A

SERIES

OF POPULAR

CHYMICAL ESSAYS:

Containing a Variety of Inſtances of the Application of Chymiſtry to Arts and Manufactures; the Explanation of natural Phænomena; and to other uſeful Purpoſes

BY

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FOR

THEIR READY AND LIBERAL ASSISTANCE

IN PROMOTING THE ESTABLISHMENT,

AND

SUPPORTING THE CONTINUANCE,

OF THAT

USEFUL AND CHARITABLE INSTITUTION,

THIS HUMBLE EFFORT

OF THE AUTHOR,

TO DIFFUSE USEFUL INFORMATION,

IS GRATEFULLY DEDICATED

BY THEIR HUMBLE SERVANT,

Kettering,
Oct. 7th, 1802.

FENWICK SKRIMSHIRE.

PREFACE.

THE substance of the present essays is part of the materials, collected by the author with a view of delivering an experimental course of popular lectures on Chymistry and Natural History. Professional engagements having prevented the adoption of his intended plan, it was thought by him, that it might prove acceptable to the public in the present form.

It is not to be considered as a strictly scientific work, but rather as one adapted to convey useful information to the class called *general readers*, by which is meant, those who are desirous of an acquaintance with various literary and scientific subjects, without entering into the minutiæ of any science.

The ſubjects, here treated of, being elucidated and explained upon their true principles, the work is calculated to remove many erroneous conceptions concerning common occurrences.

By pointing out very frequent applications of chymical knowledge to uſeful purpoſes, the reader will be led to form a notion of the extenſive utility of the ſcience; and by preſerving a connection between the ſubjects of the different eſſays, it is preſumed that he will have formed a general idea of the whole ſyſtem of Chymiſtry.

Should the view, that is here given, excite a ſingle reader to a further proſecution of the ſtudy, or ſhould the ſubject, as here treated, be the means of diffuſing information, that is at all uſeful, the author's ambition will be fully gratified.

Subjects connected with Chymiftry are fo numerous, that the work might eafily have been fwelled to a much larger fize; but by attempting too much, we frequently effect nothing. It is hoped that the felection will be thought judicious.

The prefent work differs effentially from the fcientific and well-received "Chymical Effays" of Dr. Watfon. He has given complete effays on fingle detached fubjects, whereas the author of the prefent work has introduced a very great variety of interefting matter into each effay, and has connected the different effays together into a feries. He has alfo been careful to felect fubjects, that are more generally interefting.

In a work of this kind the materials muft of courfe be collected from a variety of authors, whom it would be ufelefs and tireſome to quote. Chaptal, Prieſtley, Sauſſure, Pictet, Fourcroy, St. Fond, Rumford, Kirwan, Bancroft, Saunders, and many others, have been occaſionally had recourſe to; and ſome of the experiments related by Mr. Henry, in his valuable Epitome of Chymiſtry, have been ſelected as appropriate, and particularly correct.

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ESSAY I.

THE OBJECT AND UTILITY OF CHYMISTRY.

To the ſtudent, deſirous of information, two queſtions naturally ariſe on hearing the name of any ſcience, profeſſion, or art, which has not been the ſubject of his ſtudies. He firſt inquires what is the *object* of this science, profeſſion, or art, and what kind of information it affords. He then as eagerly demands to be informed of its *utility*.

Suppoſe geography to be the ſcience; what is geography? he aſks; what does it teach? or what does a knowledge of it imply? Geography, he is told, is the ſcience, that teaches us the diviſion of the globe into land and water; the former into kingdoms, and ſmaller portions; the latter into ſeas, lakes, and rivers; and then teaches us the relative ſituation of theſe various parts. What is the advantage of this knowledge? is the next queſtion; and he is told in anſwer, how much the traveller is benefited by it in traverſing diſtant regions; how uſeful it is to the general marching into an enemy's country; how neceſſary to the ſtudent of natural hiſtory; and how requiſite to the philoſopher, ſtudying the manners, moral and political, of different nations.

If aſtronomy is the ſubject of inquiry, the ſame questions ariſe; and he is informed that its object is, to teach the ſituation and motion of the ſun, planets, and other heavenly bodies; their ſituation with reſpect to the earth, and to each other; and their motion in their reſpective orbits, as well as on their own axes. As to the advantage of ſuch knowledge, it is various, and important. It enables us to foretel the change of ſeaſons, as well in countries that we never viſited, as in our own; to explain and to predict various natural phænomena, as eclipſes, conjunctions of the planets, and the appearances of comets; and by the aid of calculation it teaches the navigator to ſteer his courſe through unknown ſeas, and to aſcertain his preciſe ſituation either on the ocean, or on the land, though in climes never before viſited by man.

Similar queſtions to the above muſt naturally ariſe reſpecting other ſciences; and the anticipation of them reſpecting chymiſtry will furniſh us with matter for the preſent eſſay; forming an appropriate, and, I truſt, intereſting introduction to the reſt.

In pointing out the object and utility of *chymiſtry*, I ſhall explain in a general way the advantages that have been derived from it, in its extenſive application to the arts; and the aſſiſtance it affords us in explaining a variety of natural phænomena, and in ſtudying the other ſciences.

CHYMISTRY, to define it, or expreſs its object in a few words, may be ſaid to teach us, *the changes that are effected in the component parts of bodies by their mutual action.* But as definitions are always dry, and the beſt may become the ſubject of cavil and diſpute, I ſhall endeavour to illuſtrate and explain my meaning by the relation of a few ſimple experiments.

When a piece of marble or a piece of chalk is dropped into a glaſs of aqua fortis or a glaſs of vinegar, an efferveſcence immediately takes place, or the liquor froths, in conſequence of the extrication of air or gas; the marble or chalk is gradually diſſolved, and the liquor at length remains clear and tranſparent. Certain changes have here been effected in the component parts of the marble and the acid, by their mutual action of the one upon the other; and it is the object of chymiſtry to teach, both what theſe changes are, and how they have been effected. What is called *practical chymiſtry* teaches us the firſt, and *theoretical chymiſtry* the ſecond part.

This action of the acid upon the marble, and of the marble upon the acid, differs materially from any kind of mechanical action, and is called a *chymical action.* For inſtance, it differs materially from the mere diffuſion that takes place when ſand and water, or oil and water, are agitated together in a phial. By ſhaking they are made to act *mechanically*, and for a moment the ſand or the oil is diffuſed through the water; but no ſooner do you ceaſe to agitate them, than they inſtantly ſeparate; the ſand ſubſides to the bottom, or the oil ſwims on the ſurface of the water. But with reſpect to the marble and the acid, the former is not merely diffuſed; they have acted chymically, and the marble will not be depoſited on ſtanding, nor can they be again ſeparated but by other chymical actions.

The peculiarity of this kind of action, in which it differs from other kinds, is, that it only takes place at immeaſurable and inſenſible diſtances; it being neceſſary to chymical action, that the particles of one body ſhould be in cloſe contact with thoſe of the other. Hence it follows, that few ſolids can be made to act chymically on each other, a fluid and solid more eaſily, and two fluids ſtill more ſo, becauſe their particles are more readily brought into contact.

Inſtances however may be brought of chymical action between ſubſtances in all theſe forms; and we ſhall ſelect for examples ſuch as will prove very amuſing and intereſting experiments. As an inſtance of two ſolids being brought to act chymically, rub together in a mortar ſmall portions of brimſtone and the oxymuriate of potaſh, By trituration they are made to act on each other, and the consequence is repeated flashes, and slight explosions. A small portable apparatus for performing this experiment may be had at the shops in London.

As an instance of a solid and a fluid, drop some potash into an infusion of roses; and as an example of two fluids, pour an acid into the same infusion: by the former the red liquor will become green, and by the latter addition it will recover its original colour, or rather become bright red: this change may be repeated on the same liquor as often as you please by the alternate addition of an alkali and an acid.

As another example of two fluids acting chymically on each other, mix together a saturated solution of Epsom salt in water, and a saturated solution of muriate of lime. In this experiment the two transparent fluids are suddenly converted into one solid mass, and that without freezing.

Lastly, as an instance of chymical action between two gasses or aëriform fluids, mix the common air of the atmosphere with nitrous gas, as in the common eudiometer, and a diminution of volume, and formation of nitrous acid, instantly take place.

The above experiments are all examples of chymical actions; and it is the object of chymistry to ascertain, and to explain, the various changes that have taken place in them.

When two ſimple bodies are made to unite chymically, we call the ſubſtance reſulting from the union a *compound*. This compound may again unite either to a ſimple or to another compound, forming in the firſt caſe a triple ſubſtance, or in the laſt a compound of four ſimples; and theſe again may unite to others, forming ſubſtances ſtill more compound.

Now it is one of the grand objects of chymiſtry, to ſeparate theſe compounds into the ſimple elements, of which they are compoſed; and the operation by which it is performed, is called *analyſis*.

When we have accurately analyſed any compound ſubſtance, we may often reproduce it by properly combining the ſimple ſubſtances, of which we have diſcovered it to be compoſed. This proceſs is termed *ſyntheſis*, which in the inveſtigation of any chymical ſubſtance forms with the former, namely analyſis, the complete chymical teſt.

Of what I have here ſaid I ſhall now give an example in the decompoſition and recompoſition of Epſom ſalt. By diſſolving it in water, and then adding an alkali, the foſſil alkali, called ſoda, for example, an earthy powder is precipitated, which, when collected by filtering the liquor through paper, is found by particular chymical teſts to be magneſia. The filtered liquor by further teſts is diſcovered to be nothing but Glauber's falt diffolved in water. Now Glauber's falt is known to be foda combined with fulphuric acid, or oil of vitriol, the former of which was added in the experiment. We have here *analyfed* Epfom falt, and found its conftituent parts to be magnefia and fulphuric acid.

If magnefia be diffolved in fulphuric acid, diluted with water, and the liquor evaporated, a falt is cryftallifed, that is found to be Epfom falt; fo that we have here the *fynthetical* proof, that Epfom falt is a combination of magnefia and fulphuric acid.

Some chymical fubftances have a greater difpofition to unite than others, as fulphuric acid and foda, than fulphuric acid and magnefia, in the above experiment. This is termed their chymical *attraction*, or *affinity*; and in chymical language we fay, that fulphuric acid and foda have a ftronger affinity, than the former and magnefia; or we fay that fulphuric acid has a ftronger attraction for foda than for magnefia.

It is in confequence of thefe different affinities, that we are enabled to decompofe one fubftance by the addition of another, as Epfom falt by the addition of foda; and it is the object of chymiftry to teach the degrees of thefe affinities between different fubftances, whereby the chymift is able to foretel the confequence of mixing fuch and fuch fubftances, together; and he who knows the moſt in theſe reſpects is the beſt practical chymiſt.

I have now explained the object of chymiſtry, and ſhall therefore proceed to point out ſome of the moſt ſtriking inſtances of its utility, and its applicability to uſeful purpoſes.

Almoſt every art may be conſidered as a chymical proceſs; and although we ſee many of them daily performed by the moſt ignorant people, and although ſome may have been originally diſcovered, and even brought to their preſent ſtate, without any aſſiſtance from the chymiſt, yet they become to him intereſting objects of attention; and it is only by his aid, that the nature of the proceſs can be underſtood, and explained. It is by ſuch knowledge that very many have been ſimplified, and improved; nor are the original diſcoveries of the chymiſt few or unimportant.

In the art of *dyeing*, every part of the proceſs is chymical, and many improvements have been made in it by ſcientific men. Dr. Bancroft in this country, and Berthollet in France, have within theſe few years done much in ſimplifying the operations, and in rendering them leſs expenſive. They have alſo improved the dyes in ſome caſes, and introduced many new colouriug drugs, the particulars of which will fall more properly to be noticed in an eſſay on this ſubject.

Bleaching again, which ten years ago was a procefs of many months, may now be lefs expenfively and more completely performed in as many days. The difcovery of oxygenated muriatic acid, by which this great improvement in the art of bleaching has been effected, was made by Scheele, a Swedifh chymift; and Berthollet, a Frenchman, has the honour of having firft applied it to this purpofe; and various fcientific men in this country have improved the mode of ufing it. Every manufacturer has now taken advantage of this difcovery, by which the extenfive bleach-fields are contracted, and their goods brought to a much earlier market.

Tanning is another art, that has been very much, and is likely to be ftill more improved, by having become the fubject of chymical inveftigation. In tanning, the object is, to convert the foft and porous hide into a more hard and compact fubftance, that is lefs eafily penetrated by water, and lefs liable to putrefaction. This has always been chiefly effected by long continued immerfion in an infufion of fome bark, moft commonly oak bark. Seguin, a Frenchman, examining the nature of the procefs fcientifically, and afcertaining the chymical qualities of the infufion, found that it is not, as generally believed, the aftringent quality of the bark, that operates the change, but a diftinct principle, now called the tanning principle, which exifts in different proportions in the bark of different trees. This tanning principle he has devifed the means of extracting, and applying to the hides in a more concentrated form, than it had hitherto been ufed; by which means hides, that required twelve or eighteen months, may now be tanned in lefs than as many weeks, and of courfe be brought to market at a much lower price.

In the making of *pottery* and *porcelain* every one muft be aware of the great improvements that have been introduced within the laft ten or twelve years; and it is generally known too, that to Mr. Wedgwood we are indebted for moft of thefe valuable improvements. This fcientific manufacturer accurately analyfed the beft foreign wares, to difcover of what earths they were formed, and in what proportions; he examined in the fame way different antique vafes, and other articles, and by a very ingenious contrivance, which will be noticed in a future effay, he invented the means of afcertaining the exact degree of heat, to which any fuch articles had been expofed in their baking. He then fought through various parts of this country for earths, fuch as he wanted; what he could not find, he formed artificially by the due admixture of others; and, by all thefe means combined, he has been enabled to imitate the wares of China, and of other countries, that excelled us; and has invented different kinds, both more ornamental and more uſeful, than what were before manufactured.

It will require little conſideration to ſhow the application of chymiſtry to *metallurgy*. None of the metals are found naturally pure and uncombined, at leaſt not in any conſiderable quantity. They are united ſometimes with ſulphur, ſometimes with pure air under the form of calces, ſometimes with acids, and often with each other. Copper, for inſtance, is found in all theſe ſtates; in the form of pyrites with ſulphur, of calx with pure air, of blue vitriol with ſulphuric acid, and often mixed with ſilver, and other metals. It is true that the means of ſeparating and purifying many of them have been accidentally diſcovered by unſcientific men; but with how much more certainty, and how much more ſimply, will he execute the buſineſs, who, acquainted with the affinities, and other laws of the ſubſtances he employs, knows exactly, what will ſeparate their component parts, and what will purify them from adventitious matter. One or two inſtances of the advantage of chymical knowledge in this department will ſufficiently evince the extenſive applicability of it to metallurgy.

Copper is frequently found combined with vitriolic or ſulphuric acid in the form of blue vitriol; and in the mines, where it is found in this ſtate, there are frequently ſtreams of water very much impregnated with this copper ore, which were formerly thought ufelefs, and were confequently neglected.

Chymiftry teaches us that fulphuric acid has a ftronger attraction for iron than for copper; of which fact you may eafily convince yourfelf by the following fimple experiment: Diffolve fome blue vitriol in water, and immerfe into this folution the blade of a knife, a key, or any other piece of polished iron, and you will prefently perceive its furface to be covered with a layer of copper, the acid of the vitriol having feized on the iron, and in the fame proportion depofited the copper. To apply this ufefully to the point in queftion, it is only neceffary to throw old ufelefs iron into thefe ftreams, and a depofition of good copper will be gradually effected; which is a plan, that is now very generally practifed.

As another inftance, fomewhat fimilar to the former, of advantage derived from chymiftry, I fhall mention a mode of obtaining green vitriol adopted in a manufactory at Newcaftle. There is often found among the coals of that place a large quantity of an ore, called pyrites, which, as it injures the quality of the coals, is always separated from them, and was heretofore confidered as ufelefs. The chymift has now taught the manufacturer to convert thefe pyrites into green vitriol, and has thus rendered valuable what was before confidered as ufelefs.

The pyrites contain both iron and fulphur; green vitriol is a combination of iron and fulphuric acid; what is to be effected therefore is, to convert the fulphur into fulphuric acid, and difpofe it to unite with the iron. This converfion only requires, that the fulphur fhould be made to combine with oxygen, or the pure part of the air, for fulphuric acid is fulphur acidified by oxygen, and the mode adopted in the prefent inftance is as follows.

A large area of ground is enclofed, that has a gentle declivity; the furface is made even, and is covered with a fat clay, and a furrow is formed in the midft of it, to collect and convey the water to proper refervoirs. The pyrites are fpread out in layers on this area to the height of fome feet, and by expofure to the air, rains, and other viciffitudes of the weather, they foon heat, fwell, and fall into powder. This operation is affifted by turning the pyrites with rakes, that have iron teeth, and by occafionally fprinkling them with water, when the feafon is dry. The fulphur by this procefs abforbs the oxygen or pure part of the air, which converts it into fulphuric acid. This acid feizes the iron, and forms green vitriol, which, diffolved in the water, is conveyed into the refervoirs. From thefe refervoirs it is carried to coppers, where it is boiled, and evaporated to a fufficient ftrength. It is then cryſtalliſed by cooling in wooden troughs. This green vitriol, martial vitriol, or copperas, as it is often called, forms an article of traffic, and is uſed by dyers, and frequently by curriers, as alſo in many other of the arts; and it is a principal ingredient in the making of ink. It is likewiſe a very ſerviceable medicine in a variety of complaints.

In *brewing*, *baking*, *making wine*, *ſpirits*, *vinegar*, &c., we have pure chymical proceſſes, that can only be thoroughly underſtood by the chymiſt, and are conſequently moſt likely to be improved by him. To enumerate and deſcribe all the improvements made by chymiſts in theſe and other arts, would be improper in an introductory eſſay. I ſhall therefore now conclude the applicability of chymiſtry to operations of art, by a late improvement in the art of making vinegar in the large way.

It is a fact now well known, that beer, wine, ſugar and water, and other ſuch liquors, become ſour, in conſequence of their abſorbing or imbibing the pure part of the air, or oxygen. It is alſo known, that the greater the ſurface of the liquor, that is expoſed to the air, the more quickly it abſorbs the pure part of it, and becomes ſour. This therefore is the grand point that is to be aimed at in the whole proceſs; and by conſtantly pumping the liquor into a large cooler, through which it is allowed to run in a ſlow ſtream, and return to the vat, from which it was pumped, the furface thus expofed to the air is confiderably greater than it would otherwife be, and the time of making the vinegar is thereby very confiderably fhortened. For the fame reafon, when it is made in the fmall way, the air fhould be freely admitted, and the cafk be not more than half filled, that a greater furface may be in contact with the air.

The fubferviency of chymiftry to the other fciences might be expatiated upon very largely, but not without entering too minutely into the fciences themfelves. *Medicine* has been benefited by it in a variety of ways, in the compofition of remedies, as well as in the practice. Almoft all the animal functions, as refpiration, digeftion, &c. are chymical proceffes, fome perhaps peculiarly modified by the principle of life. Our breathing is a chymical procefs, that until lately was hardly at all comprehended. The difeafes of the cheft, where the organ of refpiration is feated, will naturally be fuppofed to be connected in a great meafure with the ftate of that function. This is certainly the cafe; and the phyfician therefore, who is ignorant of the nature of this chymical procefs, will be much lefs likely to employ the proper remedies, than one, who is well acquainted with this important function. Numberlefs fuch inftances might be pointed out, to fhow the fuperiority of that part of the profeffion, that is well verfed in chymiftry, over fuch a know nothing of this fcience.

The *natural philoſopher*, without the aid of chymiſtry, would form but an inadequate notion of the properties of air, water, fire, or light. He would know that the air of the atmoſphere is elaſtic, ponderous, and more or leſs compreſſible; but he would be ignorant that it is a compound of a pure and an impure air, the firſt ſupporting combuſtion, and life by reſpiration, whilſt the other is unfit for either.

The *mineralogiſt* requires chymical teſts to diſcriminate between ſubſtances that to the eye appear ſimilar, and to aſcertain more fixed characters for diſtinguiſhing between one mineral and another.

Laſtly, the *agriculturiſt* may derive advantage from chymiſtry by ſcientifically examining the nature of the ſoil, and the nature of his manures, and by theſe means learning properly to adapt the latter to the former.

I have now pointed out ſome very palpable examples of the uſeful application of chymical knowledge. To explain more fully the proceſſes, that I have here only hinted at, will occupy ſome of the future Eſſays, in which I ſhall likewiſe ſelect ſuch others, as are likely to prove moſt intereſting and moſt uſeful. I ſhall at the ſame time endeavour to preſerve ſuch a connection between the ſubjects of the different Eſſays, as ſhall convey a general idea, at leaſt of the outlines, of the whole ſcience of chymiſtry.

ESSAY II.

CHYMICAL ELEMENTS.

In every age there have been certain ſubſtances conſidered by the philoſophers of the day as elements, or ſimple ſubſtances, of which every thing elſe has been ſuppoſed to be compounded. But what have been enumerated by the philoſophers of one age as elements, have been afterwards proved by thoſe of another to be compounds; and as the ſcience of chymiſtry has been improved, we have diſcovered the means of analyſing or decompoſing what was previouſly conceived to be a ſimple. Thus water, from time immemorial to a very late period, was allowed by all philoſophers to be one of the elements of nature; modern chymiſts have however decompoſed it, and detected with accuracy the ingredients of which it is formed, and even the proportions in which they exiſt. For many ages paſt, and even to this day by many, earth, air, fire, and water, have been, and are conſidered the four elements, of which this globe, and every thing terreſtrial, are formed. Chymiſtry now teaches us, that there are many kinds of earth, and many kinds of air, perfectly diſtinct from each other, ſome of which are compound, and fome fimple. It teaches us that fire, called now caloric, is a fimple fubftance; and that water, as I faid before, is a compound.

Although we can now treat more accurately of the elementary fubftances, we cannot fpeak decidedly; and you muft ftill keep in mind, that what are at prefent termed elements, may by future chymifts be difcovered to be compounds; and that we only mean, by calling them fo, to affert that, in the prefent ftate of chymical knowledge, they are not decompofable. The fubftances at prefent confidered as elements are the following. Caloric (the matter of heat or fire); light; oxygen (the bafe of pure or vital air); azote (the bafe of impure air); hydrogen (the bafe of inflammable air); carbone, or pure charcoal; phofphorus; fulphur; two of the alkaline falts, viz. foda and potafh; the nine earths; and all the metals.

As thefe are the fimple fubftances at prefent known; a complete body of chymiftry would be given, by treating of their various combinations with each other; and perhaps the moft fcientific fyftem would be formed by treating of each fimple fubftance feparately, and noticing under the head of each all thofe compounds, that derive their moft remarkable properties from that particular element.

Whether, however, this might or might not be the beft mode of forming a complete fyftem of chymiſtry, it will afford a very convenient arrangement for the partial account intended to be given in the following Eſſays. It will afford us every opportunity, that can be wiſhed for, of noticing ſuch peculiarities in the properties both of the elements and their compounds, as will be thought worthy of attention; and will lead us to notice their uſes, to explain any art to which they may be applicable, any ſcience to which they may be ſubſervient, or any phænomena which they may tend to elucidate. The ſame plan will alſo have the advantage of connecting one Eſſay with another, and forming of the whole a connected ſeries, that will be calculated to give a general idea of chymiſtry as a ſcience. The order, in which the elements have been enumerated above, is the order, in which they will be treated of; firſt then of *heat* and *light*.

ESSAY III.

THE CONNEXION OF HEAT AND LIGHT.

There is ſo intimate a connexion between heat and light, that we have in many inſtances the appearance of the one being converted into the other; they are frequently concomitants in the ſame phænomena; and the ſame cauſes in a variety of inſtances produce both.

This their intimate connexion has given birth to a variety of hypotheſes; and various conjectures have been hazarded in conſequence, reſpecting the nature both of heat and light. We muſt not however, in treating this ſubject, indulge in thoſe ſpeculative opinions, that have occupied in vain ſo much of the time and attention of philoſophers, and concerning which there is ſtill as much diſcordancy as ever.

We muſt paſs over the long contended questions, whether heat is a mere vibration of particles, or a particular ſubſtance; whether it is a modification or a component part of light; or whether light, as ſome ſuppoſe, is a component part of heat. In a popular work of this kind it would be highly improper to enter into abſtruſe diſquiſitions on ſuch points, and we ſhall therefore, in concurrence with the generality of modern chymifts, fpeak of heat and light as fubftances, and as diftinct and fimple fubftances; and we muft content ourfelves with noticing fome few inftances of their connexion, without attempting to explain them. The fun is generally confidered to be the common fource, and the only fource, both of heat and light; and it is probable, that all proceeded originally from that fountain, although the light and heat afforded by combuftion, the emiffion of light from phofphorus, and of heat by friction, appear at firft fight to be fo many inftances of diftinct fources.

The rays of the fun feem to afford heat only when they meet with an opaque fubftance, and not when they pafs through a tranfparent one, as air, or water, or when they are reflected by a white or polifhed one. The air is not heated immediately by the rays of the fun paffing through it; but on their meeting with an opaque body, as the earth for inftance, heat is elicited, and is thence gradually communicated to the furrounding atmofphere. This accounts for the intenfe cold of lofty mountains. If the rays of the fun warmed immediately the air, through which it paffed, the air ought to have the fame temperature in thofe regions, as in the vallies below; but it is not until the rays are obftructed by the earth, that they have the effect of communicating heat; and therefore the further we remove from the earth's ſurface the greater is the degree of cold.

When the ſun's rays fall upon a white or poliſhed body, they communicate no heat; and in proportion as ſubſtances have the power of reflecting the rays, is their temperature more or leſs increaſed. An old but curious and intereſting experiment may be brought in elucidation of this fact. If pieces of cloth of different colours (white, ſcarlet, and black, for inſtance) are laid at the ſame time on the ſurface of the ſnow, where the ſun's rays can fall upon them, they will be found after ſome hours to have ſunk into the ſnow to various depths, according to their reflecting powers; the white, which reflects the moſt light, will have ſunk the leaſt; the ſcarlet, reflecting leſs, will have ſunk more; and the black, which reflects little or none, will have ſunk by far the deepeſt into the ſnow.

In this experiment the rays falling on the black being abſorbed, and not reflected, produce heat, which cauſing the ſnów to melt, neceſſarily makes that piece of cloth to ſink; the others reflecting more of the rays, leſs heat is emitted, and conſequently they ſink leſs into the ſnow. It is for the ſame reaſon that black clothes of all kinds are much warmer in ſummer than light-coloured ones. And the ſame fact, we are informed by Sauſſeur, s known to the Swiſs peaſants, and taken advantage of by them when the ſnow lies too long upon the ground. He tells us, that, when this is the caſe, and they want particularly to ſow their ſeeds, they are in the habit of ſpreading black cloths upon the ſurface of the ſnow, to facilitate its melting.

You will now eaſily underſtand, why a thermometer, that has its bulb blackened, is more ſenſible to an increaſe of heat than a common one; and why, when both are expoſed to the light, the blackened one indicates a higher temperature. In this caſe the rays of light, that are reflected by the common thermometer, are abſorbed, and emit heat in the blackened one, and conſequently increaſe the temperature of the contained mercury.

That it is the abſorption of light in this caſe, that cauſes the heat, is proved by interpoſing a plate of tranſparent glaſs between a thermometer and a lighted candle. The glaſs will evidently intercept the rays of heat, and tranſmit only thoſe of light, and yet the mercury in the thermometer will riſe, and particularly if the bulb of it is blackened.

The ſultry heat experienced on the ſurface of the water in a ſunny day ariſes from the reflection of the rays of light. The temperature of the water is but little raiſed, becauſe the light is reflected, and not abſorbed: but the reflected rays, as well as the direct rays of the ſun ſtriking upon any object, that is on the surface of the water, makes it so much the hotter to persons in that situation.

Some persons reasoning upon these facts, that light when absorbed emits heat, and that black bodies absorb whilst white ones reflect it, have argued for the propriety of forming black walls for fruit trees; but their reasonings are insufficient without experiments to determine the point, as will appear from the following consideration. The walls themselves will no doubt be warmer than if they were white; but the heat will be communicated from the walls to the air immediately in contact, and not to the fruit, which very seldom touches the wall, and then only by a small surface; the heated air being unconfined, will most of it pass away, and thus the heat emitted by the absorption of light be of little advantage towards the ripening of the fruit. But if the walls are white, they reflect the light; and these reflected rays meeting with the opaque substance of the fruit, and other part of the trees, emit heat, that is directly applied to the desired purpose. The fruit is in this respect precisely in the same situation with a person on the surface of the water.

It is therefore necessary to determine by experiments, to what extent the temperature of the air is increased at the distance from the black wall, that the fruit usually hangs; and whether it is more

more than equivalent to the heat emitted by the absorption of rays reflected from the white wall.

In a pinery, however, or other hot-house, particularly where there is no fruit growing near the wall, I conceive that a black wall would be decidedly preferable to a white one; for here the air, heated by the warmth of the wall, not being allowed to escape, would increase the temperature of the whole air in the house; whereas the rays reflected by a white wall would many of them pass again through the glass of the windows and the roof, without adding to the warmth within.

Besides the above instances of intimate connexion between heat and light, the phænomena of combustion afford still others. When the temperature of a piece of iron is raised to the state called incandescence, that is until it becomes red hot, it emits light as well as heat; and when a more inflammable substance is heated, combustion is the consequence, during which there is a rapid extrication of light in the form of flame. The source of the light in these instances is still a matter of dispute.

Although heat and light are in so many instances very intimately connected, we have examples of the existence of the one without the other.

By friction, heat is extricated unaccompanied by light.

In phoſphorus, and other bodies poſſeſſing phoſphoreſcent qualities, as glow worms, ſhining fiſh, and putrid animal and vegetable ſubſtances, we have light without heat; at leaſt the means have not yet been diſcovered of rendering the heat ſenſible. And again, the rays of light reflected from the moon have not yet been ſatisfactorily proved to emit heat.

ESSAY IV.

HEAT IN PARTICULAR. EXPANSION BY HEAT.

OUR obfervations on heat in particular will be beft arranged by confidering feparately the general effects of heat. Thefe are, 1ft. Expanfion; 2dly. A change of form, as from folid to fluid, or from fluid to vapour; and 3dly. Combuftion.

Expanfion by heat. All bodies, whether in the folid, fluid, or gaseous ftate, are more or lefs expanded in every direction by the application of heat; unlefs in fome inftances, where there feems to be a chymical change in the nature of the fubftance, as in the baking of clay, where there is a contraction in all dimenfions, inftead of expanfion, which feems to arife from a femifufion, during which there is an alteration in the arrangement of the particles, approaching fomewhat in its nature to the cryftallization of falts.

