the battery, of the power of two hundred and fifty of six and four, in a state of intense activity; and a platina wire, communicating with the positive side, was brought in contact with the upper surface of the alkali. The whole apparatus was in the open atmosphere.

Under these circumstances, a vivid action was soon observed to take place. The potash began to fuse at both its points of electrization. There was a violent effervescence at the upper surface: at the lower or negative surface, there was no liberation of elastic fluid; but small globules, having a high metallic lustre, and being precisely similar, in visible characters to quicksilver, appeared; some of which burnt with explosion, and bright flame, as soon as they were formed, others remained, and were merely tarnished, and finally covered by a white film, which formed on their surfaces. These globules, numerous experiments soon showed to be the substance I was in search of, and a peculiar inflammable principle the basis of potash. I found that the platina was in no way connected with the result, except as the medium for exhibiting the electrical powers of decomposition; and a substance of the same kind was produced, when pieces of copper, silver, gold, plumbago, and even charcoal were employed for completing the circuit. The phenomenon was independent of the presence of air. I found that it took place when the alkali was in the vacuum of an exhausted receiver. The substance was likewise produced from potash fused by means of a lamp, in glass tubes confined by mercury, and furnished with hermetically inserted platina wires, by which the electrical action was transmitted. But this operation could not be carried on for any considerable time; the glass was rapidly dissolved by the action of the alkali, and this substance soon penetrated through the body of the tube.

Soda, when acted upon in the same manner as potash, exhibited an analogous result; but the decomposition demanded greater intensity of action in the batteries, or the alkali was required to be in much thinner and smaller pieces. With the battery of one hundred of six inches in full activity, I obtained good results from pieces of potash weighing from forty to seventy grains, and of a thickness which made the distance of the electrified metallic surfaces nearly a quarter of an inch; but with a similar power it was impossible to produce the effects of decomposition on pieces of soda of more than fifteen and twenty grains in weight, and that only when the distance between the wires was about one eighth or one tenth of an inch.

The substance produced from potash remained fluid at the temperature of the atmosphere at the time of its production; that from soda, which was fluid in the degree of heat of the alkali during its formation, became solid on cooling, and appeared having the lustre of silver.

When the power of two hundred and fifty was used with a very high charge for the decomposition of soda, the globules often burnt at the moment of their formation, and sometimes violently exploded and separated into smaller globules, which flew with great velocity through the air, in a state of vivid combustion, producing a beautiful effect of continued jets of fire.

III. *Theory of the Decomposition of the fixed Alkalies; their Composition and Production.*

As in all decompositions of compound substances which I had previously examined, at the same time that combustible bases were developed at the negative surface in the electrical circuit, oxygen was produced, and evolved or carried into combination at the positive surface; it was reasonable to conclude that this substance was generated in a similar manner by the electrical action upon the alkalies, and a number of experiments made above mercury, with the apparatus for excluding external air, proved that this was the case.

When solid potash, or soda in its conducting state, was included in glass tubes, furnished with electrified platina wires, the new substances were generated at the negative surfaces; the gas given out at the other surface proved, by the most delicate examination, to be pure oxygen; and unless an excess of water was present, no gas was evolved from the negative surface.

In the synthetical experiments, a perfect coincidence likewise will be found.

I mentioned that the metallic lustre of the substance from potash immediately became destroyed in the atmosphere, and that a white crust formed upon it. This crust I soon found to be pure potash, which immediately deliquesced, and new quantities were formed, which in their turn attracted moisture from the atmosphere, till the whole globule disappeared, and assumed the form of a saturated solution of potash.

When globules were placed in appropriate tubes, containing common air or oxygen gas, confined by mercury, an absorption of oxygen took place; a crust of alkali instantly formed upon the globule; but from the want of moisture for its solution the process stopped, the interior being defended from the action of the gas.

With the substances from soda the appearances and effects were analogous. When the substances were strongly heated, confined in given portions of oxygen, a rapid combustion with a brilliant white flame was produced, and the metallic globules were found converted into a white and solid mass, which, in the case of the substance from potash, was found to be potash, and in the case of that from soda, soda.

Oxygen gas was absorbed in this operation, and nothing emitted which effected the purity of the residual air. The alkalies produced were apparently dry, or at least contained no more moisture than might well be conceived to exist in the oxygen gas absorbed; and their weights considerably exceeded those of the combustible matters consumed. The processes on which these conclusions are founded will be fully described hereafter, when the minute details which are necessary will be explained, and the proportions of oxygen and of the respective inflammable substances which enter into union to form the fixed alkalies will be given.

It appears, then, that in these facts there is the same evidence for the decomposition of potash and soda into oxygen and two peculiar substances, as there is for the decomposition of sulphuric and phosphoric acids and the metallic oxyds into oxygen and their respective combustible bases.

In the analytical experiments, no substances capable of decomposition are present, but the alkalies and a minute portion of moisture; which seems in no other way essential to the result, than in rendering them conductors at the surface: for the new substances are not generated till the interior, which is dry, begins to be fused; they explode when in rising through the fused alkali; they come in contact with the heated moistened surface; they cannot be produced from crystallized alkalies, which contain much water; and the effects produced by the electrization of ignited potash, which contains no sensible quantity of water, confirm the opinion of their formation independently of the presence of this substance.

The combustible bases of the fixed alkalies seem to be repelled as other combustible substances, by positively electrified surfaces, and attracted by negatively electrified surfaces; and the oxygen follows the contrary order; or the oxygen being naturally possessed of the negative energy, and the bases of the positive do not remain in combination when either of them is brought into an electrical state opposite to its natural one. In the synthesis, on the contrary, the natural energies or attractions come in equilibrium with each other; and when these are in a low state at common temperatures, a slow combination is effected; but when they are exalted by heat, a rapid union is the result, as in other like cases with the production of fire.

A number of circumstances relating to the agencies of the bases will be immediately stated, and will be found to offer confirmations to these general conclusions.

IV. *On the Properties and Nature of the Basis of Potash.*

After I had detected the bases of the fixed alkalies, I had considerable difficulty to preserve and confine them so as to examine their properties, and submit them to experiments; for, like the alkahests imagined by the alchemists, they acted more or less upon almost every body to which they were exposed.

The fluid substance amongst all those I have tried, on which I find they have least effect, is recently distilled naphtha. In this material, when excluded from the air, they remain for many days without considerably changing, and their physical properties may be easily examined in the atmosphere when they are covered by a thin film of it. The basis of potash at 60° Fahrenheit, the temperature in which I first examined it, appeared, as I have already mentioned, in small globules, possessing the metallic lustre, opacity and general appearance of mercury; so that when a globule of mercury was placed near a globule of the peculiar substance, it was not possible to detect a difference by the eye.

At 60° Fahrenheit it is, however, only imperfectly fluid, for it does readily run into a globule when its shape is altered ; at 70° it becomes more fluid ; and at 100° its fluidity is perfect, so that different globules may be easily made to run into one. At 50° Fahrenheit it becomes a soft and malleable solid, which has the lustre of polished silver ; and at about the freezing point of water it becomes harder and brittle ; and, when broken in fragments, exhibits a crystallized texture, which, in the microscope, seems composed of beautiful facets of a perfect whiteness and high metallic splendour.

To be converted into vapour, it requires a temperature approaching that of the red heat ; and when the experiment is conducted under proper circumstances, it is found unaltered after distillation.

It is a perfect conductor of electricity. When a spark from the voltaic battery of an hundred of six inches is taken upon a large globule in the atmosphere, the light is green, and combustion takes place at the point of contact only. When a small globule is used it is completely dissipated with explosion, accompanied by a most vivid flame, into alkaline fumes. It is an excellent conductor of heat. Resembling the metals in all these sensible properties, it is, however, remarkably different from any of them in specific gravity. I found that it rose to the surface of naphtha distilled from petroleum, and of which the specific gravity was eight hundred and sixty-one, and it did not sink in double distilled naphtha, the specific gravity of which was about seven hundred and seventy, that of water being considered as one. The small quantities in which it is produced by the highest electrical powers, rendered it very difficult to determine this quality with minute precision. I endeavored to gain approximations on the subject by comparing the weights of perfectly equal globules of the basis of potash and mercury. I used the very delicate balance of the Royal Institution, which, when loaded with the quantities I employed, and of which the mercury never exceeded ten grains, is sensible, at least, to the $\frac{1}{1000}$ of a grain. Taking the mean of four experiments, conducted with great care, its specific gravity at 62° Fahrenheit, is to that of mercury as 10 to 223, which gives a proportion to that of water nearly as 6 to 10; so that it is the lightest fluid body known. In its solid form it is a little heavier; but even in this state, when cooled to 40° Fahrenheit, it swims in the double distilled naphtha.

The chemical relations of the basis of potash are still more extraordinary than its physical ones.

I have already mentioned its alkalization and combustion in oxygen gas. It combines with oxygen slowly and without flame at all temperatures that I have tried below that of its evaporation. But at this temperature combustion takes place, and the light is of a brilliant whiteness, and the heat intense. When heated slowly in a quantity of gas not sufficient for its complete conversion into potash, and at a temperature inadequate to its inflammation, 400° Fahrenheit for instance, its tint changes to that of a red brown, and when the heat is withdrawn, all the oxygen is found to be absorbed, and a solid is formed of a greyish colour, which partly consists of potash, and partly of the basis of potash in a lower degree of oxygenation, and which becomes potash by being exposed to water, or by being again heated in fresh quantities of air. The substance consisting of the basis of potash combined with an under proportion of oxygen, may likewise be formed by fusing dry potash and its basis together under proper circumstances. The basis rapidly loses its metallic splendour; the two substances unite into a compound of a red brown colour when fluid, and of a dark grey hue when solid; and this compound soon absorbs its full proportion of oxygen when exposed to the air, and is wholly converted into potash.

And the same body is often formed in the analytical experiments when the action of the electricity is intense, and the potash much heated.

The basis of potash, when introduced into oxymuriatic acid gas, burns spontaneously with a bright red light, and a white salt, proving to be muriat of potash, is formed.

When a globule is heated in hydrogen at a degree below its point of vaporization, it seems to dissolve in it, for the globule diminishes in volume, and the gas explodes with alkaline fumes and bright light, when suffered to pass into the air ; but by cooling, this spontaneous detonating property is destroyed, and the basis is either wholly or principally deposited.

The action of the basis of potash on water exposed to the atmosphere is connected with some beautiful phenomena. When it is thrown upon water, or when it is brought into contact with a drop of water at common temperature, it decomposes it with great violence, an instantaneous explosion is produced with brilliant flame, and a solution of pure potash is the result.

In experiments of this kind, an appearance often occurs similar to that produced by the combustion of phosphorated hydrogen ; a white ring of smoke, which gradually extends as it rises into the air.

When water is made to act upon the basis of potash out of the contact of air, and preserved by means of a glass tube under naphtha, the decomposition is violent ; and there is much heat and noise but no luminous appearance ; and the gas evolved, when examined in the mercurial or water pneumatic apparatus, is found to be pure hydrogen.

When a globule of the basis of potash is placed upon ice, it instantly burns with a bright flame, and a deep hole is made in the ice, which is found to contain a solution of potash.

The theory of the action of the basis of potash upon water exposed to the atmosphere, though complicated changes occur, is far from being obscure. The phenomena seem to depend on the strong attractions of the basis for oxygen and of the potash formed for water. The heat which arises from two causes, decomposition and combination, is sufficiently intense to produce the inflammation. Water is a bad conductor of heat ; the globule seems exposed to air ; a part of it, there is the greatest reason to believe, is dissolved by the heated nascent hydrogen ; and this substance being capable of spontaneous inflammation, explodes and communicates the effect of combustion to any of the basis that may be yet uncombined.

When a globule confined out of the contact of air is acted upon by water, the theory of decomposition is very simple ; the heat produced is rapidly carried off, so that there is no ignition ; and a high temperature being requisite for the solution of the basis in hydrogen, this combination probably does not take place, or at least it may have a momentary existence only.

The production of alkali in the decomposition of water by the basis of potash, is demonstrated in a very simple and satisfactory manner by dropping a globule of it upon moistened paper tinged with termeric. At the moment that the globule comes into contact with the water, it burns, and moves rapidly upon the paper, as if in search of moisture, leaving behind it a deep reddish-brown trace, and acting upon the paper precisely as dry caustic potash.

So strong is the attraction of the basis of potash for oxygen, and so great the energy of its action upon water, that it discovers and decomposes the small quantities of water contained in alcohol and ether, even when they are carefully purified.

In ether this decomposition is connected with an instructive result. Potash is insoluble in this fluid ; and when the basis of potash is thrown into it, oxygen is furnished to it, and hydrogen disengaged, and the alkali, as it forms, renders the ether white and turbid.

In both these inflammable compounds the energy of its action is proportionable to the quantity of water they contain, and hydrogen and potash are the constant result.

The basis of potash, when thrown into solutions of the mineral acids, inflames and burns on the surface. When it is plunged by proper means beneath the surface enveloped in potash, surrounded by naphtha, it acts upon the oxygen with the greatest intensity, and all its effects are such as may be explained from its strong affinity for this substance. In sulphuric acid a white saline substance, with a yellow coating, which is, probably, sulphat of potash surrounded by sulphur, and a gas which has the smell of sulphurous acid, and which, probably, is a mixture of that substance with hydrogen gas, are formed. In nitrous acid, nitrous gas is disengaged, and nitrat of potash formed.

The basis of potash readily combines with the simple inflammable solids, and with the metals ; with phosphorus and sulphur it forms compounds similar to the metallic phosphorets and sulphurets. When it is brought in contact with a piece of phosphorus and pressed upon, there is a considerable action : they become fluid together, burn, and propuce phosphorat of potash. When the experiment is made under naphtha, their combination takes place without the liberation of any elastic matter, and they form a compound which has a considerably higher point of fusion than its two constituents, and which remains a soft solid in boiling naphtha. In its appearance it perfectly agrees with a metallic phosphoret; it is of the colour of lead, and, when spread out, has a lustre similar to polished lead. When exposed to air at common temperatures it slowly combines with oxygen, and becomes phosphat of potash. When heated upon a plate of platina, fumes exhale from it, and it does not burn till it attains the temperature of the rapid combustion of the basis of potash. When the basis of potash is brought in contact with sulphur in fusion, in tubes filled with the vapour of naphtha, they combine rapidly with the evolution of heat and light, and a grey substance, in appearance like artificial sulphuret of iron, is formed, which, if kept in fusion, rapidly dissolves the glass, and becomes bright brown. When this experiment is made in a glass tube hermetically sealed, no gas is liberated if the tube is opened under mercury ; but when it is made in a tube connected with a mercurial apparatus, a small quantity of sulphurated hydrogen is evolved, so that the phenomena are similar to those produced by the union of sulphur with the metals in which sulphurated hydrogen is likewise disengaged, except that the ignition is stronger.

Copper filings and powdered sulphur, in weight in the proportion of three to one, rendered very dry, were heated together in a retort, connected with a mercurial pneumatic apparatus. At the moment of combination a quantity of elastic fluid was liberated, amounting to nine or ten times the volume of materials employed, and which consisted of sulphurated hydrogen mixed with sulphureous acid. The first mentioned product, there is every reason to believe, must be referred to the sulphur; the last probably to the copper, which, it is easy to conceive, may have become slightly and superficially oxydated during the processes of filing and drying by heat.