As bodies in general expand when heated, fo do they contract when cooled; but to this there is an exception in the freezing of fluids, where, in confequence of the new arrangement in their particles, there is always a confiderable expanfion,

The force with which water expands when in the act of congelation is immenfe. Mufchenbroeck, who made experiments on this fubject by freezing water in metallic globes, found the force fufficient to burft one of brafs, that would have required a force equal to 27700 lbs. to have burft it.

It is by this means that huge fragments of rocks are feparated; the water that penetrates into the fiffures expanding with fuch force during congelation, as to break off the corners and projections.

The fame circumftance is fometimes taken advantage of in fplitting flate. The Collyweftern flate is dug from the quarries in large blocks, thefe are then placed in an oppofite direction to what they had in the quarry, and the rain is allowed to fall upon them; it penetrates the fiffures of the flate, and the firft fharp froft freezes the water, which, expanding with its ufual force, fplits the flate into thin layers.

The benefit that a froft is known to afford to ploughed land, is effected by the expanfion of the water breaking and crumbling down the clods of earth.

The expanfion of a *folid* body by heat may be inftanced in iron, and other metals. If a cylinder of iron, that exactly fits a ring, fo as juft to pafs through it, be heated until it becomes red hot, it will not then pafs through the fame ring; but if you immerfe it in cold water, or wait till it is gradually cooled, it will paſs through the ring again with the ſame facility as before. This fact is taken advantage of by coopers in faſtening the ſtaves of a caſk with iron hoops; they heat the iron hoops, and of courſe enlarge them, before they put them on, that in cooling they may contract, and tighten the caſk.

In time-pieces this expanſion of metals is the cauſe of ſlight errours; the vibration, or time of oscillation, of a pendulum is regulated by it's length; the longer the rod the ſlower the vibration; in the ſummer, therefore, the rod being lengthened by the heat, the pendulum oſcillates leſs quickly, and the clock goes ſlower than in winter; and this is the caſe with all clocks made in the uſual way. To rectify this errour, time-pieces, intended to be very accurate, are made with what is called the gridiron-pendulum, which is invented on the principle that different metals are expanded by heat in different degrees. Braſs, for inſtance, expands twice as much, and zinc three times as much as iron by the ſame increaſe of temperature. In the gridiron-pendulum, therefore, there are two rods of different metals, connected by a croſs-bar, ſo proportioned in length, and ſo diſpoſed, that the expanſion of the one ſhall elevate the weight in the ſame proportion as the expanſion of the other tends to depreſs it; the pendulum therefore conſtantly remains of the ſame length, and the effects of expanfion or contraction in the rod are counteracted.

In the glafs manufactories the expanfion and contraction of glafs by heating and cooling is a frequent fource of inconvenience and expenfe. It is naturally a very fragile article, and if cooled or heated very fuddenly is known to crack, and break to pieces; hence the neceffity of what is called annealing, which is the expofing of new made glafs to be very gradually cooled.

If heated glafs is fuddenly cooled, the external furface, having a tendency to contract whilft the inner parts remain in their expanded ftate, is neceffarily ruptured in the fame way that a bladder filled with air, when wet, will be cracked in drying by the exertion of its particles to contract, whilft the air within remains in the fame ftate of expanfion.

If the annealing of glafs be not well performed, the particles on the furface may be contracted fo much more, than thofe of the internal parts, as to give the glafs an irregularity in its texture, but not fo much fo as to caufe a fracture. Such glafs appears found, and is therefore faleable, but is ever after lefs able to bear fudden alternations of heat and cold. This is the caufe why fo many glafs veffels crack the firft time that hot water is poured into them, or that they are otherwife expofed to fudden heat. The reafon why glafs breaks by the too fudden application of heat is, that the particles of the furface being more heated expand more than thofe of the inner parts, and in their tendency to feparate produce a fracture.

Several ingenious modes of breaking glafs in any required direction, fuch as are practifed by chymifts, are founded on this circumftance; by which means glafs veffels that are broken may be fafhioned and fitted for a variety of ufes.

One mode, as pointed out by Mr. Henry, is to dip a piece of thread or ftring in fpirits of turpentine; wrap it round the glafs in the direction that you require it to be broken in, and then fet fire to it. Another mode is, to draw a red hot fkewer acrofs the glafs in the defired direction; and a third is, to wrap a red hot wire round the glafs, and if it does not immediately crack, to throw cold water on it, whilft the wire remains hot. The two former modes depend upon the fudden expanfion, and the laft upon the fudden contraction of the particles on the furface of the glafs.

The expanfion of *fluids* by heat is much greater than that of folids. It is made very evident by heating fpirits or any other fluid in a glafs veffel, that has a long and narrow neck; as the heat is increafed the fluid is expanded, and it confequently rifes in the neck of the veffel.

This expanfion of fluids has been very ufefully applied in the conftruction of thermometers, by which it is made the means of meaſuring the variations of heat in other bodies.

In the thermometer, which is an inſtrument ſo common as to need no deſcription, the liquor contained in the tube is expanded by heat, and contracted by cold, and conſequently riſes and falls; which riſing and falling is rendered very ſenſible to the eye, by making the bore of the tube, which may be compared to the neck of the veſſel in the former experiment, very ſmall in proportion to the bulb, which may be conſidered as the body of the veſſel.

This tube being applied to a ſcale, formed on fixed principles, the riſe and fall of the liquor within it is meaſured with accuracy, and thus becomes the true ſign of the increaſe or diminution of temperature in any ſubſtance, to which the bulb of the thermometer is applied. It does not however indicate the real quantity of heat in ſuch ſubſtances, but only ſhows that one body is warmer than another, and by how many degrees of heat the temperature of the one exceeds that of another.

When a thermometer is immerſed in water, which cauſes the mercury in the tube to ſtand at the fiftieth degree, and then into water, which raiſes it to a hundred, it is a common expreſſion to ſay, that the latter water is twice as hot, or contains twice as much heat as the former; and thus Sir

Iſaac Newton talks of boiling water being three times as hot as the blood in the human body.

This however is an errour, and it ariſes from the idea, that the ſcale of the thermometer commences at the point, below which there is no heat. Thus Newton believed the freezing point to be the natural zero, below which there was no heat; whereas we now know, that the freezing point is ſeveral degrees above the temperature of the air at certain ſeaſons in the polar regions, as in Hudſon's Bay, or at Kamtſchatka. In the latter place mercury has frozen by expoſure to the natural cold, ſo that the air at ſuch time muſt have been at leaſt 40° below the zero of Fahrenheit's ſcale, or 72° below the freezing point.

By artificial means ſtill more intenſe cold than this has been produced, and yet we have no reaſon to believe that we have reached the loweſt point, or that of the privation of all heat.

The range of heat from its loweſt to its higheſt degree may be aptly compared to an immenſe chain, formed of links, that have exactly the ſame length, the extremities of which chain are beyond the limits of our ſight. The moſt diſtant link, that we can diſtinguiſh towards one extremity, we mark as the firſt, that next to it the ſecond, and ſo on, till we come to the moſt diſtant that we can diſtinguiſh towards the other extremity. Now in ſpeaking of the links of this chain, which may be compared to the degrees of heat on the ſcale of a thermometer, it would evidently be erroneous, to ſay, that an object placed at the hundredth link was twice as far from the extremity, as one placed at the fiftieth; nor could we ſay how far either was from the extremity; but knowing that there are fifty links between the two, we can form an idea of their diſtance from each other, and their relative ſituation with reſpect to other objects placed along the ſame chain, that are within our view.

So, with reſpect to the thermometer, we know the number of degrees between the temperature of boiling water and of ice; and that the former, which is at 212°, is as much hotter than water at 122°, as this is hotter than ice, which is at 32°, there being 90° between each. Thus then the thermometer teaches us the relative, but not the abſolute heat of bodies.

The tube of the thermometer is ſometimes filled with air, ſometimes with ſpirits, and ſometimes with mercury. The air thermometers, being moſt delicate, are uſed in ſome chymical experiments; as the air is expanded or contracted in theſe thermometers, a coloured liquor is made to fall or riſe, which marks the degree of expanſion, and conſequently the variation of temperature.

The ſpirit-thermometers are applicable to intenſe degrees of cold, becauſe the ſpirit will not freeze where the mercury would; but they will not anſwer for ſuch high degrees of heat, the ſpirit being ſooner evaporated. For ordinary uſe and for moſt chymical experiments the mercurial thermometers are to be preferred, and principally for this reaſon, that mercury is equably affected by equal increments of heat at different temperatures, which is not the caſe with ſpirits, and ſtill leſs ſo with air.

Thermometers, from their conſtruction, are not calculated to meaſure very high degrees of heat; the tubes would be broken, and the mercury would be volatilized, if they were expoſed to much heat. To anſwer this purpoſe other contrivances have been offered. Some thought that the expanſion of metals would furniſh a convenient meaſure, others propoſed the rate at which metals cool, as a meaſure of their former temperature; but none can be compared in accuracy to the pyrometer invented by Mr. Wedgwood.

Noticing the contraction of clay in baking, he found that it contracts uniformly according to the degree of heat; and if the ſame kind of clay is uſed, that its contraction becomes an accurate meaſure of the temperature.

His pyrometer conſiſts of a number of ſmall pieces of ſlightly baked clay, and a braſs plate with two rulers, ſo fixed to it, that they gradually approach each other. On this plate is a ſcale of degrees, made to correſpond with thoſe of Fahrenheit's. The firſt degree of the pyrometer correſponding with $1077\frac{1}{2}^{\circ}$ of Fahrenheit's, and each degree afterwards equalling 130° of Fahrenheit's. The pieces of clay are all of a size, and fit in, between the rulers, where the firſt degree is marked.

When this inſtrument is uſed, one of the pieces is expoſed to the heat required to be aſcertained, that of a furnace for inſtance; and when it has been expoſed long enough to have acquired the heat of the furnace, it is withdrawn, cooled, and then applied to the rulers, between which it is allowed to ſlide as far as its bulk will admit it. The degree marked at the place, where it ſtops, indicates the temperature of the furnace; for the greater that has been, the more will the clay be contracted, and conſequently the further it will ſlide between the converging rulers.

Before we quit the ſubject of expanſion of fluids by heat, we muſt notice the peculiarity of water in this reſpect. Within a certain range of temperature water follows the general law of being expanded by heat, and contracted by cold; but beyond this, it is affected in the oppoſite way. When heat is applied to water at 32° it gradually contracts till it arrives at 40°, whereas other bodies expand in the ſame ſituation; but after it arrives at 40°, it follows the general law, and is dilated by the further application of it. When boiling water is gradually cooled, it regularly contracts, until it arrives again at 40°, and then it ſhows its peculiarity, and is expanded as it is further cooled.

The final cauſe of this peculiarity is to prevent the ſudden congelation of large maſſes of water, and to preſerve a warmth in ſome part of the water of lakes, and rivers, that may ſupport the life of its various inhabitants. How it effects this, is thus explained.

Water never freezes until its temperature is reduced to 32°. When the particles of water are expanded or contracted by variations in their temperature, they become ſpecifically lighter or heavier than the ſurrounding particles, and conſequently riſe in the former and ſink in the latter caſe. When therefore the water of a lake, which is at 60°, is gradually cooled by the approach of winter, the particles on its ſurface, being firſt cooled, contract, become ſpecifically heavier, and therefore ſink. Their places are ſupplied by others, which are cooled, contracted, and ſink in the ſame way; and thus the whole body of water is gradually cooled. This proceſs would continue, were it not for the peculiarity we have been ſpeaking of, till the whole body of water had been ſunk to the temperature of 32°, and then the whole would be ſuddenly frozen; which would prove certain deſtruction to all the animals it contained.

This would be the caſe, did water expand and contract by heat like other fluids; but now, as ſoon as the water of the lake is all cooled to 40°, the particles on the furface no longer contract, but on the contrary expand; they are confequently lighter than the particles below, and therefore remain at top, and are ftill further cooled till they come to 32°, and then ice begins to form.

Ice being but a bad conductor of heat, the procefs of cooling now goes on very flowly in the water; and whilft the air and ice are cooled, perhaps far below 32°, the water under the ice remains even at 40°, or little below.

This wife provifion of nature, which anfwers fuch an important end, is confined to frefh water. That of the ocean being prevented from freezing, except in the polar regions, by its immenfity, its communication with waters of warmer climes, and by its containing falt, which enables it to be reduced below 32° without freezing, needs not this peculiarity of expanding after its temperature is reduced to 40°. The water of the ocean therefore expands and contracts according to the general law, and this again is attended with confiderable advantages.

It being neceffary that the whole body of water fhould be equally reduced in temperature, that on the furface is feldom cooled fo low as 32°, and is therefore, in the winter time, warmer than the atmofphere, to which it becomes a conftant fource of heat. The winds in paffing over the ocean acquire warmth, and moderate the cold of the atmofphere on the land to which they blow; and this is the reafon why iflands are more temperate than parts of the continent fituated in the fame latitude.

The expanfion of *gaffes*, airs, or gafeous fluids, by heat, may be inftanced in the fimple experiment of holding a half-blown bladder before the fire. As the air in the bladder becomes heated, it expands, and what before only half filled it, now diftends it to the utmoft. It is by this expanfion of air by heat, that heated bodies are enabled fo readily to part with their heat to furrounding objects, and that fo juft an equilibrium is maintained.

When any part of the air is heated by the fun's rays on the earth, or by any heated body, it becomes expanded, and of courfe afcends, whilft other particles of air rufh in to fupply its place. Thus heat is tranfmitted from one place to another, and becomes more equally diffufed.

This is one caufe and the principal caufe of winds. When the atmofphere in any particular country is heated, as in the torrid zone, the expanded air afcends, and currents of cooler air rufh in on all fides to fupply its place. Thefe currents form the monfoons and trade winds, which blow regularly in certain latitudes, and at ftated times. The draughts of air perceived in rooms, where there are fires, are currents of air rufhing in to fupply the place of the expanded air, that paffes up the chimnies. It is by facilitating the egrefs of the heated air, that rooms are properly ventilated; and by contriving means to prevent its eſcape, that ſtoves and hot-houſes are able to preſerve their increaſed temperatures.

ESSAY V.

EFFECT OF HEAT IN CONVERTING SOLIDS INTO FLUIDS, AND FLUIDS INTO VAPOUR.

We now come to the fecond general effect of heat; its power of changing the form of bodies by converting folids into fluids, and fluids into vapour.

Moft fubftances are capable of being thus melted, and vaporifed by the application of heat; and moft probably all would be fo, were we able to excite a fufficient degree of heat. By abftracting the heat, we again reduce moft vapours to their fluid ftate, and fluids to that of folids. And it is likewife probable, that fuch as at prefent we cannot condenfe, or freeze, would be fubject to thefe changes, were we able to excite a fufficient degree of cold.

It is only when the temperature is raifed to a certain degree, that folids begin to melt, or fluids to be vaporifed; and this degree is different for every different fubftance, but is always precifely the fame for the fame fubftance, provided other circumftances are fimilar. Thus ice always melts when heated above 32°, as water always freezes when cooled below 32°; and water is always converted into vapour when its temperature is raifed to 212°, provided the preffure of the atmofphere is the fame.

Wax has another degree at which it is melted, lead another, filver another, and gold another. The degree of heat, at which fpirits boil, or begin to be converted into vapour, which is the fame thing, is lower than the boiling point of water; and that, at which æther boils, is a great deal lower ftill.

The point, at which falt water freezes, is lower than the freezing point of frefh water; and in the act of congelation its falt is depofited; and the ice, if feparated and melted, affords frefh water. Some of our navigators have obferved this fact with great joy, and obtained a fupply of frefh water, where they but little expected to meet with it. The mountains of ice met with at fea in the polar regions are wholly of frefh water, and pools or bafons of frefh water are often found on them from the partial melting of the ice.

Although all thefe fubftances have their fixed points, at which they boil under fimilar circumftances, yet the preffure of the atmofphere has a very confiderable influence in determining the point. The greater the preffure the greater the degree of heat requifite for making the liquor boil; and the more we can diminifh the preffure of the atmofphere, as is done by the airpump, the lefs is the degree of heat that is required to convert it into vapour.

In this way æther, ſpirits, and even water, are made to boil at the uſual temperature of the air, when the preſſure of the atmoſphere is removed by means of the airpump. So much is the boiling facilitated by this means, that philoſophers have gone ſo far as to aſſert, that, if all preſſure was removed from the earth, every ſubſtance, ſolid as well as fluid, would immediately be volatilized, or converted into vapour.

For further obſervations on this point we ſhall confine ourſelves to the conſideration of water, as its influence on this ſubſtance is moſt attended to. Water, upon an average, is found to boil at 212°, and this is generally conſidered its boiling point; but in this country there is a conſiderable difference at different times in the weight of the atmoſphere. In the barometer, which is the inſtrument for meaſuring this preſſure, the height of the mercury varies as much as three inches, and a riſe of one inch makes the water require two degrees more of heat to boil it. There is therefore in this country a variation of ſix degrees of heat in the temperature of boiling water at different times. When the barometer is at the loweſt, water will boil at 209°; and when it is at the higheſt, it will not boil till it is heated to 215°.

The more elevated the ſituation, the leſs is the preſſure of the air, and conſequently water will boil with leſs heat on the top of a mountain, than in the valley.

An amuſing experiment, eaſy to be performed, which I ſhall now deſcribe, ſhows this effect of preſſure on the boiling of water, as well as any experiments that can be performed with the air-pump. Half fill a Florence flaſk, or other glaſs veſſel, with boiling water, and cork it tightly. The water is now at reſt; but pour a little cold water on the upper part of the flaſk, and it will begin to boil; then pour hot water upon it, and it will ceaſe; pour the cold water again, and it will boil; and ſo on, for a conſiderable time.

The explanation of the experiment is this. When you cork the flaſk, the upper part of it is filled with vapour from the boiling water, and the cold water poured upon this part condenſes the vapour. Now as the air cannot get in, there is a partial vacuum; that is, the preſſure of air on the ſurface of the water is conſiderably diminiſhed. This being the caſe, the water will boil at a lower temperature; and the heat, which it retains, is ſufficient for the purpoſe. In the next place, by pouring hot water upon it, that within is partly again converted into vapour, which affords the ſame preſſure as the air would do; the water therefore ceaſes to boil, becauſe its heat is inſufficient under that preſſure to make it boil.

It has been ſaid, that, by increaſing the preſſure on the ſurface of water, you retard its boiling. It is on this principle, that what are called *digeſters*, are formed. By means of ſcrews, the top of the veſſel is kept down with ſuch force, as to prevent the eſcape of the vapour, which increaſing the preſſure on the ſurface of the water, in the ſame degree enables it to acquire a higher temperature. Papin carried his to that pitch, that the water acquired a ſufficient degree of heat to melt lead.

A veſſel on the ſame conſtruction, but of far leſs power, is now introduced into the kitchen with economical views. By enabling the water to be heated much above the boiling point, its ſolvent powers are increaſed; and thus bones are made to afford their glutinous and nutritious parts to the water, that common boiling would not be able to extract.

The immenſe power that is exerted by water, on the point of being converted into ſteam, requires digeſters, and other inſtruments, intended to confine it, to be made with great care, and with amazing ſtrength.

By a ſufficient increaſe of heat it may be made to exert almoſt any force. It has been made to burſt cannons, and ſtill ſtronger machines; and by the important invention of the ſteam engine, it is brought to move very heavy weights.

When a ſubſtance undergoes the change that we have here been talking of, from ſolid to fluid, or fluid to vapour, it is not only neceſſary to raiſe its temperature to the melting or boiling point, but to ſupply it with ſtill more heat, for the converſion is attended with an abſorption of heat.

When ice is melted it abſorbs heat from all ſurrounding bodies, which heat has not the effect of increaſing its temperature, but becomes latent; the water is not hotter to the feeling, or to the thermometer, than the ice was, before it was melted, but it has abſorbed and contains more heat.

The ſame happens, when a fluid is converted into vapour; and the ſame quantity of heat, that is thus abſorbed, is again extricated, when the vapour is condenſed into a fluid, or the fluid frozen into a ſolid.

The application of this fact aſſiſts us in explaining a variety of phenomena, that without the knowledge of it would be inexplicable. Put a veſſel of ſnow or of ice before a fire, and although it is all the time receiving heat from the fire, a thermometer immerſed in it ſhows no increaſe of temperature; all the heat, that is received, being neceſſary to convert the ſnow into water: but as ſoon as it is all melted, the thermometer begins to riſe.

Were it not for this circumſtance, all the ſnow and ice would be inſtantly melted, when the temperature of the air is raifed above 32°, the confe-quence of which would be dreadful inundations after every winter.

So much heat is abforbed when a folid becomes fluid, that if we can fuddenly effect the converfion, we produce a great degree of cold, and on this depend the effects of freezing mixtures. When fnow and falt mixed are melted in a warm room, fo much heat is abforbed by them that a veffel of water immerfed in the mixture becomes frozen, notwithftanding the warmth of the room. In this way our confectioners prepare different kinds of ices in the fummer. Various mixtures of falts, when diffolved in water, produce the fame effect without the addition of ice. Eleven parts of fal ammoniac, ten of faltpetre, and fixteen of Glauber's falt, mixed with thirty-two parts of water, will produce a cold fufficient to freeze water. By diffolving muriate of lime in nitrous acid even mercury may be frozen.

The heat that is given out, when water is frozen, tends to moderate the intenfity of our winters, and accounts for the increafe of warmth that is frequently obfervable after a fall of fnow. Other fluids give out heat during their converfion to a folid ftate. In falts it may be inftanced by the following experiment. Boil a pound of Glauber's falt in a pint of water, and when boiling hot, pour fome of this faturated folution into a phial, but not ſo much as to fill it; cork the phial cloſe, and let it ſtand to cool. When cold, the ſolution is ſtill fluid; but the inſtant you draw the cork, the ſalt becomes cryſtallized, and the whole maſs ſolid, and at the ſame time ſo much heat is evolved, as to make the phial very ſenſibly warm. This is an inſtance of heat being given out by a body during its converſion from a fluid to a ſolid ſtate.

The explanation of the experiment is this: water will diſſolve more Glauber's ſalt when hot than when cold; and cold water will diſſolve more in proportion as the preſſure of the atmoſphere is diminiſhed. The hot water was here ſaturated, and would, if ſuffered to cool in an open veſſel, have depoſited part of the ſalt; but by corking it when hot, the ſuperior part of the phial being filled with vapour, would form a partial vacuum on the ſurface of the ſolution, when by cooling the ſteam was condenſed. The preſſure of the atmoſphere being thus diminiſhed, the cold water was able to retain in ſolution all the ſalt that the hot water had diſſolved; but as ſoon as by drawing the cork you admitted the uſual preſſure of the atmoſphere, the cold water was rendered incapable of holding ſo much ſalt in ſolution, and part was inſtantly cryſtallized.

When fluids are converted into vapour, I have ſaid, that there is much heat abſorbed, and of courſe cold produced. This takes place both when they are vaporiſed by heat, and when they are raiſed by what is called ſpontaneous evaporation; which proceſs differs from the former in other reſpects, though it agrees in this.

When æther, ſpirits, or water are expoſed to the air, they are gradually evaporated, and in this proceſs abſorb heat, as well as when they are made to boil and are thus vaporized. To prove this, dip the bulb of a thermometer in æther, and expoſe it to the air, and you will find the mercury to fall conſiderably; or dip your hand into the ſame liquor, or into ſpirits, or even water, and then expoſe it to the air, and you will feel a very conſiderable degree of cold, in conſequence of its abſorbing heat from your hand to convert it into vapour.

In warm climates the inhabitants cool their water, and other liquors for drinking, by wrapping the veſſels in wet rags, and ſuſpending them in a current of air; or by keeping their water in porous earthen veſſels, through which a part gradually oozing is evaporated, and cools the reſt.

It is this evaporation that makes a perſon feel ſo cold when his clothes are wet, although he is perhaps ſitting near a fire; and it is the cold thus produced that injures the health much more than being expoſed to a cold and ſharp air. It is the abſorption of heat by the vapour that prevents water from acquiring a greater degree of heat than 212°. If you boil water ever ſo violently, or apply to it ever ſo intenſe a heat, it never increaſes in temperature;

the heat that you communicate all going to the converſion of it into vapour. In cooking therefore it is uſeleſs to apply additional heat to water that is boiling, to make it, as the ſervants call it, boil faſt. If you keep the water boiling at all, that is ſufficient; and in many caſes indeed articles will be as well done, and as ſoon done, by a heat conſiderably leſs than that of boiling.

Having obſerved that vapours contain more heat than fluids, and fluids than ſolids, when their temperature is the ſame, I muſt now add, that among fluids, among ſolids, or among vapours, one kind contains more heat than another; thus a pound of water contains more heat than a pound of mercury; a pound of iron more than a pound of tin; and a cubic foot of common air more than the ſame quantity of inflammable air.

According to the proportion that different bodies poſſeſs, ſuch we ſay is their *capacity for heat;* thus we ſay that water has a greater capacity for heat than mercury, and iron than tin. The conſequence of this difference of capacity is, that different bodies expoſed to the ſame heat require different times to be raiſed an equal number of degrees; thus, expoſe the ſame quantity of mercury and of water to the ſame heat, and the former will be heated 8°, 10°, or 12°, long before the water, becauſe it requires a leſs quantity of heat to raiſe it.

In chymical experiments, whenever there is a change of capacity without a change of temperature, there is ſure to be a ſudden evolution of heat, or abſorption of it producing cold. Thus on mixing ſpirits and water, and ſtill more on mixing vitriolic acid and water, a very ſenſible degree of heat is evolved, becauſe the mixture has leſs capacity for heat, than the two ſeparately. So the heat produced when fluids become ſolid, and the cold when they become vapours, as mentioned above, is explained by the ſolid having a leſs and the vapour a greater capacity for heat than the fluid.

All the heat afforded by combuſtion of inflammable bodies is given out, in conſequence of the reſult of combuſtion, as the aſhes, ſmoke, &c., having a leſs capacity for heat, than the combuſtible body, and the air that has been conſumed.

There is another law of heat that requires to be mentioned, viz. that it paſſes more readily through one ſubſtance than another; and this quality in the ſubſtance to tranſmit it, is termed its *conducting power*. If you hold a glaſs tube and a piece of wire with your hand in the flame of a candle, you will ſoon be made ſenſible that the wire is the beſt conductor. Air, when confined, is a bad conductor; and this is the reaſon why all porous bodies are ſo.

Wool, by admitting and confining particles of air in its interſtices, is a very warm covering for the animals that bear it, and a warm clothing for man.

Double windows and double walls make the warmeſt rooms in cold climates, and the cooleſt in warm climates; for the air encloſed between them, being a worſe conductor than either wood or ſtone, prevents the egreſs of heat in the cold, and its ingreſs in the warm climates. For the ſame reaſon partitions made with lath and plaſter, with an intermediate ſpace, make the rooms in this climate warmer than wainſcot partitions.

In hot-houſes not only the walls but the ſaſhes ſhould be double, to retain the heat moſt effectually.

Snow being a light porous body is a bad conductor of heat, and on this account is of infinite ſervice in preſerving vegetation; for let the air be ever ſo cold, the ground, that is covered with ſnow, is ſeldom reduced in heat below 32°; and this accounts for animals living ſo long, that are buried in the ſnow.

ESSAY VI.

COMBUSTION.

The third and laſt general effect of heat is *combuſtion*. When a body, that is not very inflammable, is heated to a certain degree, it becomes luminous, as iron for inſtance, and is then ſaid to be ignited, or to be in a ſtate of incandeſcence; but when a more inflammable ſubſtance is heated, it undergoes a proceſs called inflammation, during which heat and light in a greater proportion are emitted, and the chymical qualities, both of the inflammable body and of the ſurrounding air, are materially altered.

Incandeſcence is probably the ſame proceſs with inflammation, only in a ſlighter degree, and we ſhall conſider both under the term combuſtion.

The combuſtible body in common language is ſaid to be conſumed; but it muſt not be ſuppoſed that it is annihilated, that it is abſolutely deſtroyed, for in fact it is only changed; and the reſults of combuſtion are always equal in weight to the inflammable body, and the air abſorbed.

It ought here to be obſerved, that inflammation or combuſtion can never take place without air.

If an ounce of phoſphorus is confined in a veſſel of air, and the whole apparatus weighed, and if you then ſet fire to the phoſphorus, and let it burn until it is, to ſpeak in common language, all conſumed, the apparatus, on being again weighed, will be found to have neither loſt nor gained by the experiment. A change however has taken place, the volume of air is diminiſhed, and the phoſphorus is converted into an acid; which acid, if weighed, will be found equal to the phoſphorus that has been burnt, and the air that has diſappeared.

Similar facts will be aſcertained in every inſtance of combuſtion. There is a chymical change, but no abſolute loſs or conſumption. If the whole products were collected after a candle is burnt out, or after the combuſtion of any kind of fuel, they would always be found to equal in weight the inflammable body and the air, that ſeem to have been conſumed.

As the preſence of air is an eſſential requiſite in every caſe of combuſtion, and as it always undergoes a chymical change, it is probable that it is the ſource both of the heat and light that are extricated. Of the heat indeed we know it to be the chief, if not the only ſource, in conſequence of the change of capacity that attends its chymical change. The vulgar opinion, therefore, that the fuel gives out the heat, and the candle the light, is erroneous; and it is an inaccuracy in language to ſay, that one kind of fuel gives out more heat, or one kind of candle more light, than another. As, however, the errour and the inaccuracy can be the cauſe of no inconvenience, it would at leaſt be uſeleſs in common converſation to make uſe of other terms.

As air is thus neceſſary to combuſtion, great attention to procure a ſufficient ſupply becomes a point of conſiderable conſequence in promoting and keeping up the proceſs. In conſtructing furnaces, and even in fitting up fire-places, it requires the chief conſideration. In the former, the length of the chimney in a great meaſure influences the heat, by cauſing a greater or ſmaller current of air through the fire; and dampers or regiſters are in ſome caſes uſed, which, by admitting more or leſs air into the furnace, regulate the intenſity of the heat. The uſe of bellows depends on their ſupplying a greater quantity of air; and in the furnaces of iron-foundries immenſely large bellows are uſed to increaſe the draught.

In common fire-places, the dimenſions of the chimney, the poſition of the ſtove, and the free acceſſion of air, are the three points chiefly to be attended to, with a view of having good fires, and preventing the inconvenience of ſmoky chimnies.

When the chimney is very large, as moſt kitchen chimnies were formerly built, they are almoſt ſure to ſmoke. The column of air in the chimney not being all ſufficiently heated to aſcend, there are different currents; the heated air aſcends in the middle, whilſt the colder air deſcends at the ſides, and in deſcending forces part of the ſmoke with it into the room.