When the union is effected in the atmosphere, a great inflammation takes place, and sulphuret of potash is formed. The sulphureted basis likewise gradually becomes oxygenated by exposure to the air, and is finally converted into sulphate. The new substance produces some extraordinary and beautiful results with mercury. When one part of it is added to eight or ten parts of mercury in volume at 60° Fahrenheit, they instantly unite and form a substance exactly like mercury in colour, but which seems to have less coherence; for small portions of it appear as flattened spheres. When a globule is made to touch a globule of mercury about twice as large, they combine with considerable heat; the compound is fluid at the temperature of its formation; but, when cool, it appears as a solid metal, similar in colour to silver. If the quantity of the basis of potash is still farther increased, so as to be about one thirtieth the weight of the mercury, the amalgam increases in hardness, and becomes more brittle. The solid amalgam, in which the basis is in the smallest proportion, seems to consist of about one part in weight of basis, and seventy parts of mercury, and is very soft and malleable.

When these compounds are exposed to air, they rapidly absorb oxygen; potash, which deliquesces, is formed, and in a few minutes the mercury is found pure and unaltered.

When a globule of the amalgam is thrown into water it rapidly decomposes it, with a hissing noise; potash is formed, pure hydrogen is disengaged, and the mercury remains free.

The fluid amalgam of mercury and this substance dissolves all the metals I have exposed to it; and in this state of union mercury acts on iron and platina. When the basis of potash is heated with gold, or silver, or copper, in a close vessel of pure glass, it rapidly acts upon them; and when the compounds are thrown into water, this fluid is decomposed, potash formed, and the metals appear to be separated unaltered.

The basis of potash combines with fusible metal, and forms an alloy with it, which has a higher point of fusion than the fusible metal.

The action of the basis of potash upon the inflammable oily compound bodies, confirms the other facts of the strength of its attraction for oxygen.

On naphtha, colourless and recently distilled, as I have already said, it has very little power of action; but in naphtha that has been exposed to the air, it soon oxydates, and alkali is formed, which unites with the naphtha into a brown soap that collects round the globule.

On the concrete oils, (tallow, spermaceti, wax, for instance) when heated it acts slowly, coaly matter is deposited, a little gas is evolved, and a soap is formed; but in these cases it is necessary that a large quantity of the oil be employed. On the fluid fixed oils it produces the same effects, but more slowly.

By heat likewise it rapidly decomposes the volatile oils; alkali is formed, a small quantity of gas is evolved, and charcoal is deposited.

When the basis of potash is thrown into camphor in fusion, the camphor soon becomes blackened, no gas is liberated in the process of decomposition, and a saponaceous compound is formed; which seems to shew that camphor contains no more oxygen than the volatile oils.

The basis of potash readily reduces metallic oxyds when heated in contact with them. When a small quantity of the oxyd of iron was heated with it, to a temperature approaching its point of distillation, there was a vivid action; alkali and grey metallic particles, which dissolved with effervescence in muriatic acid, appeared.

The oxyds of lead and the oxyds of tin were revived still more rapidly; and when the basis of potash was in excess, an alloy was formed with the revived metal.

In consequence of this property the basis of potash readily decomposes flint glass, and green glass, by a gentle heat ; alkali is immediately formed by oxygen from the oxyds, which dissolves the glass, and a new surface is soon exposed to the agent. At a red heat even the purest glass is altered by the basis of potash : the oxygen in the alkali of the glass seems to be divided between the two bases, the basis of potash and the alkaline basis in the glass and oxyds, in the first degree of oxygenation, are the result. When the basis of potash is heated in tubes made of plate glass, filled with vapour of naphtha, it first acts upon the small quantity of oxyds of cobalt and manganese in the interior surface of the glass, and a portion of alkali is formed. As the heat approaches to redness it begins to rise in vapour, and condense in the colder parts of the tube ; but at the point, where the heat is strongest, a part of the vapour seems to penetrate the glass, rendering it a deep red-brown colour ; and by repeatedly distilling and heating the substance in a close tube of this kind, it finally loses its metallic form, and a thick brown crust, which slowly decomposes water, and which combines with oxygen when exposed to air, forming alkali, lines the interior of the tube, and in many parts is found penetrating through its substance.

The basis of soda, is solid at common temperatures. It is white opaque, and when examined under a film of naphtha has the lustre and general appearance of silver. It is exceedingly malleable. Its specific gravity is less than that of water about 9 to 10, or. 9348 to 1.

The basis of soda has a much higher point of fusion than the basis of potash, its chemical phenomena are analogous to those produced by the basis of potash.

The proportions of the peculiar basis, and oxygen in potash and soda are, about six parts basis and one of oxygen in potash, and seven parts of basis and two of oxygen in soda.

PNEUMATIC CISTERN of Yale College.

An instrument has been for several years used in the laboratory of Yale College, for experiments in the large way, on the gases which water does not rapidly adsorb, which has been found to be more convenient and complete than any other arrangement of apparatus for similar purposes. The only instrument of the kind which has ever been constructed, was manufactured in New-Haven. [*See Frontispiece.*] Being calculated for an extensive course of public lectures, delivered in a laboratory where there is plenty of room, its dimensions are larger than might be worth while in establishments on a smaller scale. Its form is that of a parallelopipedon, 7$\frac{1}{8}$ feet long, 3 feet wide, and 2 feet 2 inches deep, without allowing for the two inch pine plank of which this part of the instrument is constructed. The several planks and parts are connected by grooves and tongues, and bound together by iron rods, passing laterally through them, and terminating in screws furnished with nuts. The interior part is furnished with two shelves, [A.A.A.A.] each two feet six inches long, for sustaining air-jars and bell-glasses; the middle space between these is one foot eight inches wide, and forms a well [H] for immersing the bell-glasses; across this well is placed a sliding shelf, [G] with three inverted shallow tin funnels beneath it, corresponding with as many holes for receiving and transferring gases. Thus far, it is obvious that the instrument is only a very extensive pneumatic cistern, and has no superiority over those commonly in use, except from its affording ample space for a very important and interesting class of experiments, which are much more impressive and convincing to a large audience, when performed on a large scale. There are, however, a number of additional contrivances. Beneath each of the shelves are two inverted rectangular boxes, [*shewn by dotted lines at* I. I. *and under* A.A.A.A.] made of thin pine plank, dovetailed together at the angles, entirely open below, and attached to the inferior side of the shelves by tongues, grooves, and wood-screws. These boxes are twelve inches deep, of the capacity of about 12 gallons each, and occupy the whole space beneath the shelves except 7,5 inches at each end of the cistern, and nine inches between the bottom of the boxes and the bottom of the cistern. This latter space is reserved to give room for the action of three pair of hydrostatic bellows. [B.B.] They are made of leather, nailed to the bottom of the cistern, distended by circular iron rings, and attached by nails to a thick circular plank which serves as a top, and which is moved up and down by an iron rod connected with an iron lever, [C.C.C.] which rests on a forked iron support, attached to the upper edge of the end of the cistern. The bellows are so placed, that nearly one half projects beneath the boxes, which we may call reservoirs; the other part is beneath the open space which lies between the end of the reservoirs and the end of the cistern, and the rod of the bellows perforates the shelf immediately at the termination of the box and contiguous to it, but does not pass through the box, which must be air-tight. At the edge of that part of the bellows which projects beneath the reservoir, is a valve opening upward; in the centre of the bellows and on the bottom of the cistern, which is also the bottom of the bellows, is another valve opening upwards, covering an orifice which is connected with a duct, leading out, laterally, through the plank, edgewise, to the atmosphere. Into this duct is inserted a copper tube, [D.D.] consisting of two parts, one of which forms merely a portion of the duct, being driven into it so that it forms a perfectly tight connection; the other part is soldered to this at right angles, and ascends in close contact with the outside of the cistern, till it rises two inches higher than its upper edge, and there it opens in an orifice somewhat dilated. Each of the four reservoirs may be considered as furnished with the apparatus of bellows, duct, valves, and tube; although in the instrument to which this description refers, there are in fact but three bellows, &c. one reservoir being destitute of them. It remains to be remarked, that each reservoir is furnished with a stop-cock, which lies horizontally upon the shelf and partly imbedded in it, and passes into the reservoir by a short tube of copper, soldered at right angles with the cock. The cocks of the two contiguous reservoirs are placed parallel to each other and to the sides of the cistern, and immediately contiguous to the partition which separates the reservoirs, and they are connected by a third stop-cock soldered to each of them, opening into both by proper orifices, and thus serving, when occasion requires, to connect the reservoirs, and in fact, to convert two into one. Through each of the shelves, at the angles of the two reservoirs which are contiguous at once to that side of the cistern which may be regarded as its back part, and to the well, a hole is bored into the reservoir for the insertion of a copper tube [E.E] for a blow-pipe. These tubes are so formed, that while one part is pressed firmly into the hole so as to be air-tight, another part, at right angles with the first, and bending in a pretty large curve, terminates in a trumpet-like orifice, adapted to the insertion of a cork. Immediately beneath these two orifices is a table, [F.] attached by hinges to the side of the cistern, to sustain a lamp for the blow-pipe; when not in use, it hangs by the side of the cistern, and is raised occasionally, as it is wanted.

To an intelligent chemist, it will be obvious from an attentive perusal of the description, that this instrument will afford all the following advantages.

1. It is an extensive pneumatic cistern, with every common convenience, on a large scale.

2. By the bellows and their appendages, common air may be thrown into the reservoirs, by which means the height of the water on the shelves may be increased at pleasure, when it is too low.

3. By permitting a portion of this air to escape, by opening one of the horizontal cocks, the height of the water on the shelves may be diminished at pleasure; thus we have means of graduating the height of the water precisely to our purpose without lading it out or in.

4. We have four capacious air-holders in the very place where the gases are produced, viz. in the pneumatic cistern; thus, four different kinds of gases may be stored away under water in a space otherwise useless. For instance, common air, for regulating the height of the water, or, for the blow-pipe, may be in one reservoir; oxygen gas in a second, hydrogen gas in a third, and olefiant gas in a fourth, and they may be thus reserved for future use.

5. The gases may be drawn off for use into bell-glasses, merely by bringing those bell-glasses, filled with water, over the horizontal cocks.

6. It is obvious that the four reservoirs are in fact four large gasometers; they want nothing to entitle them to this character, except a scale which a moderate share of ingenuity would easily adapt to them; the gases may be delivered into them at once by crooked tubes passing from the gas-bottles, and any gas contained in a bell-glass may be thrown into a reservoir, by a single stroke of the bellows. For this purpose a crooked tube connected with that which leads to the bellows and terminating in the well beneath an air jar, is all that is necessary. Or, by baring the arm, the gas may be thrown up by the hand, into the reservoirs, the jar being pushed down through the water.

7. It affords an excellent blow-pipe for common purposes and for the fine experiments with oxygen gas; and, by fitting to it Mr. Hare's very ingenious apparatus of the silver cylinder, it becomes the *compound blow-pipe*, for the invention and application of which he deserves so much credit. By the same contrivance water is formed with the greatest facility by burning the two gases as they come from their respective reservoirs, and issue at a common orifice, covering the flame with a receiver.

8. The inflammable gases being confined beneath the pressure of water, will issue at any orifices, where they are permitted, and thus all the ornamental as well as useful purposes to which the combustion of these gases is applied, may be exhibited; particularly, the gas from fossil coal may be made to burn in revolving jets, stars, and other fanciful and useful forms, merely by substituting for a blow-pipe tube, the apparatus proper for this exhibition.

All these purposes, this instrument has fully answered during several years; and it may be confidently recommended to lecturers on chemistry, and, on a smaller scale would be very valuable to a private chemist. A forcing pump might be substituted for the bellows, with a saving of the space which the bellows occupy, but it would be probably less convenient in practice.

This first idea of this instrument was suggested by Mr. Hare's compound blow-pipe. Being mentioned to that gentleman, the subject was prosecuted in common, and so far matured that it was afterwards executed by the writer, B. Silliman.

MANUFACTURE OF MINERAL WATERS.

THE extensive utility of many of the natural mineral waters has been long established by the experience of mankind, and sanctioned by the opinions of the first medical practitioners of every enlightened country.—The accurate analysis of all the most important and most celebrated mineral waters has been accomplished, by men competent to the task ; and we are thus informed not only concerning the *nature*, but the *proportion* of the ingredients which they contain. They are either *solid substances*, such as water can dissolve, or *gases*, capable of being combined with this fluid. To both of these the mineral waters owe their medicinal powers, and to the latter alone, *and chiefly to the carbonic acid*, their peculiar activity, briskness and pungency.

In the manufacture of artificial mineral waters, the original water is perfectly imitated, by the addition of all the ingredients in the proper proportions ; and the gas, by a peculiar and very powerful apparatus is afterwards forced in, till the waters acquire a degree of briskness and activity far surpassing any thing which they ever exhibit in nature. The impression, entertained by some, that a perfect imitation of the native mineral waters is impossible, is therefore equally contrary to the decisions of good sense, as it is repugnant to experience ; for in London, in Paris, and in many other great towns, artificial mineral waters are thus fabricated ; and used to a great extent.

In the artificial waters, we always have it in our power, to leave out noxious, or useless ingredients ; to substitute others, and to vary the proportions at pleasure.

Every species of mineral waters whatever can be prepared by art, but the principal ones that have been attempted in this country, are the Ballstown, Soda, and the Seltzer waters.

BALLSTOWN WATER.

The Ballstown water is well known in the United States as a gentle cathartic,—an active diuretic,—a remedy against gravelly complaints,—a tonic to the stomach, and generally to the system ;—not to mention its efficacy against rheumatic, and cutaneous complaints, when applied externally, as well as internally. It remains to be added, only, that the artificial Ballstown water is found by experience to produce the effects of the natural water; it is however more powerful, and therefore an equal quantity produces more marked effects.

SODA WATER.

The Soda water is not an exact imitation of *any* natural water, but has been directed by medical men as a remedy in a number of common and troublesome complaints. It is ordered in the pharmacopeias and dispensatories, and their prescriptions should be followed in this manufacture. It is a complete remedy against sourness of the stomach, commonly called heartburn, and in most cases of indigestion and weakness of the stomach it is very useful; gradually restoring the appetite, and with it the tone of the organ; it is a preventative of many of the diseases of the stomach and bowels, which proceed from acidity, and for the same reason it often removes or prevents the sick head-ache.

As a palliative, and even a remedy, in some cases of urinary calculi and gravelly complaints, it is preferable to the Ballstown water. It may prevent, arrest, retard, or remove the complaint according to circumstances.

The Soda water is also a very refreshing, and to most persons a very grateful drink, especially after heat and fatigue, and may be made a complete substitute for the beverages of which ardent spirits form a part.—With wine and sugar it is very grateful.

SELTZER WATER.

The Seltzer water has long been known, and is one of the most famous of the natural mineral waters of Europe. On account of its agreeable taste, and exhilirating effects, it is largely used at table, and as a beverage at all hours. It is a diuretic, and possesses considerable efficacy in nephictic and urinary complaints; it is very useful against bilious and dyspeptic affections, and in many cases of cutaneous eruptions.

It possesses a peculiar power of allaying feverish irritation, and has done much service in slow hectic fevers; it mixes well with milk, and is thus used with advantage by hectic patients.—It is used also with sugar and wine.

The manufacture of mineral waters upon correct chemical principles was undertaken in New-Haven, Connecticut, about three years ago; and during the last summer, a public establishment for this purpose was opened in the same town, under the direction of Professor Silliman.