To prevent this, the fire is made larger, and the door, or a window, is opened; the heat now is ſufficient to expand all the air in the chimney; but if the door or window is not open, there not being a ſufficient quantity of air admitted by the uſual crevices, the external air forces itſelf down the ſides of the chimney to ſupply the place of that which is conſumed, and that, which being expanded, paſſes up the middle of the chimney, and thus the ſame inconvenience is repeated. By contracting the throat of ſuch a chimney, the column of air to be heated is leſs, and is ſufficiently expanded by leſs fuel, at the ſame time that the current of air required to keep up a briſk fire, is leſs; ſo that the chimney will no longer ſmoke, nor does the neceſſity of opening the door exiſt.

If a ſtove is placed very forward in the room, the heated air is expanded, and aſcends in the apartment, and the ſmoke along with it, particularly when the fire is firſt lighted; the air in the chimney being then not heated ſo as to eſtabliſh a current. This is often obſerved in old-faſhioned moveable fire-grates, and is generally remedied by pushing them a little backwarder.

The free accession of air is the most important consideration. We have seen, that without it a current of air will be formed down the chimney that must inevitably bring the smoke with it. In small and close rooms it is the most frequent cause of smoky chimnies and bad fires. When it is found, that opening a door or window prevents the smoke from descending, the cause is evident, and the cure is generally accomplished by contriving a communication with the air; and if this can be done under the grate, or near it, so much the better; as a current of cold air from a distant part of the room will be sure to prove inconvenient. If the room is lofty, a communication may be made over the door or near a window, above the height of persons in the room, which will prevent any inconvenience from the current. But in low rooms, I have seen this attempted and fail; or it has answered only when the fire is first lighted, or before the air in the room has been heated by company.

The reason of this becomes clear and evident, if a candle is held before the opening, at a time when the air in the room is heated; for the flame of the candle is drawn towards the opening, and not from it into the room; which proves clearly that, inftead of admitting air, it is the channel through which air is carried out of the room.

Many chimnies only fmoke when the fire is firft lighted, which arifes from the air in the chimney being colder than the external air; in confequence of which it defcends, and, paffing through the fire, carries the fmoke with it through the bars into the room.

This may be prevented by laying the fire very light, and fetting fire to a handful of fhavings on the top previoufly to lighting the fire at the bottom; or more certainly by fetting fire to a piece of paper, and holding it a little way up the chimney. This heating the air in the chimney is fure to eftablifh a current in the proper direction, and carry the fmoke upwards.

Moft chimnies are in this predicament when fires are lighted for the firft time after a long interval, as in the beginning of winter; and ignorant people attribute it to the air in the chimnies being damp. The fact is, that the air in the houfe, and confequently that in the chimney, is colder than the external air, as is the cafe during fummer and autumn, until by lighting fires we have increafed its temperature. The firft time a fire is lighted, therefore, as the air in the grate is expanded, its place is fupplied by cold air from the chimney, which rufhing through the fire carries the fmoke into the room, unlefs, as I have before advifed, fome means are taken firft to warm and rarefy the air in the chimney.

Argand's lamp burns better than a common one becaufe it admits a current of air through the centre of the wick. This caufes fo complete a combuftion, that the fmoke, which oil ufually gives out, is burnt in this lamp, and therefore it affords more light.

When we wifh for light rather than heat, we employ fuch inflammable fubftances as allow their particles to be volatilized, as fpirits or oils; for flame is part of the inflammable fubftance volatilized by heat, and ftill in a ftate of combuftion. It is always conical, and its external furface only is in an ignited ftate, as is eafily proved by fuddenly thrufting a match into the centre of the cone, as of that arifing from fpirits burning in a fhallow difh. If you allow it to remain there fome time, and then fuddenly withdraw it, the brimftone on the end of it will not be burnt. The reafon why only the furface is in combuftion is, that the contact of air is neceffary, and it has no accefs to the centre.

We have now gone through the confideration of the general effects of heat, and taken notice of its laws refpecting inanimate matter. It is by attending to all thefe properties that fo much has of late been done towards economifing fuel; and

Count Rumford is the perfon to whom we are indebted for moft of thefe improvements.

That patriotic and humane philofopher has fhown the true value of literary acquirements, and taught us the juft application of philofophical truths, by making them fubfervient to the relief of the poor, and to the benefit of his country.

In cooking he has taught us to economife our fuel, by applying feparate fires to the pots or boilers, to the ovens and roafters, and to fmaller utenfils, as kettles and faucepans.

In a kitchen range, as commonly fitted up, nine tenths of the heat is either carried up the chimney, or ufelefsly thrown into the kitchen, to the great inconvenience of the cook. If all this heat, that is loft, could be faved, or applied to the intended purpofes, one tenth of the fuel, that is now expended, would be found fufficient, and confequently the faving would be immenfe.

The improvements, which I am about to notice, do not lay claim to fo much as this, but have certainly accomplifhed much. The chief object is to confine, as much as poffible, the heat emitted to the ufe for which it is intended, namely, boiling, roafting, ftewing, &c.; which is only to be done by ufing clofe ftoves, and applying the fire feparately to different veffels. It will be unneceffary to detail minutely all the methods he has adopted to effect this purpofe. The leading principles of his improvements will be made evident by the following obfervations.

When in the common mode of cooking, where the kitchen is furnifhed with a range, you wifh either to roaft or boil a joint of meat, it is requifite that the fire fhould be made up, as the cook terms it, long before he can lay down the meat or put on the boiler. That is to fay, in fact, that it is neceffary to heap on an immenfe quantity of coals, and fuffer them to burn till the fire is clear and bright, before the heat can be applied to the required purpofe; and even then it is but a fmall proportion of the heat given out, that you can apply either to boil the water in the pot, or roaft the joint upon the fpit.

If you are boiling, for example, all the heat that emanates from the burning fuel in front of the fire is completely loft; and only that, which rifes from the top, and directly ftrikes againft the pot or boiler, goes to anfwer the intended purpofe, which cannot upon an average be fo much as one tenth part of the whole heat afforded by the combuftion of the fuel.

This mode of boiling upon an open fire, too, makes it neceffary to have the kitchen ranges very deep from front to back, which adds confiderably to the confumption of fuel.

In the next place, when it is required to roaft at one of thefe fires, all the heat that emanates from the top of the fire is decidedly loft; and of that which comes from the burning fuel in front, only fuch a part, as is directly oppofite to the meat to be roafted, is appropriated to the intended purpofe.

In moft kitchens, a fmoke-jack, and in many an iron oven, fitted up by the fide of the range, and heated by means of a flue going from the back of it to the oven, are part of the cooking apparatus. The plaufibility of the jack being made to act, and the oven to be heated, without an additional fire, has perfuaded moft people to believe them very economical contrivances; whereas, if duly confidered, they will prove to be very extravagant ones, adding confiderably to the expenditure of fuel.

To erect one of thefe fmoke-jacks, it is neceffary that the chimney be very large; and to put it in motion, it is requifite that the whole column of air contained and paffing through this large chimney be conftantly heated, not only fufficiently fo to carry up the fmoke, but to produce fuch a current as will keep this badly-contrived machine in motion.

To effect all this, a much larger fire muft be made, than would be required merely to roaft the meat, particularly if it is a fmall joint; for if the fire be reduced, the fmoke-jack ftands ftill.

Befides this unneceffary exhauftion of fuel, almoft every fireplace thus conftructed is found to ſmoke, unleſs the door or windows be kept open, and a briſk fire kept up; ſo that ſuch apartments cannot be preſerved uniformly warm.

To heat the iron oven, that I have ſpoken of, it is requiſite that a very briſk fire be kept up in the grate; and from the length and awkward ſtructure of the flue, in ſuch as I have ſeen, the greateſt part of the heat is loſt and diſſipated, before it reaches the oven.

Another mode of applying heat to cooking, which is thought by ſome a very great improvement, is by means of what is called a ſteam-kitchen. This apparatus is very neat, and adds much to the convenience of the kitchen, as it is not neceſſary to over-heat it by a large fire, as in the common mode of boiling. This plan, however, is found by no means to ſave ſo much fuel, as was at firſt apprehended; and when we conſider how much apparatus is to be heated by the ſteam, before it is applied to the deſired purpoſe, and ſtill more, when we conſider how much heat is abſorbed, and rendered inert, as it were, in the converſion of water into ſteam, we ſhall be aware of the great ſources of the loſs of heat in this apparatus.

Having thus pointed out how, and why, the uſual modes of cooking are attended with conſiderable waſte of fuel, it will, from what has been ſaid, immediately occur to you, that by uſing ſeparate ſmall fires under the boilers, ovens, &c., moſt of the ſources of this loſs of heat will be avoided. If the coppers and boilers are well hung, and the ovens or roaſters well ſet up, almoſt all the heat afforded by the combuſtion of the fuel is applied to them; and, in conſequence of the length of the flue, the current of air through the fire is ſo briſk, as to conſume cinder-aſhes moiſtened, or other fuel, that would hardly burn at all in open fire-places. The ſame quantity of food may thus be cooked with not more than one fourth part as much fuel, as in the common way.

As the machine called a roaſter, a late invention of Count Rumford's, is not yet become a part of the cooking apparatus, I ſhall offer a ſlight deſcription of it.—It is ſomething like the common iron oven, except that, inſtead of being ſquare, it is nearly cylindrical, flattened however at the bottom. It has a double door, with an intervening ſpace of about an inch, to prevent the eſcape and loſs of heat. There are two iron tubes running along its bottom, on the outer ſide, which turn up at the back of the machine, and open into it, near the top; the other orifices open into the kitchen, in front of the roaſter, and immediately under it; which orifices are furniſhed with plugs or ſtoppers. Another part of the apparatus is a valve, ſhutting or opening a communication between the roaſter and the chimney of the flue. The grate, which ſhould be very ſmall, to prevent too large a fire being kept up, is ſituated immediately under the machine, and not more than ſix inches below the tubes; which, with the bottom and ſides of the roaſter, are directly expoſed to the fire. When uſed, the meat is to be put upon a wire ſtand, over a pan of ſalt and water, and placed either on the bottom of the roaſter, or on a ſhelf, which moſt of them are made with, to allow of roaſting two diſhes at a time. The valve is now to be turned, ſo as to prevent any communication between the roaſter and the chimney; and the orifices of the tubes are to be cloſed with their ſtoppers. The fire being lighted, the water in the pan is ſoon converted into vapour, and the meat is, as it were, parboiled. About twenty minutes, or half an hour before you expect the meat to be ſufficiently cooked, the valve is to be opened, to let out the vapour; and the ſtoppers are to be taken from the tubes, that through them the roaſter may be ſupplied with hot and dry air. The meat now begins to be browned, and to aſſume the appearance of roaſted meat; from which, when quite done, it can ſcarcely be diſtinguiſhed by the niceſt palate. It has not the peculiar flavour of baked meat, and for the plain reaſon, that the ſteam of the water prevents any vapour riſing from the meat in the former part of the proceſs, and the opening by the valve prevents its remaining in during the latter part; from the confinement of which, in the common mode of baking, I conceive the peculiar flavour of baked meat to arife.

By putting the meat into the roafter before the fire is lighted, it becomes gradually heated, and hence retains all its juices; which makes the meat cooked in this manner particularly palatable. Indeed, on this point, the Count obferves, that the fmaller the fire, and the more flowly the meat is cooked, the better flavoured is it when done; and what is of confiderable importance, the lefs fuel becomes neceffary. If the fire is fo fmall, that a joint of meat requires fix or eight hours cooking, lefs fuel will be confumed, than if the heat is fufficient to cook it in two or three hours, and at the fame time the meat will be more palatable.

The roafter likewife anfwers all the purpofes of an oven, by heating it before the bread or other things are put in, and by keeping the valve fhut, and the tubes always open.

They may be made of any fize, but two fmaller ones are preferable to one large one. For a moderate-fized private family they are made large enough to roaft a joint of meat and a couple of fowls at the fame time. It fhould be fitted up on one fide of the fireplace; and a boiler, or, if it is neceffary, two, on the other fide, with their fteamers for vegetables, and an opening or two for faucepans and ftewpans. The firegrate in the middle, being only intended to warm the apartment, need be but a very ſmall one. And the whole appearance of a kitchen thus fitted up is very neat, and much more comfortable, as a dwelling apartment for the ſervants, never being overheated, and the chimney never ſmoking.

ESSAY VII.

THE DIFFERENT SOURCES OF HEAT.

BESIDES the combuftion of inflammable fubftances, we have other means of exciting heat. The friction of two hard bodies, one againft the other, excites heat fufficient to fet fire to combuftibles. Inftances have occurred of forefts being burned down, in confequence of the wind producing fuch confiderable friction between their boughs, as to fet fire to them.

In the whale fifhery the precaution is neceffary, of wetting the line, and the part of the boat, that it is drawn over, as foon as the whale ftruck with the harpoon dives, and carries with it the vaft length of the line. Otherwife the friction of the line drawn with fuch velocity over the edge of the boat, would unavoidably fet it on fire. Carriages by the friction of the wheel upon the axle, mills, and other machines by friction of their different parts, have frequently been fet on fire, and deftroyed.

In the iflands of the South Sea, in Africa, and in America, the natives have various means of exciting heat by friction, to light their fires. Some rub flat pieces of wood together. Others fit the end of a ftick, previoufly charred, in a hole made in a piece of wood, that is faftened to the ground, and then twirl the ftick with celerity till it inflames. Tinder is fometimes put into the hole, or brimftone rubbed on the ftick to make it take fire more readily.

Heat is likewife excited by concuffion. Iron by repeated blows with a hammer may be made hot enough to fet fire to inflammable fubftances, as is ufually practifed by blackfmiths.

By *collifion* we excite heat, when we ftrike a light with flint and fteel. A fmall part of the fteel is detached, which is fo much heated, as to be fufed, and fufficiently fo, to inflame the tinder.

The heat emitted by a change in the chymical compofition of a body, accompanied by a diminution in its capacity for heat, has been already noticed in fome inftances. Indeed combuftion is a change of this kind; but there are fome other inftances worth mentioning, and particularly fome examples of fpontaneous inflammation.

Inflammation has been known to take place from linfeed oil getting accidentally amongft hemp, or hempen cloth, which has been confumed in confequence. Some particular chymical change was here effected, accompanied with a change of capacity for heat, in confequence of which fo much heat was extricated, as to fet fire to the materials. The fame has happened with wool, and with lampblack, when mixed with linfeed oil.

When aqua fortis is poured upon any of the volatile oils, particularly if it has been previoufly mixed with one fifth of vitriolic or fulphuric acid, the mixture burfts out with a violent flame; owing to the fame caufe, *viz.* a diminution in the capacity of the fubftances for heat.

During every kind of fermentation, heat is evolved; thus, when green undried vegetable fubftances are heaped together, they begin to ferment, and often emit fo much heat, as to take fire, as in hay-ftacks made up before the hay is fufficiently dry.

There are certain chymical compofitions, that poffefs this property of fpontaneous inflammation, and they are for this reafon called *pyrophori*. The pyrophorus of Homberg which inftantly takes fire, when expofed to the air, is thus prepared.

'Melt equal parts of powdered alum and brown fugar over a fire, and keep ftirring them, till reduced to drynefs. Then introduce the mixture into a common phial coated with clay, and to which a glafs tube, open at each end, is luted. Keep the phial in a red heat furrounded with fand, till no more gas efcapes by the tube; then clofe the tube with a little moift clay, to prevent the accefs of the air, and remove the phial from the fire. The gas that iffues from the tube may be inflamed by holding to it a piece of lighted paper, and when the flame difappears, the operation is known to be completed.

A pyrophorus is ſaid to be immediately formed, by rubbing together in a mortar fifty-four grains of ſulphur, thirty-ſix of very dry willow charcoal, and three of phoſphorus.

We ſhall now conclude the ſubject of heat by obſerving, that the term is often uſed to ſignify a ſenſation, of which the preſence of caloric, or matter of heat, is the cauſe. Many are apt to imagine that this ſenſation is a ſufficiently accurate teſt of the temperature, or degree of heat of the air, and other bodies. Hence nothing is more common than to obſerve, that this is very hot; or that very cold; that this is warmer than that; or that the air is colder to day, than it was yeſterday; whereas we only mean to ſay, that to our ſenſations, or feeling, ſuch and ſuch is the caſe; but how far this is from accuracy in moſt caſes, will appear from the following obſervations.

It frequently happens, that one perſon complains of the coldneſs of the air, at a time, when another is obſerving that it is warm, which is owing to their ſenſes being differently affected. But the ſame perſon too feels very differently at different times. If he comes out of a cold ſharp air into a moderately warm room, he feels it ſufficiently warm and comfortable; but when he comes out of a ſtill hotter room into the ſame apartment, he complains much of the coldneſs of it. This proves the inaccuracy with which we judge of heat by our ſenſations; and you may ſatisfy yourſelf of the ſame point by the following experiment.

Put your right hand into a baſin of water, as hot as you can well bear it, at the ſame time put your left into very cold water, and after a few minutes take out both hands, and inſtantly immerſe them into water moderately warm, and the right will feel cold, whilſt the left feels warm.

ESSAY VIII.

OF LIGHT IN PARTICULAR.

THE confideration of the laws of light, as to its refrangibility, its reflection, &c. belongs to the natural philofopher. We have only to confider it as a chymical agent, *i. e.* to notice its influence on other bodies, fo far as its prefence or abfence regulates their chymical changes. We have already confidered it as bearing certain relations to heat; we have alfo noticed its extrication, either from the air, or from the inflammable body during combuftion; and we fhall in a future Effay find a more appropriate place, for explaining the phænomena of its emiffion from phofphorus, and certain bodies called phofphorefcent. We fhall therefore find but few circumftances to attract our attention in this place; but it is of confequence both to the chymift, and the manufacturer, to be aware, that the prefence or abfence of light is of more moment in a variety of operations, than it is generally conceived to be.

Nitric acid, when expofed to the fun's light, undergoes a gradual change, that would not take place if the light were wholly excluded from it. It firft becomes of a ftraw colour, and then paffes to a deep orange, and its other properties are at the fame time altered. The light is ſuppoſed to unite with the oxygen of the acid; for the coloured liquor certainly contains a leſs proportion of that acidifying principle, and oxygen gas is extricated from it during the action of the ſun's light.

This points out the neceſſity of keeping nitric acid, or aqua fortis, in painted bottles, or otherwiſe ſecluded from the light. Kept in this manner it undergoes no changes, but without this precaution it acquires other properties, by which both the chymiſt and the manufacturer, particularly the dyer, may in ſome caſes be diſappointed.

Very many coloured bodies are faded, or otherwiſe changed in colour, by long continued expoſure to the light. This can only be in conſequence of its effecting ſome chymical change in the colouring matter, whether it be an artificial dye or the natural colour of the ſubſtance. The druggiſt, aware of this, ſhould keep his digitalis, or fox-glove, and other green vegetable powders, in bottles painted black, as the beſt means of preſerving their colour, and probably their medicinal virtues; for there is great reaſon to believe, that the ſame chymical change that affects their colour diminiſhes their virtues as medicines.

That the fading of colours by expoſure to the ſun's light is a chymical effect, produced by the light upon the colouring matter, appears evident from its affecting differently articles dyed with different ſubſtances, though of the ſame colour; thus yarn, or other woollen goods, dyed red with kermes, retains its colour longer, and is leſs faded, than the ſame dyed red with cochineal. It is alſo well known that one painter's colours ſtand much better than another's, in conſequence of their being differently prepared.

The operation of light in effecting the fading of colours has been but little attended to; and the particular chymical changes which occur, are but imperfectly underſtood. In many inſtances it probably depends upon the attraction or affinity that exiſts between light and oxygen.

The blue colour of indigo depends upon the preſence of oxygen, for the colourleſs liquor obtained from the plants becomes blue on expoſure to oxygen gas, and the gas is at the ſame time abſorbed. This being the caſe, ſtuffs dyed blue with indigo will be faded, or loſe their colour, by the abſtraction of oxygen; and, as light has ſo ſtrong an affinity for that ſubſtance as to decompoſe nitric acid, it is probable that it alſo abſtracts it from indigo, and thus diminiſhes and ultimately deſtroys its colour.

Stuffs dyed green acquire a yellowiſh tinge by expoſure to the light; the deſtruction of the blue colour by the above means will account for this, for green is a compound of blue and yellow. Purple ſtuffs in the ſame way become reddiſh, that colour being compounded of blue and red.

In attending to the phænomena of vegetation it is found, that the preſence of light is abſolutely neceſſary to the health of plants. If it is wholly excluded from them they ſoon become pale and ſickly; they loſe the whole of their green colour, grow weak, wither, and die. Vegetables are blanched by the partial excluſion of light; celery, by earthing it up round the roots, and cabbages or lettuces by tying their leaves together. The parts thus kept from the influence of the light, become pale and almoſt colourleſs, and are then ſaid to be blanched.

Plants that grow naturally in dark ſituations are uſually of a pale colour; as the orobanche ramoſa, which always grows under the ſhade of hemp, the lathræa and others, that are found in the ſhady parts of woods, and a variety of lichens growing upon trees.

If light is admitted only into one part of the room, in which plants grow, they always incline towards that part; nature's laws being in this inſtance, as in others, ſo wiſely eſtabliſhed, and ſo connected with each other, that where benefit is to be derived from it, the effects of one lead to the completion of another.

This inclination of the plant towards the light bears ſo much the appearance of voluntary motion, regulated by a knowledge of the beneficial influence of light, that ſome philoſophers have brought it as a proof that vegetables are endowed with reafoning faculties. But how flight, how futile are their arguments, how falfe and unphilofophical their deductions; to affume a new power, a reafoning faculty in plants, merely becaufe the confined and imperfect knowledge of man is unable to explain an afcertained fact! How many thoufands of phænomena are our weak intellects unable to comprehend! and how many of nature's laws remain yet to be explored! Would it not then be lefs prefumptuous to acknowledge our ignorance; or more reafonable, to investigate the nature of the fact, than rafhly to attribute to the vegetable world a faculty that we have no grounds for fuppofing it to poffefs?

The prefence of light we find to be neceffary to healthy vegetation. Its chymical effects are fuch as to preferve and keep up thofe changes in the various parts of the plant that conftitute health. But this is not all; the Creator of the world, the eftablifher of all nature's laws, anticipating as it were the accidental wants of individual plants, has fo ordained it, that the effects of light fhall alfo be fuch as to incline the plant, that is but partially expofed to it, towards the light, in confequence of which it receives more and more of its genial influence. This is a beautiful inftance of the omnifcience and the beneficence of the Creator; and the philofopher viewing it in this light muft notice it with admiration, and acknowledge that infinite wifdom is apparent in the minuteft of his works.

We confefs ourfelves ignorant of the means by which light has this particular effect, as we avow ourfelves ignorant of the means by which it influences the colours of vegetables; or by which any other at prefent inexplicable fact is accomplifhed; but fuch may become explicable to future chymifts, and we ought to engage in the inveftigation, rather than retard it by the affumption of a new principle. This hypothetical mode of reafoning puts a ftop to inquiry by perfuading us, that we have explained facts, when we have only expreffed them in other, and thofe more obfcure terms.

Befides the effect that light has upon the colour of vegetables, it is only during the influence of the fun's rays that they emit oxygen gas, or pure air. In the day time moft plants give out this gas in abundance, by which means the purity of the air is preferved, and a frefh fupply of its pure falubrious part afforded, in lieu of that which is deftroyed, or, to fpeak more properly, abftracted hourly from the atmofphere by combuftion, refpiration, and a variety of other proceffes.

The prefence of light has confiderable effects both in the procefs of bleaching, and in that of tanning. Cloth, expofed in the bleach-field, is whitened more rapidly in the day time than during the night, and more ſo in a ſunny day than in cloudy weather. In tanning, the proceſs of handling the hides has more effect, if performed in an expoſed ſituation, and whilſt the ſun ſhines, than otherwiſe.

Phoſphorus, and ſuch other ſubſtances, as emit light by a ſimilar proceſs, which is not dependent on a previous expoſure to the ſun's rays, will be ſpoken of in another part of theſe Eſſays. But there are certain ſubſtances, that ſeem, when expoſed to light, to abſorb it, and afterwards gradually to part with it again, ſo that when taken into the dark, they become luminous. Moſt bodies poſſeſs this property more or leſs, but ſome more remarkably ſo, than others.

A mixture of ſulphur and lime forms Canton's phoſphorus, and that of ſulphur and an earth called barytes, the Bolognian phoſphorus; but theſe ſubſtances differ widely from phoſphorus, ſtrictly ſo called.

To make the former, mix equal parts of pulveriſed oyſter ſhells and ſulphur, and keep the mixture in a covered crucible, for an hour or two in a ſtrong heat. If this powder is expoſed to the light, and then taken into a darkened room, it appears luminous, and continues ſo for a conſiderable time. When it ceaſes to emit light, this property is regained by its being again expoſed to the light.

Of other ſubſtances, that poſſeſs this kind of phoſphoreſcency, a better inſtance cannot be brought, than that of white paper. If you ſhut yourſelf up in a darkened room, and contrive the means of expoſing a ſheet of writing paper to the ſun's rays on the outſide, and then drawing it into the room, you will perceive the paper, when firſt drawn in, to be very luminous. It gradually becomes leſs and leſs bright, until it emits no light at all; but you may again reſtore its brightneſs by again expoſing it to the light.

Even the hand, when firſt withdrawn from ſunſhine into a darkened room, emits light in the ſame manner.

The light thus emitted is in many inſtances increaſed by heat; thus if a warm heater, ſuch as is uſed in ironing, is drawn backwards and forwards over the ſheet of writing paper, after it is drawn into the darkened room, the paper is rendered more luminous, and is made to give out light for a longer time. Moreover, when it no longer emits light, its brightneſs may in ſome meaſure be renewed by the heater, without again expoſing it to the light.

Sulphate of barytes or heavy ſpar, and the fluate of lime or fluor ſpar, only emit light when heated.

Other ſubſtances are made to emit light by attrition, as when you break a lump of ſugar in the dark, or ſcrape with a knife pieces of phoſphorated limeſtone. It is intereſting and uſeful to be made acquainted with theſe facts, although we muſt at prefent acknowledge our ignorance refpecting the caufe of them.

Every one knows that light is emitted during the paffage of the electric fluid from one body to another. This in its paffage from one cloud to another, from a cloud to the earth, or from the earth to a cloud, conftitutes lightning. With an electrical machine many very amufing experiments may be performed, by exhibiting the light in a variety of ways; but the confideration of this belongs to the natural philofopher, not to the chymift.

When the back of a cat is ftroked by the hand in the dark, fmall flafhes of light or fparks are emitted, and at the fame time a crackling noife is heard. This is an electrical phænomenon.

In the night time flafhes of light are fometimes obferved to be given out by certain flowers, particularly thofe of the marigold. Many attribute this alfo to the electric fluid, but in fome cafes it probably occurs from the difengagement of a phofphoric gas.

ESSAY IX.

THE GASSES.

OXYGEN GAS, OR PURE AIR.

THE ſimple ſubſtances or elements, that come next in order to be conſidered after heat and light, are oxygen, azote, and hydrogen. They are never found alone or uncombined either in a ſolid or fluid ſtate; but chymically united to ſo much heat as to give them a gazeous form, they conſtitute the ſimple gaſſes. In this ſtate we ſhall treat of them, but ſhall firſt premiſe a few obſervations on gaſſes in general.

What chymiſts have now agreed to call gaſſes, differ from vapour, in being permanently aeriform in every degree of temperature. No degree of cold is able to condenſe them into fluids or ſolids.

Water is raiſed in the form of vapour by heat, and is again reduced to the ſtate of water by the abſtraction of its heat. Sulphur or brimſtone is converted into vapour, when heated, and this vapour is condenſed into a ſolid form by cold, or by abſtraction of heat. But the common air of the atmoſphere, in which we live and breathe, is not reducible to a fluid or folid ftate by any degree of cold, be it ever fo intenfe; it is therefore a gas.

All gaffes are invifible, but ftill we cannot doubt of their exiftence, for we can retain them in proper veffels, pour them from one to another, feparate, or combine them at pleafure, and afcertain the particular properties of each.

Every thing, which in common language we call empty, is full of air or gas, and the method we employ, for pouring it from one veffel into another, is this: invert the jar, for inftance, which contains the gas, in a tub of water with its mouth under the furface of the water; fill the jar which is to receive the gas with water, and invert it in the fame tub; then incline the firft jar, fo that its mouth fhall be under that of the fecond, and the gas will immediately afcend in bubbles to the top, and the water will rufh in the fame proportion into the firft jar, till all the gas has left it, and paffed into the other.

Though all gaffes are invifible, they are eafily proved to be different; and each to poffefs its diftinct properties. A lighted candle immerfed into a jar of one kind of gas will burn in the ufual way, in another it burns with a much more brilliant flame, and in a third it is immediately extinguifhed.

Thefe different properties will be difcuffed, in treating of the different gaffes feparately; but at prefent only the fimple gaffes, namely, the oxygenous, the azotic, and hydrogenous, will be treated of; the compound ones, as carbonic acid gas, and others, will be confidered under the head of the fimple fubftances, to which they owe their chief properties.

Oxygen Gas. Take a fmall apothecary's phial, into which put an ounce or two of manganefe, and pour thereon a fufficient quantity of fulphuric acid, to form a liquid pafte. Afterwards fit a cork to the mouth of the phial, with a hole through it, into which infert a recurved tube, with one of its extremities entering the bottle, while the other is placed under the mouth of a jar, or phial, filled with water, and inverted in a tub of the fame. The tub fhould be furnifhed with a fhelf, with holes in it, upon which the phial may reft in its inverted pofition.

When the apparatus is thus difpofed, apply the heat of a lamp to the phial containing the manganefe, and a gas will immediately be difengaged, which is called oxygen gas, or vital air.

It derives the firft name from its property of converting a variety of fubftances into acids, when combined with them, and from its being indeed the acidifying principle of all acids. It is called vital air, becaufe its prefence is abfolutely neceffary to fupport the life of animals. Befide thefe two properties, it has that of fupporting and being neceffary to combuftion.

These three are the distinguishing properties of oxygen gas, and are possessed by no other simple gas. Common air has the same, only in consequence of its containing oxygen; and in proportion as it contains more, it supports animal life and combustion in a greater degree.

The acids and their compounds will fall naturally to be considered, when treating of the base of each acid. There is one however of the mineral acids, which has not hitherto been satisfactorily decomposed, and of which the base consequently is not known. This is the *muriatic or marine acid*, or, as it was formerly called, spirit of salt. As there is every reason to believe, that it is a compound, and that oxygen is in this, as well as in all the other acids, the acidifying principle, we cannot treat of it with more propriety in any part of the work, than in this.

The muriatic acid is procured from common salt, by distilling it with sulphuric or vitriolic acid. It comes over in the form of fumes, which are collected and condensed. This acid, further oxygenated; is employed, either alone under the name of oxygenated muriatic acid, or combined with potash, when it is called oxymuriate of potash, in the improved method of bleaching, which has been of late so advantageously adopted.