An establishment of the same kind, and under the same direction, was effected in New-York in April of this year, (1809) by Noyes Darling & Co. Fountains of Ballstown, Soda, and Seltzer waters were opened in the bar of the Tontine Coffee House. The cisterns are placed in the cellar, and the waters are conveyed into the bar in block-tin tubes, which pass up into mahogany pillars, crowned with gilt urns, lettered with the names of the respective waters. The pillars, with their urns, stand a foot apart, and the middle one is raised above the others; silver stop-cocks inserted into the sides of the pillars, give the whole much neatness and richness of appearance.

The proprietors of this establishment intend, as we understand, to open fountains at the City Hotel, in the month of May, in a spacious room, fitted up and ornamented in a handsome style, and adapted to the accommodation of ladies as well as gentlemen.

The Ballstown and Seltzer waters are prepared according to an accurate analysis; and in order to give the Soda water its proper efficacy, it is made with the full proportion of Soda directed by the dispensatories.

The waters are bottled for exportation, in any quantity demanded.

Soda water has been made in New-York by Mr. Usher, for a year or more, and has had a good reputation and an extensive sale. It has been sold from a fountain, and in stone bottles. We understand that he is about to extend his establishment.

There have been, for some time, manufactories of mineral waters in the city of Philadelphia, and we are informed that these waters have been extensively used.

APPENDIX.

DYEING.

Principles of Dyeing.

The substances commonly employed for clothing may be reduced to four; namely, wool, silk, cotton, and linen.

Permanent alterations in the colour of cloth can only be induced two ways; either by producing a chemical change in the cloth, or by covering its fibres with some substance which possesses the wished for colour. Recourse can seldom or never be had to the first method, because it is hardly possible to produce a chemical change in the fibres of cloth without spoiling its texture and rendering it useless. The dyer, therefore, when he wishes to give a new colour to cloth, has always recourse to the second method.

The substances employed for this purpose are called *colouring matters*, or *dye stuffs*. They are for the most part extracted from animal and vegetable substances, and have usually the colour which they intend to give to the cloth.

Since the particles of colouring matter with which cloth, when dyed, is covered, are transparent, it follows, that all the light reflected from dyed cloth must be reflected, not by the dye stuff itself, but by the fibres of the cloth below the dye stuff. The colour therefore does not depend upon the dye alone, but also upon the previous colour of the cloth. If the cloth be *black*, it is clear that we cannot dye it any other colour whatever; because as no light in that case is reflected, none can be transmitted, whatever dye stuff we employ. If the cloth were red, or blue, or yellow, we could not dye it any other colour except black; because, as only red, or blue, or yellow rays were reflected, no other could be transmitted. Hence the importance of a fine white colour, when cloth is to receive bright dyes. It then reflects all the rays in abundance, and therefore any colour may be given, by covering it with a dye stuff which transmits only some particular rays.

If the colouring matters were merely spread over the surface of the fibres of cloth by the dyer, the colours produced might be very bright, but they could not be permanent; because the colouring matter would be very soon rubbed off; and would totally disappear whenever the cloth was washed, or even barely exposed to the weather. The colouring matter then, however perfect a colour it possesses, is of no value, unless it also adheres so firmly to the cloth that none of the substances usually applied to cloth, in order to clean it, &c. can displace it. Now this can only happen, when there is a strong *affinity* between the colouring matter and the cloth, and when they are actually combined together in consequence of that affinity.

Dyeing then is merely a chemical process, and consists in combining a certain colouring matter with fibres of cloth. This process can in no instance be performed, unless the dye stuff be first reduced to its integrant particles; for the attraction of aggregation between the particles of dye stuffs, is too great to be overcome by the affinity between them and the cloth, unless they could be brought within much smaller distances than is possible while they both remain in a solid form. It is necessary, therefore, previously to dissolve the colouring matter in some liquid or other, which has a weaker affinity for it than the cloth has. When the cloth is dipped into this solution, the colouring matter, reduced by this contrivance to a liquid state, is brought within the attracting distance; the cloth therefore acts upon it, and from its stronger affinity, takes it from the solvent and fixes it upon itself. By this contrivance too, the equality of the colour is in some measure secured, as every part of the cloth has an opportunity of attracting to itself the proper proportion of colouring particles.

The facility with which cloth imbibes a dye, depends upon two things; namely, the affinity between the cloth and the dye stuff, and the affinity between the dye-stuff and its solvent. It is directly as the former, and inversely as the latter. It is of importance to preserve a due proportion between these two affinities, as upon that proportion much of the accuracy of dying depends. If the affinity between the colouring matter and the cloth be too great, compared with the affinity between the colouring matter and the solvent, the cloth will take the dye too rapidly, and it will be scarcely possible to prevent its colour from being unequal. On the other hand, if the affinity between the colouring matter and the solvent be too great, compared with that between the colouring matter and the cloth, the cloth will either not take the colour at all, or it will take it very slowly and very faintly.

Wool has the strongest affinity for almost all colouring matters; silk the next strongest, cotton a considerably weaker affinity, and linen the weakest affinity of all. Therefore, in order to dye cotton or linen, the dye stuff should in many cases be dissolved in a substance for which it has a weaker affinity than for the solvent employed in the dyeing of wool or silk. Thus we may use oxyd of iron dissolved in sulphuric acid, in order to dye wool; but for cotton and linen, it is better to dissolve it in acetous acid.

Were it possible to procure a sufficient number of colouring matters, having a strong affinity for cloth, to answer all the purposes of dyeing, that art would be exceedingly simple and easy. But this is by no means the case; if we except indigo, the dyer is scarcely possessed of a dye stuff which yields of itself a good colour, sufficiently permanent to deserve the name of a dye.

This difficulty, which at first sight appears insurmountable, has been obviated by a very ingenious contrivance. Some substance is pitched upon, which has a strong affinity, both for the cloth and the colouring matter. This substance is previously combined with cloth, which is then dipped into the solution containing the dye stuff. The dye stuff combines with the intermediate substance, which, being firmly combined with the cloth, secures the permanence of the dye. Substances employed for this purpose are denominated *mordants*.

The most important part of dying, is undoubtedly the proper choice, and the proper application of mordants, as upon them, the permanency of almost every dye depends. Every thing which has been said respecting the application of colouring matters, applies equally to the application of mordants. They must previously be dissolved in some liquid, which has a weaker affinity to them than the cloth has to which they are to be applied; and the cloth must be dipped, or even steeped in this solution, in order to saturate itself with the mordant.

Almost the only substances used as mordants, are earths, metalic oxyds, tan, and oil.

Of earthy mordants, the most important, and most generally used, is alumine. It is used either in the state of common alum, in which it is combined with sulphuric acid, or in that of acetite of alumine.

Alum, when used as a mordant, is dissolved in water, and very frequently a quantity of tartar is dissolved along with it. Into this solution the cloth is put, and kept in it till it has absorbed as much alumine as is necessary. It is then taken out, and for the most part washed and dried. It is now a good deal heavier than it was before, owing to the alumine which has combined with it. The tartar serves two purposes; the potash which it contains combines with the sulphuric acid of the alum, and thus prevents that very corrosive substance from injuring the texture of the cloth, which otherwise might happen; the tartareous acid, on the other hand, combines with part of the alumine, and forms a tartrit of alumine, which is more easily decomposed by the cloth than alum.

Acetite of alumine has been but lately introduced into dying. This mordant is now prepared by pouring acetite of lead into a solution of alum; a double decomposition takes place, the sulphurious acid combines with the lead, and the compound precipitates in the form of an insoluble powder, while the alumine combines with the acetous acid, and remains dissolved in the liquid. This mordant is employed for cotton and linen, which have a weaker affinity than wool for alumine. It answers much better than alum; the cloth is more easily saturated with alumine, and takes, in consequence, both a richer and a more permanent colour.

Besides alumine, *lime* is sometimes used as a mordant. Cloth has a strong enough affinity for it; but, in general, it does not answer so well, as it does not give so good a colour. When used, it is either in the state of lime water, or of sulphat of lime dissolved in water.

Almost all the metalic oxyds have an affinity for cloth, but only two of them are extensively used as mordants, namely, the oxyds of tin, and of iron.

The oxyd of tin was first introduced into dyeing by Kuster, a German chemist, who brought the secret to London in 1543. This period forms an era in the history of dyeing. The oxyd of tin has enabled the moderns greatly to surpass the ancients in the finess of their colours; by means of it alone, *scarlet*, the brightest of all colours is produced.

Tin, as Proust has proved, is capable of two degrees of oxydation. The first oxyd is composed of 0.70 parts of tin, 0. 30 of oxygen; the second, or white oxyd, of 0. 60 parts of tin, and 0. 40 of oxygen. The first oxyd absorbs oxygen with very great facility, even from the air, and is rapidly converted into white oxyd. This fact makes it certain, that it is the white oxyd of tin alone, which is the real mordant; even if the other oxyd were applied to cloth, as it probably often is, it must soon be converted into white oxyd, by absorbing oxygen from the atmosphere.

Tin is used as a mordant in three states; dissolved in nitro muriatic acid, in acetous acid, and in a mixture of sulphuric and muriatic acids. Nitro muriat of tin is the common mordant used by dyers. They prepare it by dissolving tin in diluted nitric acid, to which a certain proportion of muriat of soda, or of ammonia is added. Part of the nitric acid decomposes these salts, combines with their base, and sets the muriatic acid at liberty. They prepared it at first, with nitric acid alone, but that mode was very defective, because the nitric acid very readily converts tin to white oxyd, and then is incapable of dissolving it. The consequence of which was, the precipitation of the whole of the tin. To remedy this defect, common salt, or sal ammoniac, was very soon added; muriatic acid having the property of dissolving white oxyd of tin very readily. A considerable saving of nitric acid might be obtained by employing as much sulphuric acid as is just sufficient to saturate the base of the common salt, or sal ammoniac employed.

When the nitro muriat of tin is to be used as a mordant, it is dissolved in a large quantity of water, and the cloth is dipped in the solution, and allowed to remain till sufficiently saturated. It is then taken out, and washed and dried. Tartar is usually dissolved in the water along with the nitro muriat. The consequence of this is a double decomposition, the nitro muriatic acid combines with the potash of the tartar, while the tartareous acid dissolves the oxyd of tin. When tartar is used, therefore, in any considerable quantity, the mordant is not a nitro muriat but a tartrit of tin.

Iron, like tin, is capable of two degrees of oxydation; but the green oxyd absorbs oxygen so readily from the atmosphere, that it is very soon converted into the red oxyd. It is only this last oxyd which is really used as a mordant in dyeing. The green oxyd is indeed, sometimes applied to cloth; but it very soon absorbs oxygen, and is converted into the red oxyd.—This oxyd has a very strong affinity for all kinds of cloth. The permanency of the iron spots on linen and cotton is a sufficient proof of this. As a mordant, it is used in two states; in that of sulphat of iron, and acetite of iron. The first is commonly used for wool. The salt is dissolved in water, and the cloth dipped in it. It may be used also for cotton, but in most cases acetite of iron is preferred. It is prepared by dissolving iron, or its oxyd, in vinegar, sour beer, &c. and the longer it is kept, the more it is preferred. The reason is, that this mordant succeeds best when the iron is in the state of red oxyd. It would be better then to oxydate the iron, or convert it into rust, before using it; which might easily be done, by keeping it for some time in a moist place, and sprinkling it accasionally with water.

Tan has a very strong affinity for cloth, and for several colouring matters; it is therefore very frequently employed as a mordant. An infusion of *nut-galls*, or of *sumach*, or any other substance containing tan, is made in water, and the cloth is dipped in this infusion, and allowed to remain till it has absorbed a sufficient quantity of tan. Silk is capable of absorbing a very great proportion of tan, and by that means acquires a great increase of weight. Manufacturers sometimes employ this method of increasing the weight of silk.

Tan is often employed also, along with other mordants, in order to produce a compound mordant. Oil is also used for the same purpose, in the dyeing of cotton and linen. The mordants with which tan most frequently is combined, are alumine, and oxyd of iron.

Besides these mordants, there are several other substances frequently used as auxiliaries, either to facilitate the combination of the mordant with the cloth, or to alter the shade of colour; the chief of these are *tartar*, *acetite of lead*, *common salt*, *sal ammoniac*, *sulphat or acetite of copper*, &c.

Mordants not only render the dye permanent, but have also considerable influence on the colour produced. The same colouring matter produces very different dyes, according as the mordant is changed. Suppose, for instance, that the colouring matter be cochineal; if we use the aluminous mordant, the cloth will acquire a crimson colour; but the oxyd of iron produces with it a black.

In dyeing then, it is not only necessary to procure a mordant which has a sufficiently strong affinity for the colouring matter and the cloth, and a colouring matter which possesses the wished for colour in perfection, but we must procure a mordant and a colouring matter of such a nature, that when *combined together*, they shall possess the wished for colour in perfection. It is evident too, that a great variety of colours may be produced with a single dye stuff, provided we can change the mordant sufficiently.

The colouring matter with which the cloth is dyed, does not cover every portion of its surface; its particles attach themselves to the cloth at certain distances from each other; for the cloth may be dyed different shades of the same colour, lighter or darker, merely by varying the quantity of colouring matter. With a small quantity, the shade is light; and it becomes deeper as the quantity increases; now this would be impossible, if the dye stuff covered the whole of the cloth.

That the particles of colouring matter, even when the shade is deep, are at some distance, is evident from this well known fact, that cloth may be dyed two colours at the same time. All those colours to which the dyers give the name of *compounds*, are in fact two different colours applied to the cloth at once. Thus cloth gets a *green* colour, by being dyed first *blue* and then *yellow*.

The colours denominated by dyers *simple*, because they are the foundation of all their other processes, are four; namely, first, *blue;* second, *yellow;* third, *red;* fourth, *black*. To these they usually add a fifth, under the name of *root* or *brown* colour.

Of Dyeing Blue.

The only colouring matters employed in dying blue, are *woad* and *indigo*.

Woad is a plant cultivated in this kingdom, and even growing wild in some parts of England.

Indigo is a blue powder, extracted from a species of plants which is cultivated for that purpose in the East and West Indies. These plants contain a peculiar green pollen, which in that state is soluble in water. This pollen has a strong affinity for oxygen, which it attracts greedily from the atmosphere; in consequence of which it assumes a *blue* colour, and becomes insoluble in water.

Indigo has a very strong affinity for wool, silk, cotton and linen. Every kind of cloth, therefore, may be dyed with it, without the assistance of any mordant whatever. The colour thus induced is very permanent; because the indigo is already saturated with oxygen, and because it is not liable to be decomposed by those substances, to the action of which the cloth is exposed. But it can only be applied to cloth in a state of solution; and the only solvent known being sulphuric acid, it would seem at first sight, that the sulphuric acid solution is the only state in which indigo can be employed as a dye.

The *sulphat of indigo* is indeed often used to dye wool and silk blue ; but it can scarcely be applied to cotton and linen, because the affinity of these substances for indigo is not great enough to enable them readily to decompose the sulphat. The colour given by sulphat of indigo is exceedingly beautiful ; it is known by the name of *Saxon blue*.

Of Dyeing Yellow.

The principal colouring matters for dyeing yellow are weld, fustic, and quercitron bark.

Weld is a plant which grows in this country.

Fustic is the wood of a large tree which grows in the West Indies.

Quercitron is a tree growing naturally in North America, the bark of which contains colouring matter.

The yellow dyed by means of fustic is more permanent, but not so beautiful as that given by weld, or quercitron. As it is permanent, and not much injured by acids, it is often used in dyeing compound colours, where a yellow is required. The mordant is alumine. When the mordant is oxyd of iron, fustic dyes a good permanent drab colour.