The oxygenated acid is procured, when three parts of the acid, and one of a mineral called manganese, are heated together; and if the vapours are received into a solution of potash, the oxymuriate is produced. The same acid is likewise obtained by pouring twelve parts of vitriolic acid, previously mixed with an equal quantity of water, upon a mixture of sixteen parts of common salt with six of manganese. The vapours in this process may likewise be received into a solution of potash.

The acid is thought fittest for the bleaching of muslins, and the neutral salt is more generally employed for other goods. For whitening raw silk, a mixture of twelve ounces of the acid with forty-eight pounds of spirits of wine is preferred.

In bleaching with this acid, it is used considerably diluted, and the goods are previously boiled in a solution of potash. Being then steeped in the acid, they are afterwards washed in clear water; and the same process is repeated as often as it is found necessary.

Common salt, from which muriatic acid is procured, is a compound of this acid with the fossil alkali. It is found in three situations; in large beds in the bowels of the earth, when it is called rock salt; in springs of water which derive their source in or near these beds, when it is called spring salt; or in the water of the sea, when it is called sea salt.

The rock ſalt is ſeldom uſed, till it has been diſſolved in water, and ſeparated again by evaporation.

Brine may be evaporated, either by expoſure to the ſun's rays, or by artificial heat. In warm countries, the former method is adopted; where, by receiving the ſea water into proper reſervoirs, that are made extenſive and ſhallow, the ſalt is left covering the bottom of the pits, after the water has been evaporated by the heat. Salt, thus procured, is called bay ſalt. In our climate the heat is inſufficient, and the rains too frequent, to allow of this plan being adopted with advantage; our ſalt is therefore procured by boiling the brine, and is of different degrees of purity, according to the heat, and as it is depoſited in the latter or early part of the proceſs.

The uſes of common ſalt as a condiment, and as a preſervative of meat, are ſufficiently well known; but it is not ſo generally underſtood, that in ſmall quantities, inſtead of retarding, it promotes putrefaction, which is the caſe.

Salt is a uſeful condiment to cattle as well as man. In ſome parts of Africa large herds of animals travel at ſtated ſeaſons to the coaſt, where the ſalt plants abound. The fattening quality of our own ſalt marſhes is well known to graziers. And in many countries it is the cuſtom to give ſalt with the food to moſt kinds of cattle.

When a candle or a piece of burning charcoal is introduced into oxygen gas, it burns much more rapidly than in common air, and the charcoal emits beautifully bright ſparks.

If an iron wire twiſted ſpirally, and having a ſmall piece of burning phoſphorus, or ſulphur, at the extremity, be introduced into a jar of this gas, the iron itſelf will be burnt, emitting ſparks, and bright corruſcations, during its combuſtion.

By directing a ſtream of this gas through a blow-pipe to the flame of a candle, or any other combuſtible body, that is ignited, the moſt intenſe heat may be produced, that art has been able to effect. Metals and earths may thus be fuſed that reſiſt all other means.

During combuſtion in oxygenous gas the volume of the gas is decreaſed, and, if the combuſtion be continued long enough, the gas wholly diſappears. A union has taken place between the oxygen and the combuſtible body, and the reſult in many caſes is an acid. Thus, if ſulphur is burnt, ſulphuric or vitriolic acid reſults; if phoſphorus, phoſphoric acid; and if carbon, or charcoal, carbonic acid.

When combuſtion takes place in COMMON AIR, the ſame phænomena occur, but leſs rapidly, and to a leſs extent. If phoſphorus be burnt in a jar of common air, inverted over water, part of the air is abſorbed, which is ſhown by the water riſing in the jar; and the phoſphorus is, part of it, converted into phofphoric acid, which proves that it is oxygen that is abforbed. The air that now remains, which is $\frac{73}{100}$ths of the whole, is no longer capable of maintaining combuftion, or life; a candle put into it would be extinguifhed, and a moufe or any fmall animal would foon perifh. From this circumftance it is called azotic gas, or impure air, which is thus proved to be the other conftituent part of common air.

Common air then is a compound of oxygen gas and azotic gas in the proportion generally of 27 parts of the former to 73 of the latter. The grand ufes of the air are well known to be, to maintain life and combuftion; and as its pure part is thereby abftracted, a continual fupply becomes neceffary, where thofe proceffes are carried on.

That a continual fupply of air is neceffary to fupport life by refpiration, is made evident by animals dying in an exhaufted receiver, and living only for a given time in a given quantity of air; a longer time the larger the quantity. A moufe, for inftance, confined in a jar of common air, the mouth of the jar being clofed, would prefently become uneafy, would gafp for breath, become convulfed, and, if allowed to remain in this fituation, would foon die; but if frefh air be in time admitted to the jar, the moufe would revive.

This fhows us, how important it is to renew the frefh air of the rooms we live in, and to admit a ſupply as faſt as the pure part of it is abſtracted by breathing, and by the burning of fires and candles. Inſtead of doing this, it appears, as if we conſpired all we could to ſtop every avenue to its ingreſs. We ſhut the windows as cloſe as poſſible, and put liſt round the doors; but luckily for us, all we can do to ſtop its entrance, is ineffectual. Such is the diſpoſition of the air to reſtore its equilibrium, that where there is a fire, to heat the air, and convey it up the chimney, the external air preſſes with ſuch force, as to make its way through every crevice.

We do, however, in many caſes ſucceed ſo far in preventing the acceſs of freſh ſalubrious air, as to prove its baneful effects. In our theatres and ball-rooms the vitiated air has ſo little opportunity to eſcape, and the freſh air ſo little to enter, that in ſome parts a candle will ſcarcely burn; and an oppreſſive weight acroſs the cheſt ſpeaks plainly to our feelings, that we want a freer atmoſphere.

In the narrow ſtreets and lanes of manufacturing and commercial towns, peſtilential diſeaſes are almoſt always prevalent, and the inhabitants of theſe places carry in their ſqualid countenances the marks of conſtitutional illneſs. All this in a great meaſure proceeds from the want of pure ſalubrious air.

Our priſons and our poor-houſes are too frequently, from the ſame cauſe, the reſidence of diſeaſe. Although much, I am happy to ſay it, has of late years been effected towards remedying thefe grievances, much ftill remains to be done; and the improvements for ventilating apartments, and maintaining the purity of the air, will not, I hope, be confined to thefe or fimilar buildings.

Not only our hofpitals, our prifons, and other public buildings, require ventilation, and airy fituations; but our private houfes, and particularly thofe of the poor, demand the fame. The fite and plan of a town is of national importance, for the health of its inhabitants muft be greatly influenced thereby.

The proper ventilation of our apartments ought to be ftrongly inculcated by thofe, who are aware of its utility, that it may become more generally adopted; and the ignorant fhould be informed of the beft modes of accomplifhing it.

Every window or cafement fhould be made to open, and that always at the top. Thefe fhould be opened when we leave the room; and in warm and moderate weather may be frequently opened for a fhort time whilft we are there, particularly if many perfons live in the fame apartment. Much good would accrue from attention to this circumftance in manufactories, where many perfons are breathing the fame air for feveral hours together.

In every fituation it is proper to let down the fafh, or open the window, of fleeping apartments before we leave them.

In many rooms it will be requifite to have a conſtant communication with the external air, by means of an opening in ſome part of it near the floor. In this caſe, and indeed in every caſe of ventilation, the vitiated air will have exit at the top, and the freſh air will come in at the bottom; for the air that we have breathed and vitiated being heated, immediately aſcends and occupies the top of the room; whilſt the freſh air, being colder, and of courſe heavier, comes in at, and occupies the lower part of the room. That this is the caſe will appear evident by the common experiment of holding a lighted candle in different parts of the door-way of a room heated by company. The flame is driven outwards when held near the top, but into the room, when the candle is held near the floor.

When a window opens from above downwards there can be no inconvenience felt from ſitting near it; for no cold air, as is uſually imagined, enters by the window, as will appear by holding a candle near the opening.

The way to prevent a current of cold air from the opening at the bottom of the room is, to have a ſlanting board, to direct it ſome way upwards. In rooms having a plaſter partition, or any other double partition, perhaps the beſt plan would be to make an external opening through the outer plaſter near the ground, and an inner one near the cieling, or at leaſt above the heads of perſons in the room, that they might ſuffer no inconvenience from the cold air.

That combuſtion, as well as reſpiration, vitiates the air, and requires a continual ſupply, is evident from a candle only burning a certain time, if confined in a cloſe jar, and by the ſame continuing to burn a longer time if freſh air be admitted to the jar.

This makes the ventilation of rooms ſtill more neceſſary, where there are candles and fires burning; and it is, in my opinion, a great objection to our mode of warming apartments by open fires. If warmed by ſtoves, the aſh-pits of which are without, the air in the rooms would not be vitiated by the combuſtion; leſs cold air would be required, and, conſequently, our rooms would be both warmer and more wholeſome.

Beſides this, all parts of the apartment would be nearly equally warm, and we ſhould not experience the cold draughts of air that often ſtarve us behind, whilſt we are in other parts almoſt burnt by ſitting near the fire; which irregular warmth proves the cauſe of rheumatiſm, chilblains, and a variety of ailments.

Beſides the uſes of common air, which we have enumerated, it anſwers a variety of other important purpoſes. The oxygen is abſorbed from it in the calcination of metals. It is neceſſary in moſt caſes of fermentation. By the expanſion of air when heated, it becomes an eafy means of tranfmitting or communicating heat, and thus preferves its equilibrium, or an equal temperature; and, laftly, by its power of diffolving water, and holding in folution more or lefs according to its temperature, it becomes the immediate caufe of fpontaneous evaporation, and of dews, fogs, rains, and fimilar phænomena.

There is conftantly going on an evaporation of water, to a very great extent, from the feas, lakes, rivers, and from the whole furface of the earth, wherever there is moifture. The fea, it has been found by calculation, lofes many millions of tons daily by this procefs; which lofs is fupplied by the rivers, that are conftantly flowing into it.

The evaporation is increafed both by heat, and by the agitation of the air; and therefore a warm and windy day is the beft for drying any thing expofed to the air. The wind affifts by removing the air, that becomes faturated with water, and thus admitting accefs to fuch as is not. It anfwers the fame purpofe as ftirring does in promoting the folution of falt in water. The heat aids the evaporation by increafing the folvent powers of the air, in the fame way that it promotes the folution of falt in water, and enables it to diffolve a greater quantity.

On this property, that air when heated is able to hold or retain more water than when cold, depends the explanation of a variety of phænomena. Hot water will diffolve more falt than cold water; therefore hot water, that is faturated, will depofit part of the falt on cooling. In the fame way, and for the fame reafon, hot air, that is faturated with moifture, will depofit part of it in form of dew, rain, &c., when it becomes cold.

During the day-time the fun's rays having warmed the earth, and that portion of air that is near its furface, this ftratum of air is enabled to hold a good deal of water in folution. But when the fun fets, the earth and adjoining ftratum of air are fo much cooled, that the latter is unable to hold all the water, which it had formerly diffolved, and the confequence is a depofition of it in the form of *dew.*

Dews are feldom feen more than a very few feet above the ground, becaufe the ftratum of air cooled by the abfence of the fun extends no higher. Pictet has afcertained by experiment, that the air is colder near the furface than fome feet above it during the night, and warmer during the day.

In the morning, when the fun has warmed the earth, and lower ftratum of air, fufficiently to enable this to diffolve all the moifture, that it now contains, there is no longer any depofition, and confequently no more dew.

Dews are moft frequent, and moft abundant, when there is the greateft difference between the temperature of the air in the night, and that in the day, as in the autumn, when very cold evenings ſucceed to very warm days.

A haze, miſt, or fog, is a ſimilar depoſition from a larger body of air, extending to a greater height. The cauſe of this depoſition is ſuppoſed to be the paſſage of a colder or a warmer ſtream over one that is of a different temperature, or the meeting of two ſtreams not equally heated; in which caſe the mixture is unable to hold all the water in ſolution, that they held when ſeparate.

In clouds the water is probably in the ſame ſtate as in miſts, but the warmth of the inferior ſtrata prevent its falling below a certain point.

When two clouds meet that are of different temperatures, or in different ſtates of electricity, I conceive that a further depoſition enſues; and that according to the temperature, and the ſuddenneſs of the depoſition, the water aſſumes the form of rain, ſnow, or hail.

Sauſſure ſuppoſes that water exiſts in three different ſtates in the atmoſphere; firſt, in a ſtate of vapour, that is inviſible, as when evaporated from moiſt bodies; ſecondly, in a veſicular form, as in clouds, where it exiſts in ſmall bladders or veſicles; and, thirdly, in a true aqueous form, as in rain. He ſuppoſes that in theſe three ſtates its capacity for heat is different; that the vapour has a greater capacity than the veſicular ſtate, and the veſicular greater than the aqueous ſtate.

According to this fuppofition there will be an evolution of heat when vapour is converted into dews, fogs, and clouds; and again when the latter are converted into rain, fnow, or hail. Accordingly, it is frequently obferved, that a fhower in cold weather, or a fall of fnow, warms the air. And it may be added, that Pictet obferved his thermometer, at the top of a pole 75 feet high, to rife between one and two degrees, when furrounded with a fog.

By the various means, which we have now mentioned, all the water that is evaporated, and taken up by the air, is again depofited in rain, and dews, to fupport the life both of the animal and vegetable world. It is then carried by the ftreams and rivers to the ocean, to be again evaporated, and anfwer again thefe beneficial purpofes.

When a glafs of cold water is brought into a warm room, or a bottle of wine out of a cold cellar, a dew is immediately depofited on the outfide; this is becaufe the warm air in contact with the glafs is fuddenly cooled, and thereby rendered incapable of retaining all the moifture which it had previoufly diffolved.

In a warm room, where there are many people, and confequently much moifture for the air to abforb, a dew is depofited on the infide of the windows; becaufe the cold external air cools, through the medium of the glafs, that portion of the internal air that is nearest to it, which of course deposits its moisture.

When the air in the room is colder than the external air, a dew is deposited on the outside of the window.

In winter time the dew deposited on the inside of the windows is frozen, assuming very grotesque appearances, as observed in a frosty morning.

ESSAY X.

AZOTIC GAS, OR IMPURE AIR.

AZOTIC gas exifts in great proportion in the atmofphere; being, as we have already faid, one of its conftituent parts. Whenever we abftract the oxygenous gas from common air, the refidue is azotic gas. If therefore we burn a candle or any other combuftible body in a jar containing common air, the remaining air after combuftion is azotic gas or impure air; and if the combuftible body is phofrus, the gas is tolerably free from any admixture.

A candle immerfed in this gas inftantly goes out; and if an animal is confined in it, it foon dies. Its prefence in the atmofphere feems to temper and moderate the action of the oxygen; for without it combuftion would be too violent and rapid, and the oxygen breathed alone would excite inflammatory complaints and foon prove fatal.

Azotic gas is emitted during animal putrefaction. It is given out by ripe fruit, and by flowers; hence the impropriety of keeping either in apartments where we live. The air is confiderably vitiated by keeping pots of flowers in clofe rooms, as in bedchambers; and bad effects have frequently proceeded from it. Mufhrooms are obferved to evolve this gas, whilſt growing, and to afford more when chymically analyzed than other vegetables; they approach in this reſpect to the compoſition of animal matter.

It is a ſubject, that requires further chymical inveſtigation, to aſcertain the particular changes, that are effected during the putrefaction of animal matter. We might be enabled by it to diſcover better means, than are now known, to preſerve meat; and probably to recover it after the putrefaction has commenced. We know that the preſence of air is neceſſary to putrefaction, and that warmth and moiſture promote it; we therefore prefer a cool and dry ſituation for our larders. Meat may be long preſerved in veſſels of fixed air, and means might, I think, be invented for making this an eaſy practice. Meat that is conſiderably tainted, may be rendered more palatable, either by burying it for a few hours under ground, or by covering it with powdered charcoal. The meat of animals, that have been hunted, or otherwiſe violently exerciſed, inclines very quickly to putrefaction, and is conſequently tenderer than other meat kept the ſame length of time. Animals killed by lightning, or by a ſtrong electric ſhock, which is the ſamething, have the ſame diſpoſition to putrefy; and the latter mode has been recommended for killing poultry, that is to be eaten immediately.

The combination of azote and oxygen, besides affording common air, which we have already treated of, constitutes a variety of other substances, according to the proportions of the two ingredients. Nitric acid or aqua fortis is a compound of these two elements, and may be made by repeatedly passing electric shocks through a mixture of oxygenous and azotic gas. The analysis of this acid proves the same thing; for when it is made to pass through a red-hot porcelain tube, a mixture of oxygenous and azotic gas is obtained.

The process used in manufacturing the aqua fortis for commerce, consists in mixing one part of saltpetre with two or three of red bolar earth. This mixture is put into coated retorts, disposed in a gallery or long furnace, to each of which is adapted a receiver. The first vapour, that arises in distillation, is nothing but water, which is suffered to escape at the place of juncture, before the luting is applied; that is, before the juncture is closed up with a composition of meal and water, or with glazier's putty, or some other substance, called luting. When the red vapours begin to appear, the phlegm, which is condensed in the receiver, is poured out, and the receiver being replaced is carefully luted to the neck of the retort. The vapours, which are condensed, form at first a greenish liquor; this colour disappears insensibly, and it then becomes more or lefs yellow. This is the common aqua fortis, which requires purification for chemical purpofes.

It may alfo be obtained by diftilling the fulphuric acid upon nitre or faltpetre. When pure, it is colourlefs. It is ufed in dyeing, and in feveral proceffes by the manufacturers in metals, as in gilding, &c. In confequence of its diffolving metals it is ufed in etching upon copper. It is alfo a ufeful medicine in a variety of complaints.

Nitric acid has a peculiar effect upon animal matter, converting it into a fatty fubftance, very like fpermaceti. The fame converfion of animal matter into an inflammable fubftance has been obferved to be effected by a natural procefs in certain fituations.

Touret, a French phyfician, has defcribed the appearances met with on opening a vault in the burial ground des Innocents. Many of the bodies, that had been buried a great number of years, were found to retain their form, and confiftence, and in many refpects their natural appearance. When they were examined, it was afcertained, that moft parts of the body were converted into a fatty or rather fpermaceti-like fubftance that was inflammable, and burned like fpermaceti.

Dead animals thrown into running ftreams have undergone a fimilar change in many of their parts, particularly the flefh or mufcular parts. And nitric acid poured upon a piece of flefh has been difcovered to effect the fame change. From thefe facts there is little doubt, but that by proper management horfeflefh, and that of animals dying of difeafe, might be converted to the ufeful purpofe of making foap or candles.

Saltpetre, from which aqua fortis is obtained, is a combination of this acid and potafh. It is procured fometimes by natural proceffes, fometimes by artificial means.

In fome countries the foil contains it, where they have only to collect what efflorefces on the furface; wafh it well, boil the water, evaporate, and then cryftallize the falt. It is found in this ftate in the Indies, and alfo in fome parts of Spain.

In general, however, it is formed artificially by collecting animal and vegetable fubftances into heaps, and fuffering them to putrefy. The animal matter affords azote, which attracts oxygen during putrefaction, and thus forms nitric acid. The vegetable matter affords potafh, which uniting with the new formed acid conftitutes the nitre.

In the North of Europe thefe faltpetre beds are formed with lime, afhes, earth of uncultivated grounds, and ftraw, watered with urine, dung-hill water, and mother waters *.

Of animal matter, blood, and next urine, favour the production of faltpetre moft Of vegetable matter, light minutely-divided earth, in which plants

* Refufe waters from various manufactures.

have grown and decayed fucceffively for ages, is fitteft to form thefe beds.

From the artificial as well as natural nitre-beds the falt is extracted by wafhing the earth in water, evaporating, and then cryftallizing.

Obtained by this firft operation the falt is never pure, but contains common falt, and an extractive colouring principle, from which it muft be cleared. For this purpofe it is diffolved in frefh water, which is evaporated, and to which bullock's blood may be added, to clarify the folution. The nitre obtained by this fecond procefs is termed *nitre of the fecond boiling*.

The purified nitre is employed in making the better fort of aqua fortis, and in the compofition of gunpowder. Saltpetre of the firft boiling is made ufe of in manufacturing an inferior aqua fortis for the ufe of dyers.

We have faid that faltpetre is an ingredient in *gunpowder*. This powerful compofition is a mixture of feventy-five parts of faltpetre, nine and a half of fulphur, and fifteen and a half of charcoal. This mixture is triturated from ten to fifteen hours in pounding-mills, having their peftles and mortars of wood, care being taken to moiften it from time to time. It is then paffed through fieves of fkin, and granulated. The powder is then fifted to feparate the duft, and, laftly, carried to the drying houfe.

Cannon powder requires nothing further; but for fowling powder, the procefs of glazing is neceffary. This is done by putting it into a kind of cafk, which turns upon an axis, by the motion of which the angles of their grains are broken, and the furfaces polifhed.

In the compofition of gunpowder, it is not neceffary to attend exactly to the proportions directed above; for, although the proportion of faltpetre cannot be varied much without detriment, that of the other two ingredients may vary confiderably, without very materially altering the properties of the powder. The purity of the materials is of very confiderable confequence, and fo is the circumftance of their being very intimately mixed. If the faltpetre contains any portion of common falt, which is ufually the cafe with the inferior forts, it injures the powder by attracting moifture from the atmofphere. Gunpowder moiftened by this caufe, or by any accident, lofes its power, in confequence of the water diffolving the faltpetre, and feparating it from the other ingredients. When thus damaged, if by pure water, it only requires to be again powdered and regranulated; but if falt water has caufed the damage, it cannot be remedied; the ingredients, however, are valuable, for the faltpetre may eafily be feparated by folution and cryftallization.

The effects of gunpowder are owing to the fudden formation of a quantity of gas, and are confequently greater when the gas is confined in all directions but one, as in our guns and cannons. The nitric acid of ſaltpetre is decompoſed, and affords the gas. The other ingredients diſpoſe it to be eaſily inflamed, which is neceſſary to the decompoſition of the acid.

A *fulminating powder*, poſſeſſing far greater powers than gunpowder, is formed by mixing and triturating three parts of nitre, two of ſalt of tartar, and one of ſulphur. A few grains of this heated in an iron ladle over the fire is firſt melted, then affords a blue flame, and at laſt a violent exploſion.

When the nitric acid is poured upon iron, copper, or zinc filings, there is a conſiderable diſengagement of air, which aſſumes a red colour, but which, if collected in a jar previouſly filled with water, and inverted in a tub of the ſame, is colourleſs, and is known by the name of *nitrous gas*.

Nitrous gas is, like nitric acid, a compound of oxygen and azote; but in this the proportion of oxygen is much ſmaller. It will ſupport neither combuſtion nor animal life.

When mixed with oxygen gas it unites and forms nitrous acid, which appears in red vapours. When mixed with common air the ſame takes place, which is the cauſe of the red vapours that appear when the nitric acid is poured upon the iron or copper filings.

As the nitrous gas combines only with the oxygenous or pure part of common air, it has been employed to aſcertain the quantity of oxygenous gas, and consequently the purity of the air. Used in this way, it is called a *eudiometer*. For this purpose, a given quantity of nitrous gas is added to a certain quantity of common air, or any other, that is required to be examined. The mixture is made in a graduated tube over water, and in proportion to the quantity of oxygen the volume of air is diminished, and the water rises in the tube. The height to which the water rises is the measure of the purity of the air.

By exposing nitrous gas for a few days to iron filings, it loses part of its oxygen, and then constitutes a gas called *nitrous oxyd*, which is consequently a compound of oxygenous and azotic gas with a less proportion of the former even than nitrous gas.

Nitrous oxyd may be obtained by a variety of other means, but the purest is got by the following process, as directed by Mr. Henry. To diluted nitric acid add carbonate of ammonia (the common smelling salts) till the acid is saturated. Then evaporate the solution; and to supply the waste of alkali, add occasionally a little more of the carbonate. Let the solution be evaporated by a very gentle heat to dryness. The salt thus obtained is next to be put into a glass retort, and distilled with a sand heat, not exceeding 500° Fahrenheit. The heat of an Argand's lamp even is sufficient. The gas may be collected over water, and allowed to stand a few hours before it is ufed; during which time it will depofit a white cloud, and will become perfectly tranfparent.

The great peculiarity of this gas is, that it fupports combuftion, and not the life of animals. Moft inflammable bodies, as charcoal, fulphur, phofphorus, and even iron wire, burn in this gas with nearly as much rapidity and fplendour as in oxygen gas. The nitrous oxyd is decompofed, and its oxygen unites to the inflammable body.

When an animal is wholly confined in this gas it fpeedily dies, but when breathed for a fhort time from a bladder or oiled-filk bag it has a very extraordinary effect. We have very refpectable teftimonies to the peculiar fenfations it excites, in an effay publifhed on the fubject by Mr. Davy.

Moft perfons exprefs their feelings on the occafion, as highly pleafurable. They experience great exhilaration, and feel an irrefiftible propenfity to laughter, as well as an unufual difpofition to mufcular exertion. Their ideas are vivid, and flow rapidly; and, in fhort, they experience what moft perfons do in the pleafant period of intoxication, without fuffering any of the unpleafant effects that ufually fucceed intoxication.

With the various compounds of oxygen and azote now defcribed, we finifh the confideration of thofe elements, and pafs to that of hydrogen.

ESSAY XI.

HYDROGEN GAS, OR INFLAMMABLE AIR.

Hydrogen, as its name imports, is a conſtituent part of water, of which oxygen is the other ingredient. It is from the decompoſition of water that we obtain hydrogen gas, and this is done in a variety of ways. We ſhall deſcribe only two; the firſt of which is the moſt eaſily accompliſhed, and the latter is moſt economical, which is of conſequence, when a large ſupply of this gas is required.

The firſt mode only requires you to pour ſulphuric acid, or oil of vitriol, previouſly diluted with five or ſix times its weight of water, upon iron filings, or ſmall iron nails, in a phial or glaſs retort with a recurved tube. An efferveſcence will enſue, and the eſcaping gas may be collected in a jar under water.

To obtain this gas in the large way, procure a gun-barrel, the breech of which has been removed, ſo as to form a tube open at each end. Fill this with iron wire, coiled up in a ſpiral form. To one end of the barrel adapt a ſmall glaſs retort, partly filled with water, and to the other a bent glaſs tube, the open end of which terminates in the receiving veſſel. Let the barrel be placed horizontally (or rather with that end to which the retort is fixed a little elevated) in a furnace having two openings in its body oppoſite to each other. Light a fire in the furnace; and, when the gun-barrel has become red hot, apply a lamp under the retort. The ſteam of the water will paſs over the red hot iron, and will be decompoſed. Its oxygen will unite with the iron, and its hydrogen will be obtained in the form of a gas.

This gas burns with a ſilent lambent flame, when in contact with common air; hence its name of inflammable air. When previouſly mixed with common air, an exploſion takes place on the approach of a lighted match or candle. This gas of itſelf, however, extinguiſhes a burning body; thus, if a jar containing inflammable air is brought in an inverted ſtate over the flame of a candle, and depreſſed, it immediately extinguiſhes it. Its other properties are, that animals confined in it ſoon die, though plants live and thrive in it, and that it is very conſiderably lighter than common air.

Knowing it to poſſeſs theſe properties, we ſhall be able to explain many very curious facts.

Artificial fireworks are made by paſſing this gas through metallic tubes, variouſly diſpoſed, and furniſhed with a variety of orifices, through which the gas can efcape. The machine, to which thefe complicated tubes are affixed, is made moveable wholly, or in part, and in different directions, fo as to add much to the effect. The gas is inflamed at all thefe orifices, where it comes in contact with the atmofpheric air, and burns with a ftill flame.

A conftant ftream of it is fupplied by preffing the bladders, or bags, that contain it, and that are connected to the main tubes, from which all the others branch out.

The moft common explanation of the AURORA BOREALIS, or northern lights, is, that a ftratum of hydrogenous gas above the atmofphere of common air is lighted by the electric fpark, and burns flowly, where it comes in contact with our common air. The corrufcations of light obferved chiefly in northern latitudes are perhaps referable to the fame caufe. The levity of this gas, compared with that of common air, will account for its occupying a higher region; and, as it can only burn, where it is in contact with the latter, the appearances we obferve in the aurora borealis are exactly fuch as we fhould expect from fuch a caufe.

Inflammable air or hydrogenous gas is frequently extricated in mines, probably from the decompofition of bituminous or coaly fubftances. It is called by the miners FIRE-DAMP; and is to them a fource of great danger, as well as inconvenience;

for, by becoming mixed with the common air, it is fubject to fudden and violent explofions, whenever a lighted candle or other ignited body is accidentally brought into contact with it.

In ftagnant muddy water, where the putrefactive procefs is conftantly going on, both of animal and vegetable matter, there is a confiderable difengagement of inflammable air, which is feen rifing to the top in bubbles. It is eafily collected by inverting a wide-mouthed jar, filled with water, in one of thefe ftagnant pools, where the bubbles are obferved, and then ftirring up the mud from the bottom with a ftick. This agitation caufes a more rapid difengagement of the gas.

The gas thus procured is found to contain a confiderable portion of another gas, viz. the carbonic acid gas or fixed air. The evolution of thefe gaffes from fuch marfhy fituations is in confequence of the decompofition of water by the putrefying animal and vegetable matter. The oxygen of the water uniting with the carbon of the putrefying mafs forms the fixed air, whilft the hydrogen of the water efcapes in the form of hydrogen gas.

It muft be remembered that the bubbles of air feen to arife from ftreams, and clearer water, in which the green conferva and other vegetables grow, as the duck-meat (lemna), or chick-weed (alfine or ftellaria media), is pure air or oxygenous gas, and not this inflammable air.

In confequence of this gas being fo much lighter than common air, it has been applied to the purpofe of forming AIR BALLOONS. A bladder or bag, made of waxed canvas, or oil-fkin, when filled with this gas, is much lighter than the fame bulk of common air, and therefore rifes from the ground when liberated, as naturally, and by the fame law, as a cork preffed down under water, rifes to the top when the force is removed.

The larger the balloon, the greater weight it is able to raife with it; but the higher it mounts, the lefs weight it is able to carry.

The reafon of this latter circumftance is, that the higher it gets the rarer is the air, and confequently the lefs is the difference between the fpecific gravity of the air in the balloon and the furrounding air.

On this depends the utility of carrying ballaft, when it is required to mount high in the air. The more ballaft your balloon is able to raife, by being made large, the higher you may afcend; for by gradually throwing out the ballaft, you mount ftill higher in the air. When it is required to defcend, the inflammable air is fuffered gradually to efcape from the balloon; by which means it becomes fpecifically heavier than the atmofpheric air, and confequently falls gradually to the ground. The inconveniences experienced by aeronauts, when the balloon has reached the ground, in confequence of its rebounding, and often dragging the travellers to a confiderable diftance, might be obviated by contriving the means to let the whole of the gas efcape as foon as the balloon has touched the ground.