Weld and quercitron bark, yield nearly the same kind of colour ; but as the bark yields colouring matter in much greater abundance, it is much more convenient, and upon the whole cheaper than weld. It is probable, therefore, that it will gradually supercede the use of that plant. The method of using each of these dye stuffs is nearly the same.

Of Dyeing Red.

The colouring matters employed for dyeing red, are *kermes*, *cochineal*, *archil*, *madder*, *carthamus*, and *Brazil-wood*.

Kermes is a species of insect, affording a red colour by solution in water ; but it is not so beautiful as cochineal, which is likewise an insect found in America.—The decoction of cochineal is a very beautiful crimson colour. Alum brightens the colour of the decoction, and occasions a crimson precipitate. Muriat of tin gives a copious fine red precipitate.

Archil is a paste formed of a species of lichen pounded, and kept moist for some time with stale urine.

Madder is the root of a well known plant.

Carthamus is the flower of a plant cultivated in Spain and the Levant. It contains two colouring matters: a yellow, which is soluble in water, and a red, insoluble in water, but soluble in alkaline carbonats. The red colouring matter of carthamus, extracted by carbonat of soder, and precipitated by lemon juice, constitutes the *rouge* used by ladies as a paint. It is afterwards ground with a certain quantity of talc. The fineness of the talc, and the proportion of it mixed with the carthamus, occasion the difference between the cheaper and dearer kinds of rouge.

Brazil wood, is the wood of a tree growing in America and the West Indies.—Its decoction is a fine red colour.

None of the red colouring matters have so strong an affinity for cloth as to produce a permanent red, without the assistance of mordants. The mordants employed are alumine, and oxyd of tin; oil, and tan, in certain processes, are also used; and tartar and muriat of soder, are frequently called in as auxiliaries.

Wool may be dyed *scarlet*, the most splendid of all colours, by first boiling it in a solution of murio sulphat of tin, then dying it pale yellow with quercitron bark, and afterwards crimson, with cochineal; for scarlet is a compound colour consisting of *crimson* mixed with a little *yellow*.

Silk is usually dyed red with cochineal, or carthamus, and sometimes with Brazil wood. Kermes does not answer for silk; madder is scarcely ever used for that purpose, because it does not yield a colour bright enough. Archil is employed to give silk a bloom; but it is scarcely used by itself, unless when the colour wanted is *lilac*.

Silk may be dyed crimson by steeping it in a solution of alum, and then dying it in the usual way in a cochineal bath.

Silk cannot be dyed a full scarlet; but a colour approaching to scarlet may be given it, by first impregnating the stuff with murio sulphat of tin, and afterwards dying it in a bath, composed of four parts of cochineal, and four parts of quercitron bark. To give the colour more body, both the mordant and the dye may be repeated. A colour approaching scarlet may be also given to silk, by first dying it crimson, then dying it with carthamus, and lastly, yellow without heat. Cotton and linnen are dyed red with madder. The process was borrowed from the East. Hence, the colour is often called Adrianople, or Turkey red. The cloth is first impregnated with oil, then with galls, and lastly with alum. It is then boiled for an hour in a decoction of madder, which is commonly mixed with a quantity of blood. After the cloth is dyed, it is plunged into a soda ley, in order to brighten the colour. The red given by this process, is very permanent, and when properly conducted, it is exceedingly beautiful. The whole difficulty consists in the application of the mordant, which is by far the most complicated employed in the whole art of dying.

Of Dyeing Black.

The substances employed to give a black colour to cloth are, red oxyd of iron, and tan. These two substances have a strong affinity for each other; and when combined, assume a deep black colour, not liable to be destroyed by the action of air or light.

Logwood is usually employed as an auxiliary, because it communicates lustre, and adds considerably to the fullness of the black. It is the wood of a tree which is a native of several of the West India islands, and of that part of Mexico which surrounds the Bay of Honduras. It yields its colouring matter to water. The decoction is at first a fine red, bordering on violet; but if left to itself, it gradually assumes a black colour. Acids give it a deep red colour; alkalies a deep violet, inclining to brown; sulphat of iron renders it as black as ink, and occasions a precipitate of the same colour.

Wool is dyed black by the following process: It is boiled for two hours in a decoction of nut-galls, and afterwards kept for two hours more in a bath composed of logwood and sulphat of iron, kept during the whole time at a scalding heat, but not boiled. During the operation it must be frequently exposed to the air; because the green oxyd of iron, of which the sulphat is composed, must be converted into red oxyd by absorbing oxygen, before the cloth can acquire a proper colour. The common proportions are five parts of galls, five of sulphat of iron, and thirty of logwood, for every hundred of cloth. A little acetite of copper, is commonly added to the sulphat of iron, because it is thought to improve the colour.

Silk is dyed nearly in the same manner. It is capable of combining with a great deal of tan; the quantity given is varied at the pleasure of the artist, by allowing the silk to remain a longer or shorter time in the decoction.

Of Dying Compound Colours.

Compound colours are produced by mixing together two simple ones; or, which is the same thing, by dying cloth first one simple colour, and then another.—These colours vary to infinity, according to the proportions of the ingredients employed. They may be arranged under the following classes:

Mixtures of 1. Blue and yellow; 2. Blue and red; 3. Yellow and red; 4. Black, and other colours.

Mixtures of blue and yellow. This forms *green*, which is distinguised by dyers into a variety of shades, according to the depth of the shade, or the prevalence of either of the component parts. Thus we have *sea-green*, *grass-green*, *pea-green*, &c.

Wool, silk, and linen, are usually dyed green, by giving them first a blue colour, and afterwards dying them yellow; because, when the yellow is first given, several inconveniencies follow: the yellow partly separates again in the blue vat, and communicates a green colour to it, and thus renders it useless for every other purpose, except dying green. Any of the usual processes for dying blue and yellow may be followed, taking care to proportion the depth of the shades to that of the green required. When sulphat of indigo is employed, it is usual to mix all the ingredients together, and to dye the cloth at once; this produces what is known by the name of *Saxon*, or *English green*.

Mixtures of blue and red. These form different shades of *violet*, *purple*, and *lilac*. Wool is generally first dyed blue, and afterwards scarlet, in the usual manner. By means of cochineal mixed with sulphate of indigo, the process may be performed at once. Silk is first dyed crimson, by means of cochineal, and then dipped into the indigo vat. Cotton and linen are first dyed blue, then galled, and soaked in a decoction of logwood; but a more permanent colour is given by means of oxyd of iron.

Mixtures of yellow and red. This produces *orange*. When blue is combined with red and yellow on cloth, the resulting colour is *olive*. Wool may be dyed orange, by first dyeing it scarlet, and then yellow. When it is dyed first with madder, the result is *cinnamon colour*.

Silk is dyed orange by means of carthamus; a cinnamon colour by logwood, Brazil-wood, and fustic mixed together.

Cotton and linen receive a cinnamon colour by means of weld and madder; and an olive colour, by being passed through a blue, yellow, and then a madder bath.

Mixtures of black with other colours. These constitute *greys*, *drabs*, and *browns*. If cloth be previously combined with brown oxyd of iron, and afterwards dyed yellow with quercitron bark, the result will be a *drab* of different shades, according to the proportion of mordant employed. When the proportion is small, the colour inclines to olive or yellow; on the contrary, the drab may be deepened or saddened, as the dyers term it, by mixing a little sumach with the bark.

TANNING.

TANNING is the art of converting the raw skins of animals into *Leather*. *Skins* are the general term for the shins of calves, seals, hogs, dogs, &c. As the methods of tanning in general use have been found tedious and expensive in their operation, various schemes, at different times, have been suggested to shorten the process and lessen the expense.

Much light has been thrown by modern chemists upon the theory of tanning. M. Seguin, in France, has particularly distinguished himself by his researches on this subject, and much improved the art in his country.

A few years since W. Lesmond obtained a patent for practising Seguin's method in England. He obtained the tanning principle by digesting oak bark, or other proper materials, in cold water, in an apparatus nearly similar to that used in the saltpetre works :— That is to say, the water which has remained upon the powdered bark a certain time, in one vessel, is drawn off by a cock, and poured upon fresh tan—this is again to be drawn off, and poured upon other fresh tan ; and in this way the process is to be continued to the fifth vessel. The liquor is then highly coloured, and marks from six to eight degrees upon the hydrometer for salts. This he calls the tanning lixivium. The criterion for ascertaining its strength, is the quantity of the solution of gelatine which a given quantity of it will precipitate. Isinglass is used for this purpose, being intirely composed of gelatine. And here it may be observed, that this is the mode of ascertaining the quantity of tanning principle in any vegetable substance, and consequently how far they may be used as a substitute for oak bark.

The hides, after being prepared in the usual way, are immersed for some hours in a weak tanning lixivium of only one or two degrees ; to obtain which, the latter portions of the infusions are set apart, or else some of that which has been partly exhausted by use in tanning. The hides are then to be put into a sronger lixivium, where, in a few days, they will be brought to the same degre of saturation with the liquor in which they are immersed. The strength of the liquor will by this means be considerably diminished, and must therefore be renewed. When the hides are by this means completely saturated, that is to say, perfectly tanned, they are to be removed, and slowly dried in the shade.

The length of time necessary to tan leather completely, according to the old process, is certainly a very great inconvenience ; and there is no doubt but that it may be much shortened by following the new method. It has been found, however, that the leather so tanned has not been so durable as that which has been formed by a slower process.

The public is much indebted to Mr. Davy, professor of chemistry in the Royal Institution, for the attention which he has paid to the subject. From his excellent paper "on the constituent parts of astringent vegetables," in the Philosophical Transactions, we present the reader with the following extract.—

"The different qualities of leather made with the same kind of skin, seem to depend very much upon the different quantities of extractive matter it contains. The leather obtained by means of infusions of galls, is generally found harder, and more liable to crack, than the leather obtained from the infusion of barks; and in all cases it contains a much larger proportion of tannin, and a smaller proportion of extractive matter.

"When skin is very slowly tanned in weak solutions of the barks, or of catechu, it combines with a considerable proportion of extractive matter ; and in these cases, though the increase of weight of the skin is comparatively small, yet it is rendered perfectly insoluble in water, and is found soft, and at the same time strong. The saturated astringent infusions of barks contain much less extractive matter in proportion to the tannin, than the weak infusions ; and when skin is quickly tanned in them, common experience shews that it produces leather less durable than the leather slowly formed.

"Besides, in the case of quick tanning by means of infusions of barks, a quantity of vegetable extractive matter is lost to the manufacturer, which might have been made to enter into the composition of his leather. These observations shew, that there is some foundation for the vulgar opinion of workmen, concerning what is technically called the *feeding* of leather in the slow method of tanning ; and though the processes of the art may in some cases be protracted for an unnecessary length of time, yet, in general, they appear to have arrived, in consequence of repeated practical expe ments, at a degree of perfection which cannot be very far extended by means of any elucidations of theory that have as yet been known."

It was first suspected by Sir JOSEPH BANKS, and afterwards confirmed by the experiments of Professor DAVY, that a substance called *catechu* or *terra Japonica*, brought from the East Indies, contained a vast quantity of tannin; so much so, that it far excels every other known substance in this respect. One pound of catechu contains as much tannin as eight or ten pounds of common oak bark, and would consequently tan proportionately as much more leather. It is an extract made from the wood of a species of mimosa, by decoction and subsequent evaporation.

Oak bark being a very expensive article in the process of tanning, various substances have been proposed as substitutes for it. All the parts of vegetables which are of an astringent nature, contain tannin (which may be known by their giving precipitates with gelatine, insoluble in water), and will answer this purpose. The leaves, branches, fruit, flowers, of a vast number of plants; every part of the oak, as the leaves and acorns, oak saw-dust, and the barks of almost all trees, contain more or less tannin.

CURRYING.

CURRYING is the art of dressing cow-hides, calves-skins, &c. The principal object in this process, is to soften and supple cow and calf skins, which are usually employed in making upper-leathers and quarters of shoes, the covers of saddles, coaches, &c. As soon as these skins are brought from the tanner's yard, the currier first soaks them for some time in common water, when he takes them out, stretches them on a smooth wooden horse, scrapes off with a *paring-knife* all the superfluous flesh, and immerses them again. They are next put on a wet hurdle, and trampled with the heels, till they become soft and pliant, when they are steeped in train-oil, and afterwards spread out on large tables, and their ends tightly secured. There, by means of a *pummel* (an instrument consisting of a thick piece of wood, the lower side of which is full of furrows, or teeth, crossing each other), the currier folds, squares, and moves the skins in various directions, to render them supple. This operation is properly called *currying*; and, with a few immaterial exceptions, is that now generally followed.

After the skins are thus dressed, they are coloured, black, white, red, green, &c. which process is performed either on the *flesh* or *grain* side; that on the former, by skinners, and that on the *grain* or *hair* side, by curriers: these, when a skin is to be made white, rub it with chalk, or white-lead, and afterwards with pumice-stone. But, when a black colour is wanted, the skin must be first oiled and dried, then passed over a puff, dipped in water impregnated with iron, when it is immersed in another water prepared with soot, vinegar, and gum-arabic. Thus it gradually acquires a deep dye, and the operations are repeated till it becomes of a shining black. The grain and wrinkles, which contribute to the pliancy of calves and cows leather, are made by the reiterated folds given to the skin in every direction, and by the great care taken to scrape off every excrescence and hard place on the grain, or colour-side.

INDEX.

D

BOOKS,

FOR SALE BY INCREASE COOKE, & CO.

Fourcroy's Elements of Chemistry,	5 vols.	8vo.
Lagrange's Manual of a course of chemisty,	2 vols.	8vo.
Nicholson's first Principles of Chemistry,	1 vol.	8vo.
Lavoisier's Elements of Chemistry,	1 vol.	8vo.
Chaptals', do. with Notes.	2 vols.	8vo.
Ewell's Discourses on Chemistry,	1 vol.	8vo.
Black's Lectures on Chemistry,	3 vol.	8vo.
Henry's Epitome of Chemistry, enlarged, 4th edition, with notes, &c.	1 vol.	8vo.
Green's Principles of Modern Chemistry,	2 vols.	8vo-
Johnson's Animal Chemistry,	3 vols.	8vo.
Smilie's Philosophy of Natural History,	1 vol.	8vo.
Euler's letters on Physics and Phylosophy,	2 vols.	8vo.
Websters's Elements of Natural Philosophy, with notes and corrections by Robert Patterson.	1 vol.	8vo.
Rumford's Philosophical Essays,	3 vols.	8vo.
do. Philosophical Papers,	1 vol.	8vo.
Imison's Elements of Science and Art,	2 vols.	8vo.
Gregory's Economy of Nature,	3 vols.	8vo.
Furguson's Astronomy,	1 vol.	8vo.
Bonnycastle's do.	1 vol.	8vo.
Bryan's, do.	1 vol.	8vo.
Cavallo's Electricity,	3 vols.	8vo.
Adam's, do.	1 vol.	8vo.
Adams' Lectnres on Philosophy, with notes, by William Jones. with plates.	5 vols.	8vo.
Ferguson's Lectures on Philosophy, with notes, and an appendix by David Brewster, with an elegant quarto volume of plates.	2 vols.	8vo.

THE variety of Books and Stationary for Sale by I. COOKE, & Co. like the works of nature at this blooming season of the year, amounts almost to infinity.

MAY, 1809.