Another kind of balloon is formed by filling the bag with heated air inftead of hydrogenous gas, and by keeping it in the fame heated ftate, which is done by means of a fire under the balloon, having a communication with its cavity. The air in the balloon in this cafe being rarefied, and made fpecifically lighter than the furrounding air, rifes and carries a weight with it upon the fame principle as the firft kind of balloon.

An amufing experiment, proving the lightnefs of this gas, may be performed by forming foap bubbles with it inftead of common air. For this purpofe fill a bladder with the gas; if the bladder is furnifhed with a ftop-cock it will be more convenient; and then adapt it to a common tobacco pipe. Dip the bowl of the pipe into a lather of foap, and by preffing the bladder blow it up into bubbles. Thefe bubbles, from their extreme levity, rife very rapidly.

We have faid that hydrogen and oxygen form WATER; and, in the experiments detailed for procuring hydrogenous gas, we have proved it analytically; for whilft this gas comes over, the other conftituent, oxygen, is united to the metal, that is employed.

We have alfo fynthetical proofs of this compofition of water, one or two of which we fhall recite; and thefe we truft will fuffice. When a mixture of hydrogenous and oxygenous gaffes is made to explode, there is always a formation of water; but in a fingle experiment it is too minute to be completely fatisfactory, although a dew may generally be obferved to be depofited on the fides of the veffel in which the experiment is performed.

By the flow but continued inflammation of hydrogen gas in common air, a fufficient quantity of water may be formed to fatisfy any one with refpect to its compofition. This may be done in the following way: fill a bladder, furnifhed with a ftop-cock and pipe, with hydrogen gas. Procure a glafs globe, having two openings oppofite to each other; then fet fire to the ftream of hydrogen gas paffing from the tube, and introduce it into the centre of the globe. The combuftion may be continued, if required, till all the inflammable air is burnt; and drops of water will be obferved running down the infide of the globe.

The electrical piftol is a machine contrived for exploding a mixture of inflammable air and common air by means of the electric fpark; and the force of explofion is made to drive out a cork, or other folid body, with fome violence.

Each time that the piſtol is fired, a minute quantity of water is formed; and if the experiment is frequently repeated with the ſame piſtol, its internal ſurface becomes very ſenſibly moiſtened.

In iron foundries, and in manufactories where other metals are melted, very ſerious accidents have happened from only ſmall quantities of water getting accidentally into contact with the heated metal. If only a few drops of water happen to be in the caſt or mould, which is to receive the melted metal, a moſt violent exploſion is ſure to enſue, as ſoon as the metal comes into contact with it. The fluid metal is thrown about in every direction, and the workmen of courſe are dreadfully burnt. The effect here is much greater than it would be from the mere converſion of the water into vapour; and it is now aſcertained, that it ariſes from the decompoſition of the water, and conſequent formation of inflammable and pure air; a few drops of water affording a very large volume of the airs.

It is unneceſſary to ſay any thing reſpecting the important uſes to which water is applied. To preſerve it ſweet during long voyages, it is neceſſary that the watercaſks ſhould be well charred on their inſides. This is found to be the beſt means of preventing the decompoſition of the water, which is the cauſe of its becoming diſagreeable to the taſte, and unwholeſome. Many ſuppoſe that water becomes tainted in conſequence of the putrefaction of animalculæ and ſmall vegetables, which it contains; but this is not ſo much the cauſe, as a real decompoſition of part of the water, which is effected by the juices and other parts of the wood of the caſk attracting the oxygen of the water. The hydrogen remains in the water, and gives all the unpleaſant properties to it. Charring of the caſks is the beſt preventive. Tainted water may be ſomewhat recovered by ſtirring in it powdered charcoal.

ESSAY XII.

CARBON, OR CHARCOAL: CARBONIC ACID GAS, OR FIXED AIR.

CARBON is the name given by chymifts to the pure part of charcoal. It is prefent in almoft all combuftible bodies, and is itfelf completely combuftible. Carbon is not decompofable, and therefore ranks amongft the chymical elements. The moft interefting compound, of which it forms the bafe, is its union with oxygen, when it forms the carbonic acid gas, or fixed air. This compound will furnifh us with materials for the prefent effay; but firft it may be as well to fay fomething of charcoal.

CHARCOAL, as met with in commerce, is obtained from the partial combuftion of wood. Billets of any kind of wood are heaped up into piles, ufually in the form of pyramids. The whole is then covered with earth, leaving an aperture at top and bottom for a current of air. The pile is now fet fire to, and when completely ignited throughout, the apertures are clofed, and the fire confequently fmothered. In this procefs all the juices of the vegetable, its oils, &c., are diffipated, leaving little more than its woody fibre. It lofes about threefourths of its weight, and what remains is called charcoal.

This charcoal contains, befides carbon, fmall quantities of different kinds of earth, fome water, and, it is now fuppofed by fome, a proportion of oxygen.

When charcoal is burnt, its carbon unites with the oxygen of the air, and fo much heat as to give it the gafeous form, and conftitutes CARBONIC ACID GAS, or fixed air.

The fame gas is alfo obtained by the combuftion of the diamond, proving that this precious and coftly article is carbon or charcoal in a very indurated ftate, and affuming a determinate form. It was not till lately that the diamond was proved to be combuftible; but by means of the blow-pipe, and a ftream of oxygen gas, it may be, to fpeak in common language, wholly confumed. The air, that is extricated during the combuftion, is carbonic acid gas, proving the diamond to have been chiefly, if not wholly, compofed of carbon.

Long before this fact refpecting the diamond was afcertained, Sir Ifaac Newton, reafoning from its great refracting power, declared it to be his opinion, that it was one of the moft combuftible of bodies. Modern difcoveries have now proved the fact; and it affords us an admirable inftance of the acumen of that great philofopher.

The CARBONIC ACID GAS, which we fha now

take into confideration, may be obtained much purer by other means than by the combuftion of charcoal. It is this gas that is extricated in almoft all cafes of effervefcence, as when vinegar, or any other acid, is poured upon chalk, marble, lime-ftone, or potafh.

The beft way of procuring it for experiment is, to pour diluted fulphuric acid upon chalk in a common phial, furnifhed with a bent tube. The gas may then be received in jars over water.

It poffeffes the following properties: it is much heavier than common air: it extinguifhes flame, and is fatal to animals: it poffeffes the properties of an acid, and precipitates lime from lime water.

By keeping in mind thefe properties, we fhall be able to detect the prefence of this gas under a variety of circumftances, and thus be enabled to account for various interefting phænomena. We fhall find that it is extricated during the fermentation of beer, and other liquors; that it is formed during many inftances of combuftion, and by the refpiration of animals; and, alfo, that it is met with naturally in certain mineral waters, and in many other fituations.

Fermentation is the term ufed to fignify thofe changes that take place in dead animal and vegetable matter, when expofed to the action of the air, and kept at a certain temperature. If the faccharine or fugary principle predominates in the fubftances employed, the product will be a ſpirituous liquor, and the proceſs is called the ſpirituous or vinous fermentation. When a mucilaginous, or gummy matter abounds, vinegar is formed, and the proceſs is then termed the acetous fermentation. Subſtances that have already undergone the ſpirituous, will, very often, paſs to the acetous fermentation, particularly if kept warm, and at the ſame time expoſed to the air. Laſtly, when gluten or jelly exiſts in conſiderable quantity, as in animal matter, that kind of fermentation, termed putrefactive, is ſure to take place; and the product here, that is characteriſtic of the kind of fermentation, is ammonia, or volatile alkali, ſuch as the common ſmelling ſalts.

We ſhall in this place confine our attention to the vinous or ſpirituous fermentation; during which there is evolved a very conſiderable quantity of carbonic acid gas, or fixed air. This is the proceſs by which we obtain ſpirits of all kinds, as rum, brandy, gin, &c., alſo every kind of wine, of cider, perry, or beer. In making any of theſe liquors, it is neceſſary that a quantity of ſpirit ſhould be formed, and the proceſs is in all alike.

Wine is made of the muſt or pure juice of grapes, or of the juice of other fruits diluted with ſugar and water in order to diſpoſe it to the vinous fermentation. The mixture ſhould be kept at a heat equal to about 70° of Fahrenheit: hence the advantage of making wines in warm weather. It now ſoon becomes turbid, and air bubbles are ſeen to riſe to the ſurface, which are the carbonic acid gas, or fixed air.

This air being entangled in the pulpy part of the fruit, cauſes part of it to riſe to the ſurface, in the form called yeaſt or barm. A ſediment is at the ſame time gradually depoſited; and as the bubbles of air at top burſt, and let fall the pulpy part that it was entangled in, the wine is left clear and tranſparent, fit for caſking.

That it is carbonic acid gas, that is thus extricated during the vinous fermentation, is proved, firſt by holding a lighted candle, or piece of lighted paper, over the fermenting liquor, when it will be inſtantly extinguiſhed; and next by half emptying a bottle of lime water in the ſame ſituation, and then ſhaking the remainder, which will thereby become white and turbid.

This gas, being much heavier than common air, always keeps its place over the ſurface of the liquor, till it riſes as high as the edge of the tub or vat, and then it deſcends to the floor; ſo that, if you hold the candle only a few inches above the edge of the vat, it is not extinguiſhed; but goes out immediately when held over the liquor, and below the top of the vat. This is the reaſon too why, when the vat is emptied of the liquor, the gas for ſome time occupies the bottom of it, ſo that it is unſafe for the workmen to get into it, with a view of cleaning it. This is well known to the labourers in breweries, who never defcend into the vats before they have tried the purity of the air in them by lowering a candle. If the candle is not extinguifhed, they know that they may defcend with fafety; for it is then certain that the fixed air has made its efcape.

After the wine is cafked, the fermentation ftill goes on, though in a much flower degree, and a depofition of tartar takes place. The carbonic acid gas, that is now extricated, not being able to efcape, is abforbed by the liquor, and gives it its brifknefs, and that pleafant fharpnefs to the palate which it now has, inftead of the flat infipid tafte which all wines have when firft made.

The fame flow fermentation, accompanied with a depofition of tartar, and formation of carbonic acid gas, continues even after the wine is in bottles, and occafions the difference between old and new wine.

In fome liquors the fermentation, and confequent formation of carbonic acid gas, is much more confiderable than in others, as in Champaign wine, in perry, or in cider; and hence their fparkling appearance and effervefcence, when uncorked. The quantity of gas formed in thefe cafes is fo great as only to be retained in combination with the liquor under great preffure; and this preffure being removed by uncorking the bottle, part of the carbonic acid immediately affumes its gafeous form, and flies off.

As the brifknefs of all wines depends upon the prefence of carbonic acid, they will always prove flat and infipid, either when the fermentation is fo moderate, that fufficient carbonic acid is not formed, or when that, that is formed, is allowed to efcape. The former cafe never occurs when the faccharine matter fufficiently abounds, and attention is paid to keep the liquor fufficiently warm. When, from want of this, it has happened, the fermentation muft be promoted by adding more fugar, and a fmall quantity of yeaft.

Wines are more frequently flat in confequence of the gas being allowed to efcape when formed, and this both in the cafked and bottled ftate. The fame may be faid of other liquors, as cider, perry, and more particularly beer. The cafks fhould always be filled, or very nearly fo, and the tighter they are the better. The greater the refiftance that is afforded to the new formed gas, the more will be abforbed by the liquor, and the pleafanter it will be to the palate. In confequence of its being neceffary to make an opening to let in air when a barrel is tapped, the carbonic acid gas is allowed to efcape, and the beer or other liquor foon becomes flat, particularly if the orifice is not clofed.

Beer, that is thus rendered flat, may be made much more palatable again, by impregnating it with carbonic acid gas. An eafy mode of doing this in the barrel might, perhaps, be contrived; but for ſmall quantities to be impregnated, as it is required for the table, nothing will anſwer better than an apparatus called Nooth's apparatus, for making Seltzer water, which will preſently be noticed.

In bottling every kind of wine, cider, beer, &c., great care ſhould be paid to the corking. The gas, as it is formed, exerts great force to eſcape; and if the cork does not fit very accurately will be ſure to make its way out. The liquor will then never acquire the briſkneſs, and ſharp taſte, that it ought to have.

It is always better to lay bottled liquor on the ſides than upright, for then the gas muſt paſs through the liquor before it can eſcape; and beſides this, the cork is kept wet and ſwelled, and is much leſs liable to decay, which would thus communicate an unpleaſant taſte to the liquor.

To make *beer*, barley is ſoaked in water, and then laid in heaps ſome inches deep, till the grain has germinated, and the germe, or new ſhoot, is about two thirds of the length of the grain. It is then dried, to ſtop its growth, generally by artificial heat in kilns, when it is called kiln-dried; and ſometimes in chambers, where the air is freely admitted, when it is called air-dried malt.

The malt previouſly ſkreened, that is ſeparated from the huſk and germe, or new ſhoot, which is called its culm, and then ground, is infuſed in boiling water in a mafh tub. The liquor, then drained off, is called fweet wort.

It is next boiled with hops, to give it a pleafant flavour, and is cooled as fpeedily as poffible, to prevent its running into the acetous fermentation, and turning four. When cooled, it is put into large tubs or vats, and brought into the vinous fermentation, by the addition of yeaft.

The fame circumftances take place as to the extrication of carbonic acid gas, when beer is in a ftate of fermentation, as when wine is made. In both it is the vinous fermentation, and in both the refult is a fpirituous liquor.

The barley is firft made to vegetate, becaufe it thereby acquires a greater quantity of faccharine matter; and this is a requifite ingredient in every cafe of vinous fermentation.

As in every cafe of this fermentation, called the fpirituous or vinous, there is a fpirituous liquor formed, we may always procure the fpirit feparate, by diftilling fuch fermented liquor; and, according to the materials made use of, we obtain different kinds of *fpirit*, having different flavours, as well as different names.

From wine lees is obtained the Rhenifh brandy. French brandy from the hufks and ftalks of grapes fermented. Rum from the fugar-cane. Gin, whifky, and other Britifh fpirits, from malt.

Carrots, beet-root, potatoes, and fome other roots, by being ſimilarly fermented, have been made to afford ſpirits. And amongſt the Tartars a ſpirituous liquor, called koumiſs, is made by fermenting mare's milk.

Beſides being extricated during fermentation, carbonic acid gas is formed in many inſtances of *combuſtion*. As moſt inflammable bodies contain carbon, ſo moſt afford carbonic acid, when burnt, by the union of this carbon with the oxygen of the air. When charcoal is burnt, it is formed in ſuch quantity, as to be made ſenſible by its baneful effects.

We have before ſtated, that it will not ſupport life; and many a perſon has been killed by not being aware of this circumſtance, and that it is given out, wherever charcoal is burnt.

It is very common to light a charcoal fire in cellars, and vaults, when wine is to be bottled off in cold weather; and in ſuch ſituations there being no current of air to waft away the noxious gas, many have experienced its deleterious effects. In warming and airing damp or cold rooms it is frequently burnt, and in many manufactories the workmen are a good deal expoſed to the effluvia. In theſe, and in all other caſes, where burning charcoal is uſed, great caution ſhould be taken, to remove the gas as effectually as poſſible, and for the workmen to be as little expoſed to it.

The firſt effects that are experienced by a perſon expoſed to this gas, are extreme laſſitude and drowſineſs. He ſoon becomes unable to ſupport himſelf, and faints away. If he has not the power to remove from the effluvia, when he firſt feels its influence, and is not fortunately removed ſhortly after he faints, he remains ſenſeleſs, and is ſoon irrecoverably loſt.

When a perſon is diſcovered ſuffering from this cauſe, he ſhould inſtantly be removed to the open air, and the ſame plan be adopted as in caſes of apparent death from drowning. If the perſon ſhows any ſigns of life, as ſoon as brought into the air, the preſerving a free circulation of air, and the daſhing of cold water on the ſurface of the body, to excite the action of the reſpiratory organs, will be ſufficient.

But, if he appears lifeleſs, artificial reſpiration with the double bellows, continued friction, and the application of heat, muſt be had recourſe to. If an electrical machine be at hand, a ſhock ſhould be paſſed through the region of the heart.

Bleeding, the uſe of emetics, and the adminiſtration of tobacco glyſters, as recommended by ſome phyſicians, I look upon not only as unſerviceable, but as likely to deſtroy what ſmall ſpark of life may yet remain.

We have ſaid, that carbonic acid gas is given out by the *reſpiration of animals*, as well as by combuſtion. This is eaſily proved by breathing through lime water; for it immediately becomes turbid, which we have before ſtated to be one of the properties, and a diſtinguiſhing property, of carbonic acid gas. The cauſe of it we ſhall give preſently.

This extrication of carbonic acid gas in breathing is another cauſe, to be added to that of the abſorption of oxygen, or the pure part of the air, why animals can live only a ſhort time when confined in cloſe veſſels, and why we ſo conſtantly require the acceſs of freſh air.

From the greater ſpecific gravity of carbonic acid gas, it is frequently found occupying pits, and low ſituations. It often occupies the bottom of wells, and therefore workmen ought always to be cautioned againſt deſcending into ſuch places, without firſt lowering a lighted candle. If the candle continues to burn, they may deſcend with ſafety; but if not, it is ſure to be dangerous.

There are ſeveral caves and grottoes, in different countries, that are occupied, at leaſt near their bottoms, by this heavy gas. A man may often walk in them without any ill effects; whilſt a dog, or other animal, breathing a ſtratum of air nearer to the ground, will ſoon experience unpleaſant ſymptoms.

In mines this gas is called the *choak-damp*, as inflammable air is called the fire-damp. A lighted candle is a ſufficient teſt, to determine the preſence or abſence of the choak-damp: but, for reaſons before mentioned, it would be attended with great danger, where the fire-damp is prefent.

In all cafes where the prefence of fixed air is likely to be attended with inconvenience, the following rules fhould be obferved to obviate it.

Where it can be done, it fhould be removed by ventilation. In rooms where charcoal is burnt, frefh air fhould be freely admitted. In mines, fires fhould be kept up near one entrance, fo as to caufe a conftant current of air through the mine; and, where it is practicable, a ftream of water fhould be made to flow through that part that is moft charged with the gas; for water will abforb a confiderable quantity of it.

The plan that is moft frequently applicable for removing this baneful gas, is to abforb it by means of lime. In apartments where it is prefent, tubs of water with a quantity of quick lime in it will be fufficient. In wells the fame mode will anfwer; and, in mines, pits or pools of water may be impregnated with lime, and quick lime may be fprinkled about the floors.

Springs of water are fometimes met with, naturally impregnated with carbonic acid gas, as that of Seltzer, which is noted for its medical virtues. To imitate fuch natural waters, we have only to pour diluted fulphuric acid on powdered chalk, and fuffer the gas, that is extricated, to pafs repeatedly through water, till a fufficient quantity is abforbed.

An apparatus, known by the name of Nooth's apparatus, effects this purpofe with great eafe; and, when properly managed, without much danger of its breaking. When the mixture of the acid and chalk is carelefsly made, there is fo much gas fuddenly evolved, as frequently to burft the veffel, and inconvenience the operator. The way to prevent this accident, and the proper mode of managing the mixture is this. Firft put your acid in, and by inclining the apparatus, let it remain on one fide; then drop in the powdered chalk, fo as to occupy the other fide of the veffel; and always let it ftand a little inclined. Now, when you wifh more gas to be evolved, you have only to fhake it gently, fo as to wafh down a little of the chalk with the acid, and then return the veffel to its inclined pofition. By this means the evolution of gas will be gradual; and all danger of the apparatus burfting be obviated.

This Seltzer water, whether natural or artificial, is drunk with advantage in many cafes of indigeftion, and in calculous or gravelly complaints.

Water impregnated with carbonic acid gas is enabled to diffolve more lime than common water; and water thus charged depofits its redundant lime, when by expofure to the atmofphere it lofes its carbonic acid gas. This is the caufe of all the calcareous incruftations, termed petrifactions, and all the ftalactites formed in caverns.

The water in ſuch ſituations, being impregnated with fixed air, diſſolves more lime than it can afterwards hold in ſolution, when by expoſure to the atmoſphere it loſes its air. As the water loſes its fixed air, therefore, it gradually depoſits its lime; and if there happens to be moſs or any other ſubſtance in the ſtream, it becomes incruſted with the lime, whilſt it retains its natural form.

Carbonic acid, like other acids, enters into combination with the *earths*, and *alkalies*, forming neutral ſalts. When united to lime, it forms chalk, or lime-ſtone, or marble; and theſe ſubſtances, when again deprived of the carbonic acid, are reduced to lime. For the purpoſes of making mortar, lime-ſtone is deprived of its carbonic acid by heat; the ſtone and ſome kind of fuel being burnt together in a kiln. The carbonic acid gas being thus driven off by heat, leaves the ſtone in the ſtate called quick lime, which is a cauſtic corroding ſubſtance.

When expoſed to the air, it gradually attracts the carbonic acid gas, which is always preſent in a ſmall proportion, and is thus reconverted into chalk or lime-ſtone. It is now mild, and inert, inſtead of being cauſtic, and is no longer fit for making mortar.

The extrication of carbonic acid gas, when lime is burnt, makes it a very unhealthy employment to be engaged conſtantly in lime-kilns; and many accidents have happened, from perfons fleeping too near the burning lime.

It is the great difpofition that lime has to unite with this gas, that caufes the turbid appearance in lime-water, when expofed to the gas. Lime by itfelf is foluble in water, but chalk is not; when therefore the lime in the lime-water has attracted the carbonic acid gas, and thus become chalk, it is depofited, and caufes the turbid appearance.

As the lime will gradually attract the gas from the air, lime-water fhould always be kept in bottles well corked, otherwife the lime is feparated, as appears by the pellicle on its furface, and the lime-water becomes only common water.

We have now finifhed the confideration of carbonic acid gas, and fhall in the next effay treat of other combinations of carbon.

ESSAY XIII.

CARBON, OR CHARCOAL: COALS, OILS.

The compounds remaining to be noticed, which have carbon for their principal ingredient, are coals of different kinds, and oils. The bitumen of coals, as well as oils, is a compound of carbon and hydrogen, with a ſmall proportion of oxygen, and ſometimes of azote. The ſoot, which they afford, is chiefly carbon; and the more ſlowly or incompletely they are burnt, the more ſoot they afford. That from oils forms lamp-black.

Whatever be the origin of COAL, whether vegetable, animal, or mineral, and how numerous ſoever its varieties, it has certain uniform characters, and differs but little in its chymical qualities.

Coal is a compound of oily or bituminous matter and ſulphur with an earthy baſe, generally aluminous, argillaceous, or clayey, which are ſynonimous terms. It is a kind of ſchiſtus impregnated with bitumen and ſulphur. And this ſchiſtus is found thus impregnated in various degrees.

It is only when it contains ſo much bitumen, as to make it burn with facility, that we denominate it coal; but in the ſame mountains, that we find coal in, are other ſtrata of the ſchiſtus leſs impregnated with bitumen, and theſe are known under other names.

Coals are commonly found in hilly ſituations, and always under ſtrata of grit, which is a mixture of ſand and clay; or under ſchiſtus, which is clay hardened, and ſplitting into layers, forming either ſlates, or a ſubſtance called ſhivers, according to its fracture.

The coal is found in theſe mountains in ſtrata, from a few inches to ſome feet in thickneſs, and alternating with ſtrata of grit or ſchiſtus. The beds of coal run in various directions, generally with a dip or inclination from the horizontal poſition. They are frequently intercepted by columns of other matter; and the continuation of the bed may be either higher, or lower, than the part from which it has been, or ſeems to have been, ſeparated. The continuation too ſometimes takes the ſame, ſometimes a very different degree of inclination, or dip.

It generally happens that the firſt ſtratum of coals, that we come to, is not worth working, either from the inferior quality of the coal, it containing too little bitumen, or from the ſtratum being of too little depth.

From the degree and direction of the dip, and the level of the country, much information is to be obtained, concerning the proper place for opening the pit. A variety of circumſtances require to be taken into conſideration, to work a coal mine to the greateſt advantage; or to determine, whether a mine ought to be worked at all. Even in countries, or in thoſe parts of the country, where none has been found, very probable conjectures may be formed concerning its preſence, by attending to the ſoil, to the general appearance of the country, and to the kind of clay, ſand, or other earth, that is found, when the ſoil is removed. There are certain appearances that indicate its preſence, its value, its extent; and others, that point out the proper mode of working the mines, when diſcovered. Theſe indications are ſubject to variations; and theſe variations are often appreciable by certain other rules. The buſineſs of mining is therefore an intricate art; and none ought to enter upon it, without a practical knowledge of it, or the aſſiſtance of practical miners.

When a ſtratum of coals is come to, that is conſidered worth the working, it is dug out from the ſuperior and inferior ſtrata, which are generally grit, or ſchiſtus, and which are then termed the roof, and floor. In doing this, care is always taken to leave columns of the coal ſtanding here and there, ſufficient to ſupport the roof. When the roof is ſhivery, it is frequently neceſſary to ſupport it with a roof of timber. Theſe means being taken to ſupport the ſuperior ſtratum, the miners proceed to very confiderable diftances from the original pits; and occafionally new fhafts or pits are funk, to facilitate the removal of the coals, and to afford a proper ventilation in the mines.

The *varieties* of coal have been very differently arranged by different authors; fome dividing them according to their external appearances; fome as to the fituations in which they are found; others according to the manner of their burning; and ftill others as to the peculiarity of their fracture.

The fact is, that almoft every mine affords a coal, differing in fome refpects from that of others; and, although the inland coal is generally very different from the Newcaftle, which we call fea-coal, yet both vary fo much, as procured from different mines, or even different parts of the fame mine, that one parcel of inland or of fea-coal fhall differ very confiderably from another, both in its burning, and its general appearances.

The different manner in which coals burn deferves notice; and, if any arrangement of the varieties of coal is to be made, this affords the beft grounds for it.

The difference does not depend wholly upon the proportion of bitumen, but partly upon the kind, whether it is more or lefs volatile, and whether it is more or lefs eafily feparated from the earthy bafe. As the coal varies in thefe refpects, it comes under, or approaches to, more or lefs, one of the following divifions.

The firft includes fuch coal as affords a very confiderable flame, and burns with fo much rapidity, as only to require being lighted, like a candle, to continue its combuftion. This contains moft bitumen. The candle or cannel-coal is of this kind.

The fecond, which includes moft of the inland coals, called by fome fplit coal, contains fuch as burn with more or lefs flame, but require to be kept in a ftate of ignition by furrounding fuel, and leave a larger quantity of afhes, having more of the fchiftus in their compofition.

The third divifion includes thofe coals that unite or cake together when heated, in confequence of the extrication of their bitumen. Of this kind are the fea or Newcaftle-coals. This property of caking does not feem to depend upon the proportion of the bitumen, but upon its being extricated by a lefs degree of heat, than is fufficient to inflame it; for coals of this kind often afford as much afhes as the inland coals.

The laft divifion contains what is called blind coal, which affords neither flame nor fmoke, but when kindled makes a brifk and clear fire like coke. The Kilkenny coal is of this fort. In its external appearance it fometimes refembles the cannel-coal, and fometimes the fplit or inland coal. The peculiarity of this kind feems to depend upon its poffeffing a lefs inflammable bitumen, or to fpeak more correctly, a lefs volatile bitumen; for, as flame is nothing but the inflammable body ignited in a ftate of vapour, the quantity of flame muft depend chiefly on the volatility of the fubftance.

When coal is piled up, ignited, and the fire then fmothered, as in making charcoal, the refult is a light porous fubftance, called COKE, which burns much like charcoal without flame or fmoke. It is ufed in drying malt, and other operations, where the flame and fmoke would be injurious. In fome places furnaces or ovens are built for making coke, and the fires are put out by dampers, when it is fufficiently burnt. In this operation the more volatile, oily, or bituminous matter is exhaled, and, if collected, as in fome manufactories is the cafe, it forms a very excellent tar. It is the caking coal that makes the beft coke, for it is neceffary that the pieces fhould be at firft fmall, that the heat may extricate the bitumen without confuming it; and that it fhould afterwards run together into larger maffes, that it may be left porous and fpongy.

At Newcaftle, the coal duft, that is too fmall for common ufe, is burnt into coke, and forms excellent fuel. Might not the coal duft in inland mines, which will not anfwer for making coke, be worked up into combuftible bricks with a fmall proportion of clay, and, if requifite, a fmall quantity of fome inflammable fubftance, as the coal-tar, fo as to make a neat and perhaps economical fuel for our open fire-places?

With refpect to the *origin of coals*, the moft probable fuppofition is this. That the trees and other vegetables, that are carried down the ftreams into the ocean, are collected in ftrata at the bottom, together with the immenfe quantity of fea weeds, that grow there, and perhaps the fea animals too. That they are afterwards covered with clay or fand; and, undergoing a gradual decompofition, form fo many ftrata of coal, placed alternately with ftrata of clay or fand.

That the coal itfelf is of vegetable origin, is fairly inferred from a variety of vegetable remains and impreffions, that are found both in the ftrata of coal, and in the earthy ftrata above and below them. That it is of fubmarine origin, alfo appears from the prefence of fhells, and other productions of the ocean.

The popular opinion, that coals grow like vegetables, fo that the mines, that are worked out, may be opened, and worked again after a feries of years, is too erroneous to need any formal refutation.

We need not, however, be alarmed for the wants of future generations, as to this ufeful article. The immenfe beds of coal yet untouched, will fupply many thoufands of generations to come; and there is no doubt but the fame procefs, that produced what we at prefent ufe, is ftill continued, and that fome future convulfions will bring to light new coal mountains, perhaps from the bottom of the fea; for that, it is moft probable, is the place where nature has fixed her laboratory for preparing this fuel for far diftant ages.

Oils are a well known vegetable production. They are either fixed, or volatile; the former containing mucilage, and the latter an aroma, which is different in every different oil. They are obtained either by expreffion, as the olive oil, and linfeed oil, among the fixed; and the oil of lemons among the volatile kind; or they are obtained by diftillation, as the oil of peppermint, of thyme, and indeed moft of the volatile oils.

When the fixed oils are expofed to the air, they abforb oxygen, and become rancid. The oxygen in this cafe unites with the mucilage of the oil; and therefore fuch as are deprived of their mucilage are not liable to become rancid.

The feed of the flax, from which linfeed oil is obtained, contains fo much mucilage, that it is neceffary to torrefy or roaft it, previoufly to expreffing the oil. This deftroys the mucilage, and hence linfeed oil hardly ever turns rancid.

If oil of almonds is well agitated with water, its mucilage is partly feparated, and the oil is lefs fubject to become rancid.

Although oils, that are deprived of their mucilage, do not attract oxygen from the air, and confequently do not turn rancid, yet they may be made to unite with it in other ways, and then they become *drying oils*.

Drying oil is generally made by the painters, by boiling a calx of lead, as the litharge, in linſeed oil. The oil attracts the oxygen from the metal, and thus becomes a drying oil. If an oil is uſed that contains mucilage, the latter is ſeparated in boiling, and ſwims at the top; but, ſuch as contains no mucilage, makes the beſt drying oil.

When the volatile oils are expoſed to the air, inſtead of becoming rancid, they become thick, and reſinous, and loſe their aroma. This alſo ariſes from the abſorption of oxygen; and the ſame effect is produced by forming the combination in other ways, as by adding an acid to the oil.

The uſes of all the oils are too well known to require enumeration.

Tallow and fat, which are animal oils, differ from the vegetable oils principally in containing a peculiar acid, called the ſebacic acid.

ESSAY XIV.

PHOSPHORUS.

Phosphorus is one of the chymical elements. It is a ſolid ſubſtance, but ſo ſoft as to be eaſily ſcraped or cut with a knife. It is generally of a fleſh colour; and when pure it is tranſparent. In the air it emits a white ſmoke, a peculiar ſmell, and a beautiful though faint light, which becomes viſible in the dark. It inflames by the application of a gentle heat, and then burns with a very brilliant flame.

This curious ſubſtance is of animal origin. It exiſts in a compound ſtate in all kinds of bones, and likewiſe in conſiderable quantity in urine. The means of obtaining it from either are not very ſimple, and the proceſs cannot be well underſtood until we have treated more at length of its properties.

If any device is traced with a ſtick of phoſphorus on paper, as with a crayon, every line becomes beautifully luminous in the dark, and continues ſo for ſome minutes. If held before the fire for a moment the brilliancy is increaſed; but this muſt be done with caution, as very little heat is required to inflame the phofphorus, and then the paper will take fire.

By handling the phofphorus, part of it adheres to the fingers, and covers them with the fame light. This is not at all dangerous, as no fenfible heat is emitted; but if you rub your hand much, with a view of getting rid of it, the heat excited by the friction will inflame the phofphorus; and if there is much of it, it will then burn the hand. I have obferved great inconvenience from perfons getting fmall pieces of the phofphorus under their nails, by handling it injudicioufly; for, when they have approached the fire to warm their hands, fuch pieces have inflamed and given great pain.

To prove how eafily phofphorus is made to burn, rub it on a piece of tow, wrap this tow round a Florence-flafk, or other glafs veffel, and pour hot water into it. The heat of the water will inftantly inflame the phofphorus and the tow on the outfide.

Phofphorus is foluble in oils, particularly the volatile oils, which it renders luminous like itfelf. This folution may, without danger, be rubbed about the face and hands, fo as to render them luminous. The folution of phofphorus in ether when thrown upon boiling water, exhibits a pleafing appearance; the heat inflaming the phofphorus, and rendering it beautifully bright. This folution is alfo luminous of itfelf.

Phofphorus is likewife foluble in hydrogenous gas, or inflammable air, which it renders luminous. This very amufing compound may be obtained by boiling a little phofphorus in a folution of pure potafh. The water is decompofed in this experiment, and affords the inflammable air. The retort fhould be very nearly filled with the folution, otherwife the gas will inflame, and diminifhing the volume of air in the retort, occafion the water to rufh in from the trough.

When this phofphorated hydrogenous gas is in contact with common air it emits light, and, like phofphorus itfelf, undergoes a flow combuftion; but when it is mixed with pure air, (oxygenous gas) it immediately detonates.

To make the phofphoric match bottles, nothing more is neceffary than to drop fmall pieces of dry phofphorus into a common phial, gently to heat it till it melts, and then turn the bottle round that it may adhere to the fides. The phial fhould be clofely corked, and when ufed, the match (a common brimftone match) is to be introduced, and rubbed againft the fides of the phial. It thus acquires a portion of phofphorus, which inflames on being brought into the air.

When phofphorus is confumed either by the flow combuftion, that fpontaneoufly takes place when it is expofed to the air, or by the more rapid one produced by inflaming it, the pure part of the air (oxygen) combines with the phofphorus, and forms phofphoric acid.

This acid, like others, unites with the fimple earths and alkalies, forming neutral falts. It is the compound refulting from its union with lime that forms the hard offeous matter, that is the bafis of all bones. The urine contains this acid, united both to lime and to the alkalies.

After being made acquainted with thefe facts, we fhall more eafily comprehend the nature of the proceffes, by which phofphorus is obtained.

To obtain it from bones, felect the hardeft; burn and then pulverife them. To this powder add half its weight of vitriolic acid, ftir it well, and then leave it for two or three days; afterwards add water gradually, and ftir the mixture; when the powder has fubfided, decant the fupernatant liquor, and evaporate it to drynefs. Upon this dry extract pour boiling water as long as it continues to tinge the water, and then evaporate this folution to the confiftence of a thick firup. To this extract add juft fufficient water to diffolve the phofphoric acid, and filter through linen. Laftly, mix this extract with powdered charcoal, and diftil from an earthen retort, the neck of which is immerfed in water. The phofphorus will drop into the water, and may be worked into form with the fingers. Some prefer converting the phofphoric acid into a glafs, which is done by expofing the extract in a crucible to a ſtrong heat. To obtain phoſphorus from this glaſs, nothing more is neceſſary than to powder it; mix it with an equal quantity of powdered charcoal, and diſtil.

The ſulphuric acid in this proceſs combines with the lime, and detaches the phoſphoric acid, which, when mixed with the charcoal, is likewiſe decompoſed; its oxygen uniting with the carbon, forms carbonic acid gas, or fixed air, whilſt the phoſphorus comes over in its pure ſtate.

To obtain phoſphorus from urine, it is generally recommended to evaporate the urine, and then diſtil with charcoal; but a leſs troubleſome, and leſs diſagreeable way is, to add a ſolution of lead in muriatic acid to freſh urine, until it cauſes no more ſediment to fall; then filter the whole through two or three folds of linen, and mix up the ſediment, that is left on the filter, with powdered charcoal into a paſte. This paſte diſtilled in an earthen retort, with a pretty ſtrong heat, affords the phoſphorus.

The muriatic acid here diſengages the phoſphoric from both the lime and the ſoda, with which it was combined, and the ſediment is a phoſphat of lead which is afterwards decompoſed by the charcoal.

It is here that I ſhall notice what may be termed NATURAL PHOSPHORI; by which I mean ſuch bodies as naturally emit light, ſimilar to that, and regulated nearly by the ſame laws as that of phoſphorus. They will include living animals, that poſſeſs this property, dead animal matter, and decayed vegetables.

Of living animals, that appear luminous in the dark, there are in this country two land inſects; and on our coaſt ſeveral marine inſects and fiſhes.

The two land inſects are both vulgarly called glow-worms, but are very different both in their manners and appearance. The one is a ſcolopendra (*ſcolopendra electrica*), ſomething like the centipes, being a thin and flattiſh worm with a great number of feet. It is often found in houſes about old furniture.

The other is a ſoft, broad, and flat inſect, ſomething like the millepes (the woodlouſe or old-ſow), extended and flattened. It is apterous, or without wings, but is the female of a winged inſect of the beetle tribe (*lampyris noctiluca*). The inſect is very common on the heaths in Norfolk, and in ſimilar ſituations elſewhere. The light emitted by this inſect proceeds from the three laſt rings of the abdomen, is of a beautiful ſulphur colour, and appears, when accurately examined, to proceed from diſtinct but numerous ſmall globules within the abdomen, which are probably the ova or eggs. It is a ſubject worthy of further attention from the naturaliſt.

The marine inſects will be noticed in treating of the luminous appearances of the ſea, which will fall preſently to be conſidered.

In other countries, particularly in warm climates, there are feveral luminous infects, and much larger ones than we have here. Such are the lantern-fly of China, and the candle-fly or fire-fly of the Weft Indies, which emit a very ftrong light from the probofcis or fnout.

Of dead animal matter almoft every kind has at times been obferved to be luminous, as whole joints of mutton, and venifon, pieces of veal-bones, lobfters claws, &c.; but what peculiar circumftances determine thefe fubftances to emit light at one time, and not at another, have hitherto eluded our inquiries; for, although they never fhine, but when in a ftate of putrefaction, they more frequently pafs through the whole putrefactive procefs without affuming this appearance.

There are other fubftances that conftantly fhine, when in a certain ftage of putrefaction. Thefe are various kinds of fifh, as mackerel, herrings, whitings, and fome others, which will be noticed in confidering the caufe of the brightnefs of the fea.

In the vegetable world, rotten wood, when in that light fpongy ftate called touchwood, is the moft remarkable. This requires moifture to emit its phofphoric light. It is yet uncertain, whether the accefs of air is neceffary to fupport the light. Boyle fays, that it ceafed to fhine in an exhaufted receiver; but Achard, a French chymift, afferts that it continued to emit light in that fituation. When it becomes quite dry, its light is extinguifhed, but reappears, when the wood is moiftened.

The colour of the light in all thefe inftances is pale blue, exactly refembling that of phofphorus. It is in all cafes, except that of the rotten wood, increafed and rendered more intenfe by immerfing the luminous body in oxygen gas, and is extinguifhed by immerfion in azotic, or in nitrous gas. It is in all cafes too, except that of the wood, attended with the extrication of an oily matter, which adheres to the fingers, and makes them appear luminous. Which circumftances tend ftrongly to fupport the opinion, that the light is emitted in confequence of the formation of a phofphorated oil, or folution of phofphorus in animal oil.

The opinion of fome modern chymifts is, that the light is a conftituent part of the fifh, but the neceffity of the prefence of oxygen gas makes it much more probable that the fixation of oxygen, with the confequent feparation of its light and heat, is the true caufe of its appearance. We acknowledge this to be the fource of light in common combuftion, and in the flow combuftion of phofphorus; why then look for any other in the inftance before us, where the prefence of oxygen gas is equally neceffary? Some have doubted, whether oxygen gas is neceffary to the emiffion of light from phofphorus; but this I fatisfactorily proved to be the cafe by the following experiment. A piece of phoſphorus being inflamed in a jar of common air, inverted over water, burnt readily, till nearly all the oxygen gas was conſumed. The ſame piece, being again inflamed in the ſame ſituation, burnt for a few moments longer, and ſo a third time. Even after this the phoſphorus ſhone for a few hours, but at length its light was wholly extinguiſhed. After ſome hours, the phoſphorus ſtill remaining dark, freſh air was admitted into the jar, and the light immediately reappeared.

In rotten wood, that is luminous, as moiſture ſeems neceſſary, and oxygen gas not ſo, a different proceſs, not yet aſcertained, is probably the cauſe of the phænomenon.

As the luminous appearance of the ſea has frequently attracted the notice of navigators; and as, in conſequence of its aſſuming a variety of appearances, it has been very differently explained; I ſhall enter more into detail upon this point, and beg leave to do it in the words of a diſſertation which I wrote ſeveral years ago.

DISSERTATION *on the* LUMINOUS APPEARANCE *of the* SEA, *read before the Natural Hiſtory Society of Edinburgh, in December,* 1796.

The luminous appearance of the ſea is ſo common, as well as curious a phænomenon, that almoſt every one, who has been on the ſea in a ſummer's evening, particularly in warm climates, muſt have obſerved it.

Its variety of appearances has however given riſe to ſuch different deſcriptions, and contrariety of opinions reſpecting its cauſe, that on a ſlight view it appears almoſt impoſſible to reconcile theſe various accounts, and aſcertain its real nature. To attempt this, however, is the object of the preſent paper.

That celebrated philoſopher Boyle did not let this curious phænomenon eſcape his extenſive reſearches into the operations of nature. But, learning from ſome, that the ſea was only luminous when diſturbed and agitated; from others, that they had ſeen the whole ſurface of the ſea covered with a bright light, like burning ſulphur, as far as their view extended; whilſt others again deſcribed the light, as being confined to certain parts of the ſurface, other parts, not far diſtant, being not at all luminous; he was ſo confounded with theſe various accounts, that he concludes by referring the phænomenon to ſome coſmical law, or cuſtom of the terreſtrial globe.

Father Bourzes in his voyage to the Indies, in 1704, ſays, that he could ſometimes diſtinguiſh in the wake of the ſhip the particles, that were luminous, from thoſe, that were not ſo. Some, he ſays, were like points of light, others like ſtars;

fome like globes of a line or two in diameter, and others as large as a man's hand.

Sometimes all thefe different figures were vifible together; and at other times there were what he calls vortices of light, appearing and then difappearing, like flafhes of lightning. Not only the wake of the fhip produced this light, but fifhes alfo in fwimming left a luminous track behind them, fo that their fize and fhape might eafily be diftinguifhed. He remarks too, that this appearance is greateft when the water is *fatteft and fulleft of foam.*

In thefe obfervations are I think defcribed all the appearances that have been obferved, and noticed by others. And, I think, that they may be reduced to two kinds, which differ effentially not only in the appearance of the light, but alfo, as I fhall afterwards endeavour to fhow, in their caufes.

The firft kind includes thofe cafes, where the furface of the water appears luminous without agitation; and where, when agitation is neceffary, to produce a luminous appearance in the body of the water, the part illuminated affumes no determinate figure, but gives out its phofphorefcency wherever the agitating caufe prefides. Of this kind are the expanded lights mentioned by Boyle, and the luminous track left by the fifh in fwimming, as defcribed by father Bourzes.

The fecond divifion includes all cafes, where the light is of a determinate figure, and where it appears and difappears repeatedly without any apparent caufe. In moft of thefe cafes agitation will produce the light, though it is not always neceffary.

Of this kind are the beautiful fcintillations obferved by every mariner, and met with more frequently than any other fpecies, in our own latitude in the fummer feafon; and likewife the ftars and globes of light mentioned in the narration of modern navigators.

Let us now proceed to inveftigate the caufe of this phænomenon. The Abbé Nollet and feveral others, having examined the fea water near Venice, which in the dark was feen to contain luminous fpots when agitated, thought they found fmall infects, to which they attributed the light.

M. le Roi, examining fome water which poffeffed the fame property, was perfuaded that it was not entirely owing to infects; for the luminous fpots, which he took up, were round fubftances of the fize of pins'-heads, which had no appearance of being animals.

M. Dagelet too obferved fimilar bright bodies, which he fufpected to be the fpawn of fome kind of fifh.

M. Canton, from fome experiments which he performed, and which we fhall have occafion to mention prefently, attributes the light of the fea to putrid fifh.

Count Gregorius Razamoufky afcribes the light, which is obſerved in the ſhip's wake, to phoſphorical gas, diſengaged by the friction of the waves againſt the ſides of the veſſel.

Mr. White ſuppoſes that it is ſometimes owing to large fiſh having the property of ſhining whilſt alive; but, as this property is generally confined to the ſmaller animals, it was probably owing in the inſtances, to which he alludes, to the ſmall paraſitical inſects, that burrow under the ſcales of fiſh, and which poſſeſs this phoſphoreſcent quality. I have often ſeen theſe little animals burrowing under the laminæ of oyſter ſhells.

From the above obſervations, it appears that the light in the ſea is ſometimes derived from living, and ſometimes from dead and putrid animals. For reaſons, which I ſhall give preſently, I ſuſpect that our firſt kind of luminous appearances is always owing to putrid fiſh, and the ſecond to living animals, under which I include the ſpawn of fiſh. Let us now conſider theſe cauſes ſeparately.

That putrid fiſh will not only ſhine itſelf, but communicate this property to ſea water, or a ſolution of common ſalt in water, was, I believe, firſt obſerved by Dr. Beal, in 1665; but Canton firſt made experiments with a view of aſcertaining its cauſe.

The appearances in theſe experiments are ſo ſimilar to thoſe obſerved in the ſea, which we have included in our firſt diviſion, that I am induced to attribute them to the ſame cauſe.

M. Canton immerſed a herring, which appeared very bright in a darkened chamber, into ſalt water, and the ſurface of the water became inſtantly luminous; the light too was increaſed by agitation.

When he repeated the experiments with whitings, inſtead of herrings, he remarks, that the water did not appear luminous, unleſs when agitated, but that when a ſtick was drawn through the water, it left a luminous track behind it. I have obſerved the ſame when mackerel are uſed. This difference between the herring and the whiting is a curious fact, but what I cannot ſatisfactorily explain *.

That the light given out by dead fiſh is owing to the changes it undergoes during putrefaction, may, I think, be fairly deduced from the following experiments. Mr. Canton immerſed a whiting (freſh caught) in ſea water, and it gave no light, till the next day.

I have obſerved that herrings emit very little, if any, light, till about twenty-four hours after death †: and a mackerel, which I did not procure till a day after it was caught, ſhone very little;

* May it not depend upon the oily matter of the herring being ſpecifically lighter than the water, and therefore ſwimming on the ſurface, whilſt that of the whiting, being nearly the ſame with it, is ſuſpended in the body of the water?

† Herrings, and, I believe, mackerel, ſhine conſiderably when ſwimming in the water, but ceaſe to do ſo when firſt killed.

but the light of this, as well as of the herrings, continued to increafe till fixty or feventy hours after death. The tail, fins, and head always fhine firft, and have generally ceafed to fhine, before the more flefhy parts attain their greateft luftre. Generally, by the end of the fourth day, the whole has ceafed to emit light. Mr. Canton kept a whiting in a ftrong brine for three days, and it did not fhine; when he took it out it was quite frefh.

I immerfed a piece of mackerel, that fhone at the time very bright, in nitrous gas, and in about five minutes it had loft its brightnefs, which it regained in about five minutes after it was taken out.

In the next experiment, being allowed to remain for five minutes in the gas, after its light had difappeared, it did not regain its brightnefs in a quarter of an hour, at which time I left the laboratory; but, on my return fome hours after, it was fhining nearly as bright as at firft.

This effect of nitrous gas I attribute to its well-known antifeptic quality; and this, with the preceding experiments, fufficiently proves, that the fifh emits this light during a certain ftage of its putrefaction only.

On what the extrication of light immediately depends, it is more difficult to afcertain. From the fimilarity in its appearance, I think it probable, that the formation of fome combination of phofphorus is the immediate caufe; and from the falt water, rendered luminous by fiſh having its ſurface covered with oil, and from a greaſy ſubſtance adhering to the fingers, which continues to emit light after touching luminous fiſh, or water rendered luminous by them, I rather ſuſpect it to be a phoſphorated oil, than a gas.

We ſhall now proceed to conſider the cauſe of our ſecond diviſion of luminous appearances, which I have before ſtated to ariſe from living bodies.

From the obſervations of M. le Roi and M. Dagelet, it ſeems to proceed in ſome inſtances from the ſpawn of fiſh: but the bright ſparkling, ſo often obſerved on agitation, is more commonly owing to ſmall inſects, frequently to a ſpecies of monoculus, as that deſcribed by the Abbé Nollet, found in the water near Venice, and that by M. le Riville in the water near the Maldivia iſlands, in the Eaſt Indies.

The ſame, or a very ſimilar inſect, has been lately found by a friend * of mine in the ſalt water of a river in Cambridgeſhire, about ten or twelve miles from the ſea. This gentleman procuring ſome of the water, which contained theſe luminous ſpots when agitated, took it into a darkened room, and dipping his hand into the water, ſeveral of the bright ſpecks adhered to it. Theſe he carefully took off with the point of a knife, and dropped into a glaſs of clear freſh water, where they continued to ſhine

* Mr. William Skrimſhire, a very accurate and attentive obſerver of nature.

for a moment. This water, when viewed in the light, was feen to contain fmall fpherical tranfparent bags, which, when examined through a microfcope, were found to be infects, very like the common monoculus.

M. le Riville fays, that the parts of the infect, that give the light, are bunches of fmall bodies in its pofterior part, which he fuppofes to be the eggs. Thefe little animals never admit light but when the water is agitated, as by the motion of a veffel, or the oars of a boat, which come out of the water every time beautifully befpangled with brilliant fpots; or by throwing a ftone or other body into the water, in which cafe many of the infects become vifible.

This circumftance has induced Dr. Darwin to believe, that this kind of light is not produced by infects; but it appears to me a very inconclufive argument; for it is poffible that the infects may only appear luminous when hurt or actuated by fear, which will account for their fhining only when the water is difturbed; or, what is ftill more probable, the agitation may produce the light, by expofing the infects to the contact of the air, which may be neceffary to their fhining, as it is to the light of phofphorus and other phofphorefcent fubftances.

There are feveral other marine animals poffeffing this power, which may therefore occafionally prove the caufe of this phænomenon, viz. the *Medufa* *ſimplex*, the phoſphorical property of which was even known to Pliny; the *Dagyſa*, firſt diſcovered by Sir J. Banks and Dr. Solander, off the coaſt of Galicia, which, apparently, from the account given in Hawkesworth's Voyages, emits its light without the intervention of agitation; *Carcinium Opalinum*, diſcovered by the ſame gentlemen; the *Nereis Nocticula;* the *Pholas*, well known by the experiments made with them by the Bolognian academicians; the *Pennatula Phoſphorea;* the *Cancer Fulgens;* and, I believe, ſome other ſpecies of *Meduſa*.

For what purpoſe theſe marine animals are endowed with this property, has not been aſcertained. The female Lampyris Noctiluca (common glow-worm) poſſeſſes its ſhining property for the ſake of attracting the male, which being a winged inſect has very different habits from the female, and would otherwiſe have difficulty in diſcovering her haunts.

Another natural phænomenon which the properties of phoſphorus enable us to explain is, the will-o'the-wiſp, or ignis fatuus.

This luminous appearance is a blue light, often of a columnar, often of other ſhapes, very movable, generally having a tremulous motion, diſappearing and reappearing ſuddenly; and it is moſtly repreſented as changing its ſituation inſtantaneouſly, and appearing in different and diſtant ſpots. It is uſually met with in heathy or boggy ſituations; and there is a prevailing opinion amongſt the vulgar, that it has the power of attracting and miſleading travellers into bogs and miry places. The fact is, that many perſons miſtaking ſuch an appearance for a light in ſome houſe, have made their way towards it, and not diſcovered their miſtake till they were ſinking in a ſwamp.

To a more attentive obſerver, theſe ignes fatui bear all the appearance of ignited vapour; and it is now very well known to be phoſphorated hydrogenous gas, or phoſphorus diſſolved in inflammable air, which I have before mentioned as poſſeſſing the property of being luminous in the dark.

This gas is extricated from a mixture of animal and vegetable matter, in a ſtate of putrefaction, a circumſtance that muſt frequently occur in marſhy places.

A ſimilar light has been frequently obſerved in church-yards, and been ſuppoſed by the ignorant to be ſomething ſupernatural. From ſuch a circumſtance, which ſcience teaches us to account for by natural laws, many a perſon has been fully perſuaded that he has ſeen ſomething ſupernatural; and ſuch has often been the origin of the moſt wonderful ghoſt and apparition ſtories.

The human mind ſeems prone to attribute to ſupernatural agents whatever is not within its reach to comprehend. It is therefore amongſt men of weak and unenlightened minds, that we find moſt inſtances of a belief in the appearance of apparitions.

But ought we not to be more humble, and acknowledge our ignorance? When we meet with a viſible appearance that we cannot explain, or hear a noiſe that we cannot account for, would it not be more becoming in us to attribute it to ſome natural cauſe, that from our confined knowledge we are unacquainted with, than to conclude that it is inexplicable by natural laws, and muſt be ſomething ſupernatural, becauſe we are ignorant of its cauſe?

How many people are ignorant that there is a peculiar gas, often extricated from putrid matter, which burns of itſelf, and appears luminous in the dark! and to us, who know the fact, how abſurd, how prepoſterous it appears, that ſuch people ſhould therefore attribute ſuch an appearance to the agency of ſupernatural powers! It is prepoſterous, but ſurely not more ſo, than for us to attribute to the ſame powers other occurrences which we cannot explain; and yet many, whoſe minds are well informed, are too apt to make ſuch an inference.

I cannot avoid bringing forward another argument againſt the probability of every tale or ſtory that tends to inculcate a belief in the agency of ſupernatural powers in theſe, and ſimilar occurrences. It is an argument that I have obſerved more frequently than any other to diſcourage ſuch belief, and this induces me to notice it.

Is it at all probable, that the eſtabliſhed laws of nature, laws which the Creator himſelf has eſtabliſhed and ordained, ſhould in any inſtance be ſuſpended, or others appointed, unleſs for the effecting of ſome grand, ſome important object? Is it likely, I aſk the ſuperſtitious narrator of the ſtory, that ſuch means ſhould be had recourſe to, for the purpoſe of frightening and terrifying any one? And yet ſuch in general, if the tales were true, would ſeem to be the only effect, and the only object of this deviation from fixed and eſtabliſhed laws.

Or is it probable, that ſuch extraordinary means ſhould be adopted, even to alarm the conſcience, and to puniſh or reclaim an individual ſinner? No, be aſſured the conſcience of the wicked man needs no ſuch ſpur to increaſe its poignancy. It is ever on the alert, and its ſting will, without ſuch intervention, at times be felt by the moſt hardened and abandoned profligate. And as to puniſhment, it is not in this, but in the world to come, that the deeds of the wicked will be judged, and their puniſhments awarded.

ESSAY XV.

SULPHUR, OR BRIMSTONE.

Sulphur, or brimſtone, is an inflammable ſubſtance, found alone or combined with other bodies, in a variety of ſituations.

In volcanic countries it is found almoſt pure, having been volatilized and thrown out by the volcanoes. In ſuch ſituations the earth and ſtones, in which it abounds, are diſtilled, and the reſult of this diſtillation is brought to market as crude ſulphur. By fuſion and caſting in moulds, it forms roll brimſtone; and by ſubliming or volatilizing it with a gentle heat in cloſe chambers, we obtain the flowers of brimſtone.

Sulphur is alſo found in abundance in coal mines, and in the ores of different metals. In this ſtate it bears the name of pyrites; and the copper and iron pyrites are the ſource of moſt of the ſulphur uſed in this country. In roaſting the ores to obtain the metals, much ſulphur is ſublimed and collected. In other caſes the pyrites are piled in the form of pyramids, the ſides of which are earthed up. By the addition of a ſmall quantity of fuel the pile is lighted, and made to burn ſlowly, during which the ſulphur is volatilized, and eſcaping to the top, is there condenfed, and then melted in cavities deftined to receive it.

When fulphur is burnt, it combines with oxygen, and forms fulphuric acid, or oil of vitriol. In the manufacturing of this acid, about one eighth of faltpetre is added to the fulphur, to affift the combuftion, by affording oxygen. The operation is performed in chambers lined with lead, and the acid vapours are condenfed againft the fides, or abforbed by water, with which the floor of the chamber is covered. When this water is fufficiently impregnated, it is concentrated in leaden boilers, and rectified in glafs retorts, to render it white and pure.

Sulphuric acid is much ufed by the dyers, and in a lefs oxygenated or acidified ftate, when it is called fulphureous acid, it is ufed to bleach or whiten filk.

When a match is lighted, and a rofe held over the vapours, its colour foon fades, and the rofe becomes white. This is effected by the fulphureous acid vapours that are formed, and proves its bleaching qualities.

Sulphur united to the alkaline falts forms the different hepars, or livers of fulphur. Acids decompofe thefe, and at the fame time difengage a very offenfive gas, which is inflammable air, holding fulphur in folution.

The SULPHURATED HYDROGEN GAS gives

the peculiar ſmell and taſte to Harrowgate water. It is like that of rotten eggs, or the ſcourings of a gun-barrel. Notwithſtanding this peculiar, and, to moſt people, very diſagreeable flavour, Harrowgate water is ſoon drunk without diſguſt, the palate being by habit ſoon reconciled to it. It tarniſhes ſilver, and blackens white paint. Characters written on paper with a ſolution of ſugar of lead in water, are made viſible, and rendered almoſt black, by holding the paper over freſh Harrowgate water; and ſtill more readily by immerſing it in the water. This has been had recourſe to for ſecret correſpondence, for the characters are quite inviſible before the application of the water.

Many curious tales are circulated about ladies who have uſed white paint, being disfigured by bathing in theſe waters. The paint being a calx of lead (white lead) is immediately blackened by the application of the water.

Sulphur ſeems to be afforded by animal and vegetable putrefaction.

ESSAY XVI.

THE ALKALIES.

THE alkalies are divided into volatile and fixed. Ammonia is the volatile, and ſoda and potaſh are the two fixed alkalies. The latter are ſtill conſidered as elementary ſubſtances, although many circumſtances render it probable, that they are compounds of azote with one or other of the earths. Ammonia or the volatile alkali, it is now well aſcertained, is a compound of azote (the baſe of impure air) and hydrogen (the baſe of inflammable air).

Notwithſtanding its being a compound, we ſhall treat of ammonia, in this place, as allied in many of its properties to the fixed alkalies. Like them it changes vegetable blue colours to a green; it has an acrid taſte; renders oils ſoluble in water; and when pure diſſolves, or reduces to a jelly, wool and ſome other animal ſubſtances. Theſe may be conſidered the general qualities of alkalies; and now let us conſider each of theſe ſubſtances ſeparately.

AMMONIA, or volatile alkali, in its pure ſtate, is in the form of gas; when abſorbed by water, it is the *aqua ammoniæ puræ*, ſometimes uſed in ſmelling-bottles; and when rendered mild by its union with carbonic acid or fixed air, and cryſtallized, it conſtitutes the common ſmelling ſalts.

When equal parts of ſal ammoniac (muriate of ammonia) and quick lime, each in powder, are heated in a glaſs retort, a gas is extricated, which, if collected over mercury, retains its aeriform condition, and is the pure ammonia, or ammoniacal gas. If collected in a veſſel containing water, it is immediately abſorbed, and conſtitutes the *aqua ammoniæ puræ*, or liquid ammonia.

The gas has a pungent ſmell, turns red vegetable infuſions to green, extinguiſhes flame, and is fatal to animals.

The chief uſes of volatile alkali are as a medicine. It is produced by the putrefaction, or by the diſtillation, of almoſt all animal matter. It is this ſalt in a ſtate of gas that gives the pungent ſmell, and affects the eyes, on entering ſtables, ſlaughter-houſes, and ſimilar places, that are not well cleanſed.

Sal ammoniac, from which the volatile alkali is chiefly procured, is a compound of ammonia and muriatic or marine acid; hence its name in the new nomenclature is *muriate of ammonia*. This compound ſalt is obtained by diſtilling the ſoot, that ariſes from burning the dung of certain animals. It is moſtly imported from Egypt, where the dung of the camel is dried in the ſun, then burnt, and the ſoot carefully collected; from which the ſal ammoniac is procured by ſimple diſtillation. It is only the dung of ſuch animals as feed on ſaline vegetables, that will afford the ſal ammoniac. There is nothing peculiar in that of the camel, as has been very generally believed. It depends ſolely on the kind of food; and unleſs the animal has eaten the ſaline vegetables, ſuch as grow on the ſea ſhore, and near to it, its dung will afford no ammoniac.

There is a manufactory of ſal ammoniac at Edinburgh, but the proceſs is kept a ſecret.

This ſalt is uſed in ſome proceſſes in the art of dyeing. It is uſed as a flux in ſoldering, and in ſome caſes as a medicine.

The FIXED ALKALIES are of two kinds: the one called vegetable alkali, or potaſh; the other mineral alkali, or ſoda. They are both known in commerce under different names, according to the ſubſtances from which they are procured.

POTASH, or the vegetable alkali, is generally obtained from wood aſhes; but ſometimes from the tartar, or from the lees of wine, in which caſe it is called *ſalt of tartar*. Moſt of our potaſh is imported from the North, where wood is in ſufficient abundance to allow of its being burnt for this purpoſe. The hard woods afford the moſt ſalt; but every vegetable, when burnt, affords ſome. The aſhes are waſhed in water, which diſſolves the potaſh; the ſolution is then concentrated by boiling, and evaporating in iron boilers; and the ſalt thus procured is ſometimes heated in the fire to purify it from colouring matter.

The vegetable alkali is uſed in bleaching, in making ſoap and glaſs, and as a medicine. Wood aſhes are frequently uſed in waſhing; in which it is the potaſh that proves ſerviceable; for by uniting with greaſe, and other filth, it renders them ſoluble in water. For the ſame reaſon ſalt of tartar is ſometimes uſed to take out greaſe ſpots.

SODA, or the foſſil alkali, is ſometimes found in a native ſtate, as in the lakes of Natron in Egypt, which are dry in the ſummer ſeaſon; the water leaving, after evaporation, a bed of ſoda, or, as it is there called, natron, of two feet in thickneſs, which is dug out with iron crows, for ſale. Such as is not obtained from this ſource, is procured from the aſhes of ſeaweeds, and certain plants that grow on the ſeaſhore. Theſe vegetables are thrown together in heaps, and burnt; the aſhes are then collected, and treated in the ſame way as wood aſhes for obtaining the vegetable alkali.

When it is obtained from the ſeaweeds, as ſea wrack, or tang, which are different ſpecies of fucus, the ſalt is called *kelp*. When obtained from a plant called barilla, which grows in great perfection on the Spaniſh coaſt, the ſalt is alſo called *barilla*. There are ſeveral other vegetables which afford the mineral alkali; as *ſalſola kali*, ſome of the genus *chenopodium*, and alſo ſome of the *atriplices*.

The ufes of this alkali are nearly the fame with thofe of the vegetable alkali, but it is more ufed in glafs-making.

The alkalies, as we ufually meet with them, are in a mild ftate, in confequence of their combination with carbonic acid, or fixed air, which is the caufe of their effervefcing with acids. When boiled with quick lime, they lofe the fixed air, and become cauftic.

The alkalies combine with all the acids, and form neutral falts; thus, when beer is four, a few grains of falt of tartar, or other vegetable alkali, added to a glafs of the beer, will neutralize the acid, and take off the tartnefs.

The alkalies will all of them unite with oils, and the refult of fuch a combination is a SOAP; the kind and quality of which depend upon the kind and quality, and alfo upon the proportion, of the ingredients.

The firft part of the procefs confifts in making the alkali pure or cauftic by mixture with quick lime, which abftracts from it the carbonic acid or fixed air. This cauftic lie, mixed with oil or tallow in due proportion, and boiled to a proper confiftence, forms foap.

Boil one part of good barilla with two of quick lime in a fufficient quantity of water, ftrain the liquor through a cloth, and evaporate, till a phial, holding eight ounces of water, will hold eleven of this folution; then boil one part of the lie with two of the oil, and you will have a good hard foap.

In manufactories, where the fuel is of material confequence, the lie is made without boiling. Equal meafures of barilla and flaked quick lime are heaped up together, water is poured on the top, and filtering through the heap is caught in proper veffels; more water is then poured on, till no falt comes with it, and the lie of different ftrengths is kept feparately. It is now mixed with the oil and tallow in boilers, the weakeft lie firft, then that that is ftronger, and fo on; and when boiled fufficiently the foap is made.

The beft foft foap is made with five parts of potafh, three of whale oil, and one of tallow.

For foaps of an inferior quality, more tallow, kitchen greafe, or oil of an inferior quality, is ufed.

And lately the French chymifts have recommended a cheap foap to be made, by ufing woolen rags and old woollen clothes of all kinds, locks of wool, hair, and even the horns of animals, inftead of oil. Thefe fubftances are all foluble in the cauftic lie, and by proper boiling form a foap. The chief inconvenience of fuch a foap is, that it poffeffes a very unpleafant fmell. It is however ufed by many of the cloth manufacturers in cleanfing their ftuffs; and as they require repeated wafhing, the fmell is thereby completely taken off.

The moſt delicate ſoap is made with olive oil; and a peculiar kind, called Starkey's ſoap, is made by triturating ten parts of cauſtic alkali hot, with eight parts of oil of turpentine, which inſtantly forms a very hard ſoap.

Another important uſe of the two fixed alkalies is in the manufacture of GLASS. Mixed with the ſiliceous or flinty earth, they form a compound that is very fuſible, and according to the ingredients more or leſs tranſparent; and of ſuch a mixture is glaſs of every kind manufactured.

The ſiliceous earth is uſed either in the form of ſand, of flint, of quartz, or ſome other hard ſtone of this genus. Such being ſelected as is fitteſt for the particular kind of glaſs required.

The common green bottle glaſs is made of the common ſand from the ſea-ſhore, for the ſilex, and the ſoap boiler's refuſe for the alkali. Both the ingredients therefore are impure, and conſequently the glaſs is of an ordinary quality. The alkali in the ſoap boiler's refuſe is calculated to aſſiſt the fuſion of the maſs very conſiderably, the quantity of ſilex renders it a very hard glaſs, and it derives its green colour from a portion of iron, contained in the ingredients.

The maſs is fuſed in veſſels made of Stourbridge clay, in a furnace of conſiderable power, and the bottles are faſhioned by blowing; after which they are immediately put into the annealing oven, and allowed to cool gradually.

Window-glass is generally made of a fine white ſand, ſuch as is found on the Norfolk coaſt, and is called Lynn-ſand, and the ſoda obtained from burning the ſea weeds, which is known by the name of kelp.

The kelp is previouſly calcined to expel the fixed air. When the maſs is melted, it is run into large plates, and this operation is termed flaſhing.

The ſame kind of ſand is uſed for what is called flint glaſs, but in this there is an addition of litharge, or ſome other preparation of lead, which, beſides promoting the fuſion, makes the glaſs to be more eaſily cut, and alſo gives it a greater poliſh.

The ſtronger the heat required to fuſe the maſs, in general the finer is the glaſs; and therefore when only a coarſe glaſs is required, a greater quantity of flux is added.

The addition of manganeſe deſtroys the colour, that would otherwiſe ariſe from the foreign admixture of any inflammable matter; and that too, in a great meaſure, that ariſes from iron. It is therefore always uſed, when a colourleſs and tranſparent glaſs is required. It is uſed for inſtance in fine window glaſs.

When it is wiſhed to give an artificial colour to glaſs, different ſubſtances are employed for that purpofe. The blue colour, and various fhades of violet are given by the admixture of a metal, called Cobalt; and a fine green by fome preparation of iron.

Quartz cryftal powdered, is ufed inftead of fand, in manufacturing a fine glafs for optical inftruments. Other kinds of filiceous earth are ufed in particular manufactories, as being either more eafily procured, or more particularly adapted to the kind of glafs there required.

ESSAY XVII.

THE EARTHS.

The ſimple earths are nine in number; but ſeveral being newly diſcovered, and by no means generally known, and little or not at all applied to uſeful purpoſes, we ſhall merely mention the names by which they are deſignated, and paſs to the conſideration of ſuch as are more intereſting.

They are known by the following names: 1ſt, lime; 2d, magneſia; 3d, alumine; 4th, ſilex; 5th, barytes; 6th, ſtrontian; 7th, jargonia; 8th, glucine; and, 9th, aguſtine. The four firſt are thoſe that will be more particularly conſidered.

They are never found perfectly pure, but always blended with each other, and often with other ſubſtances. Such earths and ſtones however as conſiſt chiefly, or owe their chief properties to any one of the ſimple earths, are claſſed together, and arranged as ſpecies under that particular earth, as a genus. Thus we ſhall commence with conſidering ſome of the various forms under which lime is found, which is called the calcareous genus.

Lime is found in moſt countries, and frequently in great abundance. Like the alkalies it is cauſtic, when quite pure, but it is never found naturally in this ftate. It is generally combined with carbonic acid or fixed air, which renders it mild, and it is moftly mixed with fome of the other earths.

The variety of forms, under which lime is found, may be divided into two claffes, the firft comprehending thofe irregular maffes, that conftitute the calcareous ftrata, and fometimes form whole mountains, and the fecond including the calcareous cryftals, or fpars, that are regular in their figure, and found in confiderably lefs quantities. Both kinds effervefce with acids, and are converted into quick-lime by burning.

Of the firft clafs, *chalk* is the fofteft, and apparently of the lateft formation. It is found in large beds in many parts of this kingdom. When white and eafily pulverifable, it is formed into what is called whiting. For this purpofe the chalk is agitated in water, to feparate the foreign fubftances, as flints, pyrites, &c.; the water is then poured off, and the chalk fuffered to fubfide; which, when dried, is the whiting of the fhops.

It has been obferved, that rooms newly white-wafhed are unwholefome; and this has been accounted for, by fuppofing that the lime or chalk has the power of abforbing the pure part of the air. All the earths have been faid to poffefs this property, but the fact is not yet decidedly afcertained. The white-wafhing of apartments is neceſſary to cleanlineſs, and has been very properly recommended as part of the plan, for purifying hoſpitals, and other buildings, from contagion; but if the preceding ſuppoſition be founded in fact, ſuch rooms ſhould not be uſed, till two or three days after the operation.

In a ſtate harder than chalk, lime is known in ſome diſtricts under the name of *clunch*, which is burnt for lime, but is inferior for that purpoſe to the more indurated ſubſtance called *limeſtone*. This is of various kinds, according to the ſtate of induration, and the nature of the ſubſtances with which the lime is admixed. Some ſpecies are fitteſt for burning into quick-lime, and others for building. In general, the hardeſt limeſtones afford the beſt lime.

In countries, where neither chalk nor limeſtone is found, ſea-ſhells, corals, and madrepores are collected from the ſea ſhore, and burnt for lime.

When limeſtone is to be burnt, to expel the fixed air, and convert it into quick-lime, it is broken into ſmall pieces, and placed on the kiln, with alternate layers of ſome fuel, which is generally coal; the fire is then lighted, and the maſs kept in a ſtate of ignition, till the air is all expelled, which may be known by its no longer effervefcing with acids.

In this ſtate the lime is white or grayiſh, it is cauſtic, and has a great avidity for water, by application of which it heats, burſts, and is reduced to a fine powder. It is now called ſlaked lime, and when ſifted, is fit for making mortar, which is done by working it up with ſand, the fragments or duſt of ſtone, cinder-aſhes, or ſome ſuch hard ſubſtance, and a ſufficient quantity of water. Horſe-hair, or chopped hay or ſtraw, are occaſionally added, to make it, as the workmen term it, more binding.

Quick-lime, whether alone or mixed up into mortar, has ſo ſtrong an attraction for carbonic acid, or fixed air, that, when expoſed to the air, it gradually abſorbs it from the atmoſphere. Hence the neceſſity of uſing lime, for making mortar, as ſoon as it is burnt. It ſeems to be by this gradual converſion of lime into limeſtone, that mortar hardens by age, and as it is a long time in acquiring its full quantity of fixed air, ſo it is a long time before it has acquired its greateſt degree of hardneſs. It is generally obſerved, in pulling down very old buildings, that the mortar is as hard as the ſtone; and it has been inferred from thence, that the ancients poſſeſſed the art of making a much firmer cement, than what we uſe; but it is very probable, that its ſuperior hardneſs depends upon its having acquired more fixed air from the atmoſphere.

Another ſtate, in which lime is found, is in admixture with clay and ſand, when it is denominated *marl*, which, as well as limeſtone, is very much applied to the manuring of land.

Marl is called calcareous, argillaceous, or ſandy marl, according to the proportion of lime, clay, or ſand.

The firſt, or *calcareous marl*, is generally of a yellowiſh white, or yellowiſh gray colour, and is found a few feet under the ſoil on the ſides of hills, or under turf in bogs. It is ſometimes diſtinguiſhed by the name of ſhell marl, when it abounds in the remains and fragments of ſhells, and by that of ſtone marl, when it is particularly hard and indurated.

Argillaceous marl is gray or brown, or reddiſh brown, or yellowiſh, or blueiſh gray. It is more unctuous or greaſy to the feel, and harder than the former.

Sandy marl is browniſh, gray, or lead coloured, and contains ſo much ſiliceous or flinty ſand, that the reſiduum, or what is left after pouring acid upon it, will not be ductile enough to form a brick, as is the caſe with the other marls.

With reſpect to its utility in manuring land, a marl is not reckoned of any value, unleſs it contains thirty-five or forty per cent of lime. The eaſieſt mode of aſcertaining which, is to immerſe a hundred parts of the marl, the value of which you wiſh to aſcertain, into a ſufficient quantity of diluted muriatic acid. All that is diſſolved by this means, is lime, and no more of it; by weighing the remainder therefore, and ſubtracting it from the whole, you afcertain the exact proportion, that a hundred parts of the marl contain.

The laft form, in which the lime of this clafs is found, is in a ftate of MARBLE. This is a lime-ftone capable of bearing a polifh; it is of different degrees of hardnefs, and of different colours. Its furface too is diverfified with veins, lines, fpots, and other figures, differing in colour from the ground, and frequently containing the remains of fhells, and a variety of madrepores and corals. The ufe of marble, as the moft ornamental ftone for building, for fculpture, &c. is very generally known.

There is reafon for believing, that moft lime-ftone rocks and ftrata, marbles, marles, and other calcareous fubftances, have been originally formed by animals, and chiefly by marine animals, the exuviæ of which have been gradually collected into thefe vaft heaps, in which we now find them, and have by trituration and partial decompofition affumed their prefent appearance.

A ftrong argument in favour of this opinion is deduced from the frequent appearance of fhells, bones, and other animal remains, in the different fpecies of calcareous ftones, particularly in chalk-beds, and marble quarries.

The fhells of the teftaceous animals confift wholly of carbonate of lime, or chalk, with more or lefs animal matter, and that differently difpofed, being in the porcellaneous ſhells, as the cypræa, &c., in much ſmaller proportion, than in the mother-of-pearl ſhells, as oyſters, muſcles, &c. In the former, the animal matter ſeems to be uniformly diſperſed through the calcareous matter, as a connecting medium. In the latter, it is membranaceous, and ſtratified, being depoſited by the animal in alternate layers with the carbonate, ſo that the membrane in theſe ſhells retains its form after the calcareous matter is diſſolved by an acid.

The cruſtaceous animals, as crabs, lobſters, ſhrimps, and craw-fiſh, have their ſhells, conſiſting partly of carbonate of lime, and partly of phoſphate of lime, reſembling in this reſpect the ſhells of birds eggs.

From this view we can eaſily conceive, how the exuviæ of theſe animals may form beds of chalk, and other calcareous ſtones, there being little more requiſite, than the decompoſition of the animal matter.

The ſecond claſs of calcareous productions is, where the lime combined with fixed air, or with ſome other acid, aſſumes a cryſtallized form, in which caſe it is generally called SPAR.

With the carbonic acid it forms the dog-tooth ſpar, the columnar or pyramidal calcareous ſpar, according to the ſhape it aſſumes; and, when tranſparent, it poſſeſſes the property of double refraction as the Iceland cryſtal.

When combined with a peculiar acid, termed the fluoric acid, it forms Derbyſhire ſpar, or blue John, as the miners call it, a ſtone much uſed for ornaments. It is various, and often beautiful, in its appearance, and bears an excellent poliſh. In ornaments of this kind, it is a practice, frequently had recourſe to by the workmen, to fill up the accidental cracks and flaws with an ore of lead, or of copper, which they execute very neatly, even ſo as to enhance the value of them, deceiving the purchaſer with the aſſurance that it is natural.

Lime, combined with ſulphuric acid, is called GYPSUM, plaſter of Paris, plaſter ſtone, or ſelenite. It is very abundant in ſome countries. The hills near Paris are chiefly compoſed of it, and in ſome parts of America it is uſed as a manure, chiefly as a top dreſſing to graſs land. When burnt or calcined, it is miſcible with water, forming a liquid, which, from its ſuddenly drying, and becoming ſolid, is much uſed for caſting ornaments, as buſts, &c.

In Derbyſhire, and the neighbouring counties, the plaſter ſtone is much uſed for flooring. For this purpoſe it is firſt calcined, and then powdered. The powder being mixed with water to the proper conſiſtence, is ſpread to the required thickneſs upon reed, when it immediately becomes ſolid.

It is this ſelenite, or gypſum, that generally gives to water the quality called hardneſs. Such water curdles ſoap, and is therefore unfit to waſh with. The ſulphuric acid of the ſelenite attaches itſelf to the alkali of the ſoap, whilſt the oil and lime are ſeparated in flakes, and give the appearance of curdling.

It is a common practice to add wood-aſhes to hard water when it is required to uſe it for waſhing; in this caſe the alkali of the wood-aſhes decompoſes the ſelenite.

Hard water almoſt always contains carbonate of lime or chalk, as well as ſelenite. By boiling the water this is ſeparated, and forms the fur or cruſt on the inſide of tea-kettles; ſo that hard water is rendered ſomewhat ſofter by boiling, though not quite ſo. For chymical purpoſes this property may be wholly obviated, by adding to the water a ſmall quantity of barytic ſolution.

Peaſe, and other greens, retain their colour better when boiled in hard, than when boiled in ſoft water; but they are not ſo ſoft and tender. Soft water is beſt adapted to moſt manufactures, as brewing, dyeing, &c. In dyeing, if hard water is uſed, the ſelenite, or its earthy part, is depoſited in the ſtuff, and prevents the colouring particles from penetrating. In brewing, or any other proceſs where water is uſed to extract the virtues from vegetable, or from animal matter, ſoft water is best, because its solvent powers are greatest. In making tea, hard water will not extract so much as soft, unless the tea be powdered; for it has not so much the power of softening and opening the tea leaves.

Lime being evidently an animal secretion, it has become a matter of dispute, whether it is absolutely formed by animals, or only separated from the food, and deposited in the form of shells or bones in particular situations. If it could be proved that all the lime contained in the shell of the lobster, or in the shells or bones of any other animal, has not been received by the stomach with its food, it must follow, that lime is a compound, not a simple substance; whereas the chymist has not yet been able to detect its constituent parts.

It appears, however, probable from several facts, that the lime is received into the stomach, and not formed by the animal. For instance, chickens fed purposely, and with great care, on such food as contains least lime, compared with others fed in the usual way, were much more feeble, and their bones both smaller and more flexible.

Hens, also, kept carefully from lime, laid eggs without shells; but on being allowed again to pick up pieces of lime, mortar, and the like, they laid eggs covered with their natural shells. Most articles of food contain lime in small quantity. The fairest experiments might be made by keeping fishes in diſtilled water, as free from animalcula as poſſible, either in the water or the ſurrounding air. Such fiſhes we know will live and grow with no other aliment than air and water; and if the quantity of lime in their bones, ſcales, and other parts, is found to be at the ſame time increaſed, it would amount to a proof that the fiſhes have formed the lime, and, conſequently, that lime is a compound. Such experiments require to be conducted with the greateſt accuracy and attention to become ſatisfactory.

MAGNESIA is an earth that is much leſs frequently met with than lime, and is never found alone. The ſtones in which it conſtitutes a conſiderable part, are known by a peculiar greaſy feel, as the *French chalk* (a ſteatite), which is uſed to take greaſe ſpots out of ſilk; *lapis ollaris*, a blueiſh ſtone, ſo ſoft as to be eaſily cut and faſhioned by a turning machine into a variety of utenſils; and laſtly *aſbeſtos*, a fibrous ſtone, that may be ſpun and woven into cloth. In ſuch a cloth, which is perfectly incombuſtible, did the Romans ſometimes burn their dead bodies, to preſerve their aſhes.

Epſom ſalt is a combination of magneſia with ſulphuric acid, and is found in a variety of natural waters. By adding an alkali to a ſolution of this ſalt in water, the magneſia is precipitated in a pure ſtate, forming a white impalpable powder.

Alumine, argil, or clay, is the next earth to be confidered. From its ductility when moiftened, and its hardening in the fire, it is made the bafis of bricks, tiles, and every kind of pottery or earthenware. It is found of various degrees of purity, and mixed with a variety of other earths; fuch, therefore, are felected by the manufacturers as are fitteft for the purpofe required; and for the nicer kinds of wares, artificial mixtures of clay and other earths are ufed.

A tolerably pure white clay is ufed for making pipes. A ftiff blueifh or grayifh clay, with a greafy feel, is fitteft for bricks and tiles, which being naturally coloured with an iron ore, turns red by burning.

To make bricks, the clay being dug, and thrown into heaps, is moiftened with water, and worked by men treading it down with their feet. It is then cut again with wooden fpades, thrown into heaps, and, if required, again worked with the feet. It is now carried to the brick-maker, who cuts off enough for a fingle brick, kneads it like dough, on a board fprinkled with fand; he then puts it into a wooden mould, previoufly moiftened, and levels it at top. A boy then turns it out upon the ground, where it remains till it is dry, being occafionally turned. The bricks are then piled up into walls, and expofed to the air, but fheltered from the rain, and after a few weeks are put into the kilns and burnt.

For pantiles, the ſame clay is uſed; but it is kneaded or worked very fine, generally by means of a mill contrived for the purpoſe.

The common ſtone ware is made by mixing a certain proportion of ſand with the clay; and the white or Staffordſhire ſtone ware, by mixing pipe clay and powdered flint in different proportions. The clay is well worked in water, to ſeparate the ſandy parts; and the fluid maſs, containing the purer parts of the clay, is then paſſed through ſieves. The flints are calcined and then ground, by means of a very hard ſtone called chert; being then ſifted into water, this fluid maſs is mixed with the fluid clay, and left to ſet. The mixture, after being dried in a kiln, is tempered till fit for turning, and in this ſtate is uſed for a variety of wares.

The fineſt China-ware is formed by an admixture of what is called petunze, with clay. This petunze is a granite partly decompoſed, found at the bottoms of certain mountains, and properly prepared.

Theſe mixtures are made into a ductile maſs with water, are well kneaded, and then faſhioned by a turning machine or lathe, to the proper ſhape, and, laſtly, baked in ovens or furnaces, heated to the degree ſuitable to the particular article.

The coarſer kinds of pottery would be pervious to water were they not glazed, which is generally done with what is called potter's lead ore, or ſome other calx of lead; or, if a black glazing is required, with a mixture of white lead, and an ore called manganeſe. The glazing material is powdered and mixed with water, into which the veſſels, previouſly dried by a ſlight baking, are dipped. The porous veſſel abſorbs the water, and leaves the powdered ore on the ſurface, which, by expoſure to heat in the oven, vitrifies and forms the glazing.

The finer kinds of pottery, as the Staffordſhire ware, are glazed with common ſalt, which, being vaporized by the heat of the oven, unites with the clay, and vitrifies the ſurface, and in ſome caſes, as with Queen's-ware, the glazing is a mixture of white lead, powdered flint, and flint glaſs. Other kinds become ſemivitrified in baking without any addition, in conſequence of the ſiliceous earth which they contain in their compoſition.

The glazing material of Delft-ware is glaſs rendered opaque by an addition of oxyde, or calx of tin.

In the manufacture of China and porcelain, after a firſt baking they apply the glaze, then bake to vitrify this, next paint it, and, laſtly, bake again, to combine or amalgamate the paint with the glaze.

For this kind of painting the colours are all prepared from metallic ſubſtances, as beſt adapted to bear heat, and unite with the enamel in the laſt baking, which they call burning in, or fixing the colours. Gold gives a beautiful purple; iron a red; lead, antimony, and filver, yellows; copper, green; cobalt, blue; and manganefe, a violet coloured paint.

Queen's-ware, the name firft given to the pottery made by Wedgwood, and called often Wedgwood-ware, is fuperior to moft others, being at the fame time cheap and ornamental, and poffeffing the valuable properties of refifting the corroding effects of acids, and bearing a very great degree of heat.

Befides the very important ufes of clay, juft mentioned, it ferves another as important, namely, the manuring of particular foils. How the clay is to be felected for this purpofe, and to what kind of foils applied, I fhall defer mentioning for the prefent, as I intend to treat prefently of manures in general.

We fhall conclude the confideration of clay, or alumine, with an account of the manufacture of alum. ALUM is a mixture of fulphate of clay and fulphate of potafh; it confifts, therefore, of fulphur acidified by oxygen, and combined, in the ftate of an acid, partly with clay and partly with potafh.

It is chiefly manufactured from a flaty fubftance, called fhale, or aluminous fchiftus, which contains both clay and fulphur. This fchiftus is fometimes inflammable enough to burn by itfelf; but when this is not the cafe, fome kind of fuel is added to it, and the fire kept up fome time. The fulphur thus becomes acidified, and unites with the clay, forming an efflorefcence on the furface of the fchiftus. This is elutriated by pouring water on the heaps; and, when faturated, this water is put into leaden boilers, and evaporated. During the evaporation, potafh is added to faturate the acid, which is ufually predominant, and likewife to affift, which it effentially does, the cryftallization of the alum. The lixivium, reduced to a proper ftrength, is put into coolers, and the alum is cryftallized as the liquor cools.

The principal ufe of alum is, as a mordant or fixer of colours in dyeing and in printing on cottons. It is alfo ufed in the preparation of leather. It is added to tallow, to render it harder for the making of candles. Mixed with glue, it in a great meafure prevents the depredation of infects on furniture. And the printers rub their balls with calcined alum, to make them take the ink more readily.

Silex, or filica, the laft of the fimple earths that I fhall mention, differs from all others, in being much harder, and infoluble in acids. Moft ftones, that are hard enough to ftrike fire with fteel, are of the filiceous genus. Flints, quartz, rock-cryftal, and the precious ftones, are all of this kind.

The filiceous earth becomes eafily fufible by addition of an alkali, and is therefore, as we before mentioned, the principal ingredient in glafs. Sands of different kinds, which are the filiceous ftones broken down by expofure to the weather, to water, and to accidents, and wafhed away by the waters, to be depofited in beds or ftrata, are preferred in the manufacture of glafs, becaufe they are already in powder, and therefore fit for mixing with the other ingredients.

The fimple earths, we have faid before, are feldom found alone, but generally combined with each other, forming, however, an uniform mafs, in confequence of their being intimately blended. In this ftate they are denominated ftones fimply, as limeftone, quartz, flint, afbeftos, talc, garnet, &c. But frequently thefe ftones are mixed, feveral of them together, into an irregular mafs, connected by a common cement, and in this cafe they are termed aggregate ftones, as the granite, porphyry, pudding-ftone, &c. Thefe conftitute what are called the primary mountains, whilft the limeftone mountains, chalk-hills, and ftrata of fand-ftone, are termed fecondary, being fuppofed to be of later formation.

As connected with the earths, we fhall now take into confideration the fubject of manures, and give a flight defcription of the different kinds of foils.

ESSAY XVIII.

EARTHS,
SOILS, AND MANURES.

THE confideration of the fimple earths leads us naturally to that of foils, which confift of thefe fimple earths in different proportions; and, as intimately connected with this, we fhall at the fame time treat of the different fubftances employed as manures, and endeavour to afcertain the beft rules for adapting the latter to the former.

The chief part that foils act in the growth of plants, is to fupport the vegetable by its roots with fufficient firmnefs, and to fupply it with a proper quantity of water; befides which, it fhould contain charcoal, or coaly matter, and certain falts in fmall proportion.

From this it appears, that a good foil fhould be fufficiently porous, to allow the roots to ftrike freely, and to fuffer the fuperfluous water to drain off; but, at the fame time, clofe and compact enough, to retain the roots firm, and prevent the water draining off too faft. This is only to be obtained by a mixture of lime, clay, and filex or fand in due proportion; for thefe earths retain the water in very different degrees, and form foils of very different degrees of compactnefs, according to their proportions.

The foils, moft frequently met with, are clay, chalk, fand or gravel, clayey loam, chalky loam, fandy loam, gravelly loam, ferrugineous loam, and boggy or heathy foil, or, as it is often called, mountain foil.

CLAY* is of very different colours, white, gray, brownifh red, brownifh black, yellow or bluifh. It feels fmooth, and fomewhat unctuous; if moift, it adheres to the fingers, and is ductile. If thrown into water, it gradually diffufes itfelf through it, and then flowly fubfides. Ufually it does not effervefce with acids, unlefs a ftrong heat be applied. If heated, it hardens, contracts in all its dimenfions, and, if fufficiently heated, forms bricks. It confifts of alumine (pure clay) and fand, with a fmall proportion of calx of iron, which gives it its colour. The proportion of pure clay varies from twenty to feventy-five per cent, and is feparable from the fand, by boiling in ftrong vitriolic or fulphuric acid.

CHALK, if tolerably pure, is of a white colour, moderate confiftence, and dufty furface; ftains the fingers, adheres flightly to the tongue, and does not harden, but burns to lime, when heated; lofing at the fame time four tenths of its weight. It effer-

* By clay in this place I do not mean argil, or alumine, the fimple earth, but clayey foil, which is a compound of different earths, among which alumine is moft predominant.

vefces with acids, and is diffolved almoft entirely therein.

By SAND is meant fmall loofe grains of great hardnefs, not cohering when wet. It is generally filiceous, and therefore infoluble in acids. *Gravel* differs from fand chiefly in the fize of its particles; but calcareous ftones, when fmall and rounded, are often comprehended under the fame term.

LOAM denotes any foil moderately cohefive, that is, lefs fo than clay, but more fo than loofe chalk, and confifts of clay and fand, with fometimes chalk.

Clayey loam is that in which clay predominates, and is by farmers generally called ftrong, ftiff, cold and heavy loam. *Chalky loam* is a mixture of clay, fand and chalk, the latter being in greater proportion, than it is ever found in clayey loam. It is alfo lefs cohefive than clayey loam. *Sandy loam*, in which fand, partly coarfe and partly fine, forms from eighty to ninety per cent, is lefs coherent than either. *Gravelly loam* differs from the laft, in containing coarfer fand, and pebbles. This, with the two laft foils, are termed by the farmers, light and hungry foils. *Ferruginous loam*, or till, is of a dark brown, or reddifh colour, much harder and heavier than the other loams. It confifts of clay and the calces of iron more or lefs intimately mixed.

BOGGY SOIL confifts chiefly of ligneous particles, being the roots of decayed vegetables mixed with argillaceous earth and ſand, and a coaly ſubſtance derived from decayed vegetables.

HEATHY SOIL is that which is naturally productive of heath.

Of the various ſoils, which we have now deſcribed, ſome are much better adapted to ſupport vegetation than others. Some are too ſtiff and retentive of water, others too looſe and too little retentive. Whatever will meliorate the ſoil in theſe particulars, is called a manure; and different ſoils, of courſe, require different manures. Thoſe ſubſtances, too, that improve the ſoil by ſupplying coaly matter, and certain ſalts, as dung and compoſts of every kind, are termed manures; but as all ſoils require this kind of manure, when exhauſted of thoſe principles, I ſhall confine my obſervations to manures of the firſt claſs, which act chiefly in a mechanical way.

I may however firſt obſerve, that paring and burning the land improves the ſoil, by reducing to aſhes the old roots, and thus affording the ſame nutriment to freſh vegetables, as is ſupplied by dung or other compoſt. Burnt gypſum and quick lime anſwer the ſame end, by aiding the putrefaction of the old graſs, and dead vegetables.

Our firſt object muſt be to aſcertain in what particular any ſoil is deficient, and the next to diſcover a manure that abounds in the particular earth required.

To afcertain precifely the compofition of a foil, requires a great deal of chymical knowledge; but for common purpofes a fufficient degree of accuracy will be obtained, by attending to the difcriminating qualities of the different foils, that I have given in defcribing them. The chief fubftances employed as manures are chalk, lime, clay, fand, marl, and gypfum; all of which I have defcribed in a former effay. The particular earth in which each abounds, as well as the properties by which they are diftinguifhed, may be learned by attending to that defcription.

The fituation of the land will make fome difference in the proportions of the different earths requifite to form a fertile foil. On a declivity, for inftance, the foil requires more clay than on a plain. In a very rainy country, again, a lighter and more fandy foil is neceffary, than where there is lefs rain. In the rainy climate of Turin, the moft fertile foil has from feventy-feven to eighty per cent of filiceous earth, and from nine to fourteen of calcareous; whereas in the neighbourhood of Paris, where there is much lefs rain, the filex bears only the proportion of from forty-fix to fifty-one per cent in the moft fertile parts.

The following obfervations will ferve as general rules for the adaptation of manures to the foils.

Clayey foils require calcareous earth for a manure, and in that form that is beft fitted for opening the texture of the ſoil, and making it leſs retentive of moiſture. For this purpoſe nothing anſwers ſo well as marles; and of theſe a gravelly marl, or as it is called by ſome limeſtone gravel, which is a marl mixed with lumps of limeſtone, is the beſt. Calcareous marl is next in goodneſs; next the ſiliceous; and, laſtly, the argillaceous. Where theſe manures cannot be had, a mixture of coarſe ſand with lime or chalk; and, if theſe are not to be procured, coal-aſhes, chips of wood, burnt clay, coarſe brick-duſt, gravel, or even pebbles, will prove uſeful.

Clayey loams may be defective either in the calcareous ingredient or the ſandy, or in both. If in the firſt, the proper manure is chalk; if in the ſecond, ſand; and if in both, ſiliceous marl, limeſtone gravel, or mild lime and ſand.

There is a limeſtone, found in Yorkſhire and ſome other counties, called by the farmers hot lime, which, if uſed in the ſame quantities with common lime, is very injurious to vegetation. It has been lately examined, and found to contain a large proportion of magneſia. This magneſian limeſtone is eaſily diſtinguiſhed from that which is purely calcareous, by being much more ſlowly diſſolved in acids, even the ſofteſt kind being much longer in diſſolving than marble.

A chalky ſoil wants both clay and ſand, or gravel, therefore the beſt manure for it is a clayey or ſandy loam; but when the chalk is ſo hard, and ſo difficultly reducible to powder, as to keep the ſoil ſufficiently open of itſelf, then clay is the beſt manure.

Chalky loams, or light limeſtone ſoils, which do not differ from them eſſentially, require clay or argillaceous marl.

The beſt manure for *ſandy ſoils* is calcareous marl; the next beſt is argillaceous marl; and next to theſe clay mixed with lime, or calcareous or argillaceous loams. Lime or chalk are leſs proper, as they do not give ſufficient coherence to the ſoil; but, when mixed with earth or dung, they anſwer very well.

Sandy loams are moſt benefited by calcareous or argillaceous marls, or by chalk for a firſt, and clay for a ſecond dreſſing.

Boggy ſoils, after draining, generally require burning; and, as they are moſtly clayey, they ſhould have limeſtone gravel, or lime mixed with coarſe ſand; but if, as ſometimes happens, they are ſandy, lime or calcareous marl may be required.

The above are to be conſidered only as general rules; and as the ſoils partake more or leſs of the nature of thoſe deſcribed, the manures muſt be ſelected that correſpond more or leſs with thoſe recommended.

ESSAY XIX.

THE METALS.

All the metals are fimple fubftances. According to the lateft difcoveries, there are twenty-one diftinct metals. Their names are as follows: 1. platina; 2. gold; 3. filver; 4. quickfilver; 5. copper; 6. iron; 7. lead; 8. tin; 9. zinc; 10. antimony; 11. bifmuth; 12. cobalt; 13. nickel; 14. manganefe; 15. uranite; 16. fylvanite; 17. titanite; 18. chrome; 19. arfenic; 20. molybdenite; 21. tungftenite.

Metals are diftinguifhed from other fubftances by their great fpecific gravity, by their brilliancy, and by being more or lefs ductile or malleable. In this latter property, however, they differ confiderably; and thofe which poffefs it in the greateft degree are termed metals, whilft the others are called femimetals. Platina, gold, and filver, undergoing no oxydation or calcination in our furnaces, are called perfect or noble metals, and the others imperfect or bafe.

Previoufly to noticing fuch interefting circumftances refpecting particular metals, as I have felected for this effay, I fhall make fome few obfervations upon the ores of metals in general, as they are difcovered in the mines.

Metals are found in four different conditions.

1ft. They are fometimes found in their metallic ftate, either pure and alone, or alloyed with other metals; in which ftate they are called native. Gold is generally found in this condition; filver, mercury, copper, and cobalt, not unfrequently; and now and then iron, tin, and lead. In this ftate they only require pounding, wafhing, and then fufing or melting.

2dly. They are found mixed with fulphur, and fometimes arfenic, when they are faid to be mineralized. In this ftate they are brittle, and have not always the metallic luftre. Thefe ores are ufually called pyrites, of which the iron pyrites are by far the moft common.

Metals thus mineralized, after being broken down or pounded, are feparated from the mineralizer by torrefaction, or roafting; the heat driving off the fulphur or arfenic.

3dly. Metals are found in a ftate of calx or oxyde, that is, combined with pure air or oxygen, and moftly with a proportion of carbonic acid. Thefe ores are friable, have an earthy appearance, have different colours according to the degree of oxydation, and have no luftre.

They are reducible to the metallic ftate by heat alone, or with the addition of charcoal. Iron, copper, tin, lead, and fome others, are occafionally met with in this ftate.

4thly. They are found combined with fome of the acids, in which cafe they are often regularly cryftallized. When combined with the vitriolic or fulphuric acid, they are termed vitriols; as green vitriol or vitriol of iron (fulphate of iron); blue vitriol or vitriol of copper (fulphate of copper;) and white vitriol or vitriol of zinc (fulphate of zinc).

In one or other of thefe ftates now defcribed are the metals found, principally in the crevices of rocks, and they are called ores. Sometimes they are found in fands and the beds of rivers, as gold in its native ftate; and frequently the metallic falts are found in natural waters, which are then called mineral waters.

The ores, filling up the crevices in rocks and mountains, are termed veins. Thefe veins fometimes contain nothing but the ore, but more frequently it is mixed in a confufed manner with fome earthy or ftony fubftance, generally of the filiceous clafs, and this is called the matrix.

The ore is extracted with iron crows, or other implements; and recourfe is frequently had to gunpowder, to feparate pieces of the rock, and make way for the working of the veins of ore.

The working of mines is now become quite an art. The mode of doing it depends upon the ſituation and direction of the vein, the nature of the rock or mountain in which the vein runs, and ſeveral other circumſtances, that none can appreciate but thoſe that are in the habits of attending to ſuch buſineſs.

There are few circumſtances that indicate the preſence of a mine, and none that can be abſolutely depended upon. This, however, may be remembered, that granite rocks very ſeldom afford any, but that veins generally run in the ſecondary mountains, as thoſe of ſchiſtus, and ſuch calcareous ſtone as retains no impreſſion of animals or vegetables. The preſence of a ſtone called heavy ſpar, too, is reckoned a favourable ſign; but the operation of boring can alone decide, whether our ſuſpicions reſpecting the preſence of a mine are well or ill founded.

GOLD is found in its native ſtate in the ſands of many rivers, and particularly in thoſe of South America. It is obtained by waſhing ſuch ſand, and picking out the grains of gold; or by powdering the earth or ſand, and then adding quickſilver. The quickſilver will unite with other metals, but not with earths; it is therefore intimately mixed with the earth or ſand, that contains gold or ſilver, and uniting itſelf to thoſe metals affords an eaſy means of ſeparating them from all impurities. The quickſilver is afterwards driven off by expoſing the mixture to a ſtrong heat.

Surprifing as it may appear, yet it is true, that gold exifts in a variety of vegetables, and may be obtained by a careful analyfis of their afhes, and likewife by that of vegetable mould. The quantity however is too minute to make it a profitable employment. This metal is fo very malleable, that one grain weight of it may be beaten out into gold leaf, fufficient to cover fifty-fix fquare inches. What is ufed for the coin of this kingdom is not pure, but alloyed with a certain proportion of copper.

In the art of gilding upon copper, filver, brafs, &c., the gold is applied in a variety of ways, fome of which we fhall defcribe. 1ft. *Hot gilding*. In this the metal to be gilt is immerfed in, or wafhed with a folution of quickfilver in aqua fortis. This gives it a mercurial furface, to which is afterwards to be applied an amalgam of gold, that is, a mixture of quickfilver and gold. The article being now expofed to heat, the mercury flies off, leaving only a thin covering of gold.

If iron is the metal to be gilded, it muft be firft immerfed in a folution of blue vitriol (fulphate of copper) to acquire a furface of copper, which will receive the gilding, whereas iron itfelf will not.

The colour of this kind of gilding is heightened by burning on it a covering of what is called gilder's wax, which is formed of wax, verdigrife, and blue vitriol. It is laftly polifhed, and brightened with a boiling ſolution of common ſalt and cream of tartar.

The ſecond mode is called the *Grecian gilding* of ſilver. A ſalt, called ſal alembroth, which is a triple ſalt containing marine acid, ammonia, and mercury, is added to a ſolution of gold in aqua regia, which is a mixture of marine acid and aqua fortis, called aqua regia, from its property of diſſolving gold, which neither of them poſſeſſes ſeparately This is evaporated to the conſiſtence of oil, and applied to the ſilver that is to be gilded.

The third kind, called *cold gilding*, is performed by rubbing the metal with the aſhes of linen rags that have been impregnated with a ſolution of gold in aqua regia. Gold wire is made by coating a ſilver rod with gold-leaf, and afterwards drawing it out into wire, which may be drawn ſo fine that the covering of gold in ſome places does not exceed the fourteen millionth part of an inch.

SILVER is alloyed with copper, both for coinage, and for ſilverſmiths' work, which renders it much more hard and durable. In the coinage of this country nearly one twelfth of copper is allowed. Any other metal may be ſilvered by rubbing it with a paſte made in the following way. Diſſolve fine ſilver in aqua fortis, and then add as much tartar finely powdered as will make it into a paſte. The modes employed for giving a ſurface of ſilver to other metals are very numerous. The plating of copper is performed by faſtening plates of ſilver upon thicker plates of copper, and then rolling the two together into thin plates. The copper is generally twelve times thicker than the ſilver, and one ounce of ſilver is often thus rolled out to a ſurface of three ſquare feet.

What is called French plate is made by covering the copper, or more commonly braſs, with ſilver leaf when heated.

MERCURY, or quickſilver, which differs from all other metals in being fluid at the temperature of this climate, has however been frozen both by the natural cold of high northern latitudes, as at Kamtſchatka, and by artificial cold, produced by mixtures of ſnow and aqua fortis. It is found to congeal at forty degrees below zero of Fahrenheit's ſcale. Mercury unites with other metals, forming always a ſoft maſs, termed an amalgam. On this property depends the art of gilding, as above deſcribed, and alſo the art of coating looking-glaſſes.

To ſilver looking-glaſſes in the uſual way, a ſheet or leaf of tin foil, of the ſize of the glaſs, is ſpread out upon a table; mercury is then poured upon it, and rubbed about with a bruſh; and more mercury poured on, till it covers the tin a full line in thickneſs. The glaſs is now to be ſlided upon it, preſſing its edge cloſe down, and along the tin. The glaſs muſt then be very equally preſſed with weights, and allowed to remain ſo for two or three days.

For convex and concave mirrors, which cannot be ſo preſſed, an amalgam is uſed that is formed of two parts of mercury, one of tin, one of lead, and one of biſmuth.

Mercury, when combined with ſulphur, is called cinnabar, whether it is a natural or artificial combination; and the beſt cinnabar, when finely levigated, forms the beautiful paint called vermilion.

It is uſually in the form of cinnabar, that mercury is found in the mines; but ſometimes it is found pure in beds of calcareous earth or of clay. There are but few mines of quickſilver; the greateſt quantity is procured from Spain. To ſeparate the mercury from the ſulphur, quicklime or iron filings are added to the cinnabar to detain the ſulphur, whilſt the heat drives off the mercury.

Copper is uſed in a variety of the arts. With tin it forms bell-metal and gun-metal, and with a metal called zinc it forms braſs; or, if a leſs proportion of zinc is employed, an ornamental and uſeful compound, called Pinchbeck.

Veſſels made of copper for culinary purpoſes are highly prejudicial; for all acids, and all oily or fatty ſubſtances, when allowed to turn rancid, combine with the copper, and form verdigriſe, which is poiſonous, if taken in ſufficient quantity, and very detrimental, even in the ſmalleſt quantities. Copper boilers muſt conſequently be highly improper; for it is impoſſible to keep them ſo clean, but that ſome verdigriſe will be formed about the edges, and unevenneſſes, where the oily or fatty matters are ſure to lodge.

To prevent theſe bad effects, moſt copper veſſels are tinned on their inſides. To do this, the ſurface is well cleaned, by rubbing it either with ſal ammoniac, or an acid; the tin, or a compoſition of tin and lead, or lead and pewter, is then melted in the veſſel, and rubbed well about with old rags doubled up. But this tinning, let it be remembered, does not wholly prevent the bad effects of the copper, as it ſoon wears off.

It has been uſual to attribute the unpleaſant effects, often experienced from tea, to its being ſomewhat impregnated with copper, from being dried on plates of that metal; but it is now known, that iron plates, not copper ones, are employed for that purpoſe. The ill effects of tea muſt therefore be attributed to its own properties, or perhaps in a great meaſure to the debilitating power of hot water.

Verdigriſe for ſale is made by putting ſheets of copper in alternate layers with a mixture of ſour wine and the refuſe of grapes. After a certain time the plates are taken out, and placed edgewiſe in a cellar, where they are repeatedly ſprinkled with ſour wine. The verdigriſe, as it is formed on the ſurface of the copper, is ſcraped off, and packed up in leathern bags for the market.

Blue vitriol, we have before ſaid, is a ſulphate of copper. The common mode of browning fowling-pieces is to waſh the barrels with a ſolution of this in water, by which a layer of copper is depoſited, and this is leſs affected by the weather than iron. The ſulphate of copper is uſed in dyeing, cryſtals of verdigriſe in painting, and copper itſelf in a variety of ways.

IRON is chiefly found in the form of an oxyde, that is, combined with oxygen. It is diffuſed more through different natural productions than any other of the metals. It exiſts in ſmall proportion in moſt animal and vegetable, as well as in moſt mineral productions. According to the degree of oxydation, it aſſumes different colours. It is the colouring ſubſtance of moſt of the gems and precious ſtones, of the different clays, and other earths, and of a variety of paints and pigments.

From the variety of conditions, which it is capable of aſſuming, according as it is mixed with more or leſs carbon, and oxygen, it is the moſt uſeful of metals.

It is the proportion and ſtate of combination of theſe ſubſtances with iron, that conſtitutes the difference between iron and ſteel, between caſt iron and forged iron, between red ſhort iron and cold ſhort iron, and between all theſe and plumbago or black lead. When combined with a certain proportion of carbon or charcoal it conſtitutes ſteel, and with a much larger proportion it forms plumbago; for which laſt, therefore, black lead, as it is generally called, is a very improper name. The uſes of iron in theſe various ſtates it is needleſs to mention.

The plumbago is found moſt abundantly in Cumberland. It is ſawed into ſmall ſlips, to form the black lead pencils; but an inferior ſort is made by mixing up the black lead duſt into a paſte.

Iron combined with vitriolic acid forms green vitriol; from which, when diſſolved in water, the iron is precipitated in form of a black powder, by adding to it any vegetable aſtringent, as galls, oak bark, or the like. On this depends the art of making inks, and black dyes. A very good ink is made by the following proportion of ingredients.

Nut-galls, one pound;
Gum arabic, } of each ſix ounces;
Green copperas, }
Water four pints.

The galls are to be bruiſed and ſuffered to ſtand in the water (being now and then ſhaken) for four hours. The gum is next to be added, and when this is diſſolved, the copperas. The liquor immediately becomes black, in conſequence of the precipitation of the iron; and the uſe of the gum is to ſuſpend the black powder, which would otherwiſe fall to the bottom. Inkſtains may be eaſily taken out by any of the acids, either from cloth, paper, or wood. Lemon juice is the beft, becaufe with it there is no danger of injuring the article. The acids will only take out writing ink, not printing ink, and therefore they may be ufed for cleaning books that have been defaced by writing.

When ink-fpots have remained long, they become iron moulds, and are then taken out with more difficulty; and the more fo, the longer they ftand, in confequence of the iron, by repeated moiftening and expofure to the air, having acquired fuch an addition of oxygen, as to make it infoluble in acids. To difcharge thefe old ftains, an alkaline fulphuret, or liver of fulphur, fhould be firft applied in folution, and after this is well wafhed off, the lemon juice or other acid fhould be applied.

As connected with this, I fhall here mention the beft mode of taking out fruit or wine ftains, and fpots of greafe or of wax. For the firft, put about a table fpoonful of marine acid (fpirit of falt) into a teacup, and add to it a tea fpoonful of powdered manganefe. Then fet this cup in a larger one filled with hot water. Moiften the ftained fpot with water, and expofe it to the fumes, that arife from the teacup, till the ftain difappears.

The fumes are thofe of the oxygenated muriatic acid; but as they difcharge all printed and dyed colours, this mode is only applicable to white articles.

Greafe-fpots are moft effectually removed by a diluted folution of pure potafh, or cauftic lie. Stains of white wax are taken out by fpirit of turpentine, or fulphuric ether; and the marks of white paint may likewife be removed by the laft mentioned fubftance.

Pruffian blue, fo much admired as a pigment, is a combination of iron with a peculiar acid, called the Pruffic acid. It is obtained, by a complicated procefs, from blood and fome other animal productions.

I fhall conclude thefe few obfervations refpecting iron, with the procefs of making what are called tin plates; for you muft know that thefe plates are not tin, but iron flightly coated with tin. What are ufually called tin veffels, therefore, are iron veffels, having the furface covered with tin; and fuch only as are faid to be made of block tin, are really compofed of that metal.

Soft iron is made into plates, by rolling, for this purpofe; and they are cleanfed by immerfion in water acidulated by the fermentation of malt, which is called four wort. When dried the plates are dipped into a bath of melted tin, the furface of which is covered with pitch or tallow; they are turned in this bath, and then taken out; after which they are fcoured with fawduft or bran.

Lead is often found mineralized by fulphur, in pieces of a cubical form, denominated *galena*. It is often mixed with ſmall quantities of arſenic or of ſilver, the latter being in the largeſt quantity in thoſe cubes or dice that are ſmalleſt in ſize.

Lead oxydated or calcined in different degrees aſſumes different colours; firſt gray, as the dull cruſt, that always covers lead that is expoſed to the air; ſecondly, yellow, as the oxyde of lead, called maſſicot; thirdly, red, as minium or red lead; fourthly, a reddiſh yellow or orange, as the ſcaly oxyde, called litharge; and, laſtly, white, as the white lead, uſed by painters, which is obtained by expoſing ſheets of lead to vinegar in an uniform heat, as that of a hotbed, or by expoſing it to the vapour or ſteam of vinegar.

To make ſhot, a ſmall quantity of arſenic is melted with the lead, to render it more brittle; and when it is ſo far cooled, that a card may be plunged into it without being burnt, it is poured into a kind of cullender, pierced at the bottom with many holes, and containing lighted charcoal. This cullender is held over water, and the lead aſſumes a round form as it paſſes into it.

Lead has very injurious effects upon the conſtitution, when taken in any way along with our food, or when introduced into the body by other means, as by expoſure to the duſt or fumes of lead, or by ſuffering white lead in the form of paint to remain on any part of the ſurface of the body. It is a frequent cauſe of diſeaſe amongſt plumbers and painters; and feveral inftances have occurred of ladies ufing white paint having brought on very alarming fymptoms thereby, and fometimes even death.

Water kept in leaden veffels for a length of time becomes impregnated with it: and fometimes even pump water, in confequence of this metal being ufed in the conftruction of the pump, and pipes, has been fo much impregnated with it, as to effect the health of thofe who drank it. To avoid the poffibility of this, the water that is lodged in the pump and pipe fhould be firft pumped off, before the water is taken for ufe.

Sugar of lead, which is lead diffolved in vinegar and cryftallized, is fometimes fraudulently added to bad wines to clarify them, and often to take off a flight acidity. It is likewife added to brandy, to deprive it of colour.

To detect lead in water, the moft delicate teft is water impregnated with fulphurated hydrogen gas (as the Harrowgate water). To the fufpected water add half its bulk of this fulphureous water, and if lead is prefent it will give a dark brown or blackifh tinge.

To detect lead in wines, add a few drops of the following liquor to a glafs of the wine, and the lead if prefent will be precipitated of a black colour. Take of calcined oyfter-fhells and crude fulphur equal parts, keep them in a white heat for fifteen minutes; when cold, add an equal quantity of cream of tartar, and boil it in water for an hour in a glafs veffel. When the powder has fubfided, decant the clear liquor into phials, holding an ounce each, and add twenty drops of muriatic acid (fpirit of falt) to each phial. Let the phials be kept well corked. Copper, if prefent, will be precipitated by this liquor as well as lead.

TIN is a metal that is procured in very great abundance from the mines in Cornwall, chiefly in form of a white ore, with quartz for its matrix. Mixed with lead and antimony, it forms pewter, a compound that is ufed for a variety of purpofes. Tin alone is often made into kitchen utenfils; but it is more frequently employed as a coating for other metals that are more lafting, as iron or copper.

Pins are made of brafs wire, and are afterwards tinned by the following procefs. A proper veffel is filled with alternate layers of pins and plates of tin, the latter being both at top and bottom. A folution of cream of tartar in water is then poured upon them, fo as to fill the veffel, and is made to boil for four or five hours, when the pins are taken out completely tinned.

The acid of the tartar in this procefs diffolves the tin firft, and then gradually depofits it on the furface of the pins, in confequence of its greater affinity for the zinc, which enters into the compofition of the brafs wire, of which the pins are formed.

Tin is very eafily calcined, as is feen by the furface of melted tin or pewter being very foon covered with a powdery calx, which the purchafers of old pewter call drofs, and pretend to make no ufe of, and therefore pay only for the remainder. They however well know that this drofs, as they call it, which is a true oxyde of the metal, when expofed to a ftrong heat with charcoal, is eafily reduced to the metallic ftate, and forms good pewter. The fame deceit is often practifed by plumbers, when they purchafe old lead.

The calx or oxyde of tin is called putty, and is ufed in polifhing hard bodies, and to convert glafs into a kind of enamel.

A folution of tin in muriatic or in nitro-muriatic acid is ufed by dyers, as a fixer of colours, and particularly in dying fcarlet.

Three parts of tin, with five of bifmuth and two of lead, form a compound fo eafily melted, that it liquifies in boiling water.

The fpecula for reflecting telefcopes are a compound of tin, copper, and arfenic.

Zinc is a metal that enters into the compofition of brafs and bell-metal. It is found abundantly in Somerfetfhire, Derbyfhire, and Flintfhire, in an earthy form, of a gray colour, without luftre, called calamine. This is an oxyde or calx of zinc, ufually combined with fixed air. It is found in North Wales, in Cornwall, and in Derbyfhire, in an ore called blend, or black jack, greatly refembling galena, which is an ore of lead. In this ftate the zinc is mineralized by fulphur. Thefe ores are both ufed in making brafs. Calamine is, however, preferred. After being calcined and powdered, it is mixed with charcoal and copper, in thin plates, or in grains, and expofed to a heat, at firft not fufficient to melt the copper, but afterwards increafed; fo that the mafs, which is a compound of the two metals, is fufed, and is now called brafs.

Zinc is the metal that is generally felected for exhibiting the phænomena which have received the denomination of Galvanifm; and I fhall, therefore, in this place, take notice of that newly difcovered property which is found to belong more or lefs to all the different metals.

GALVANISM: more than thirty years ago it was difcovered, that when two pieces of metal, the one of lead, the other of filver, are joined together, fo that their edges form one furface, a certain fenfation will be produced on applying it to the tongue, which comes near to the tafte of martial vitriol or copperas; whereas each piece by itfelf betrays not the leaft traces of that tafte.

No further notice feems to have been taken of this fact, and no other Galvanic phænomenon difcovered, till M. Galvani, an Italian, was led to a variety of experiments on the fubject, which he publifhed ten or eleven years ago, and from whom the term Galvanifm is derived. Since this time the attention of the learned has been a good deal directed to the fubject, and many very curious circumftances have been afcertained, particularly by the very late difcovery of what is termed the Galvanic pile, by S. Volta.

We fhall not enter into the minutiæ of Galvanifm, either as to the hiftory of its difcovery, or the phænomena it comprifes. With refpect to the firft I fhall add nothing to what has been faid above; and with regard to the phænomena, the following are the moft remarkable.

When one piece of metal is laid on the tongue, and another of a different metal is held between the upper lip and the gums, a tafte of copperas, and frequently a flafh of light is perceived, the moment that the two metals are brought into contact.

The nerve of a living animal, or of an animal newly flain, being made part of the circle of communication, the mufcles to which that nerve runs, are convulfed at the moment the communication is made. Thus, the lower extremities of a frog being feparated from the body, and the fciatic nerves laid bare being placed on a plate of zinc, and the toes of the frog upon a plate of filver, as foon as a communication is made between the two plates by any metallic wire, the legs of the frog become convulfed.

When alternate layers of ſilver, zinc, and moiſtened cloth, or paſteboard, are piled upon each other ſucceſſively, to a conſiderable number, all the Galvanic phænomena are rendered more evident on forming a communication between the top and bottom of the pile, which muſt have different metals at thoſe two places.

This is called the Galvanic pile, the chief properties of which are the following; and, to make them the more evident, let there be as many as fifty pieces of each metal; let the ſilver be half-crowns, and the zinc of the ſame ſize, but rather thicker; and, laſtly, let the circular pieces of cloth be wetted with ſalt and water.

On applying one hand, wetted with ſalt and water, to the top, and the other to the bottom of the pile, a ſhock, ſimilar to that from a charged electric jar, is immediately felt in both arms.

When a wire from the top, and another from the bottom, are placed, one upon, and the other under the tongue, a pricking ſenſation, and ſomewhat of an acid taſte, is perceived.

When the head is made part of the circuit, the wires being placed in the ears, a crackling ſound is heard; and a flaſh of light appears if the eyes are brought into its courſe.

If, by means of the wires, the Galvanic fluid is directed over a ſore, or any part where the ſkin is abraded, a ſmarting and conſiderable pain is induced.

When water is made part of the circle of communication, by introducing the wires under water, and bringing them near to, but not into contact with each other, a ſlow but continued decompoſition of the water is the conſequence. If the wires are of iron, or any metal that is oxydable, only hydrogen gas eſcapes in bubbles to the ſurface, the oxygen, uniting with, and oxydating the wire. But if gold wire be employed, both oxygenous and hydrogenous gaſſes are diſengaged.

By means of this ſimple apparatus, which poſſeſſes the above properties as long as the pieces of cloth remain moiſt, a variety of intereſting chymical experiments have been performed. It exhibits nearly the ſame effects, as a chymical agent, with thoſe produced by repeated ſhocks or ſparks from an electrical machine.

Cobalt is a metal that is chiefly obtained from the mines in Saxony. When deprived of arſenic, with which it is generally mineralized, it is called zaffre. This mixed with three parts of ſand, and one of potaſh, is melted into a blue glaſs, which, being powdered and waſhed, is known by the name of ſmalt, or azure; and this, by mixture with ſtarch, forms the blue uſed by laundreſſes, and is made the baſis of many blue paints.

ARSENIC is the laſt of the metals which we ſhall mention; and this, chiefly, with a view of noticing its baneful effects as a poiſon. Miners, and other workmen, who are expoſed to the duſt and fumes of this mineral, and particularly thoſe of the cobalt mines, are ſo ſoon, and ſo violently affected by it, that they live but a few years in the employment, and are ſubject to pulmonary affections, and diſeaſes of the abdominal viſcera. In Saxony the work is only done by convicts, whoſe puniſhment would otherwiſe have been death.

When taken into the ſtomach in conſiderable quantities by miſtake, or with an intent to commit ſuicide, it firſt ſets the teeth on edge, conſtricts the throat, heats the mouth, and cauſes ſpitting. Then comes on a burning heat, and excruciating pain in the ſtomach, a vomiting of glairy bloody matter, cold ſweats, convulſions, and death.

Mucilaginous drinks, milk, oils, and butter, have been the uſual remedies recommended in caſes, where this poiſon has been taken; but what is much better than either of theſe is, a drachm of ſulphure of potaſh (liver of ſulphur), diſſolved in a pint of water, to be taken at ſeveral draughts.

Whilſt this is preparing, let the patient take plentifully of vinegar; and if the ſulphure cannot be procured, let an emetic be given after the vinegar; but not at all if the ſulphure can be ſpeedily adminiſtered.

When it is required to know whether a perſon has died in conſequence of taking arſenic, or whether a dog or other animal may have been poiſoned by it, let the contents of the ſtomach be well waſhed, and if there is any powder ſinks to the bottom, carefully collect and dry it. Let a portion of this powder, mixed with a little charcoal, or other inflammable matter, be thrown upon a red-hot poker; and if it is arſenic it will fly off in vapour, giving, in a ſtrong degree, the odour of garlic.

With this ſhort account of the moſt important of the metals I conclude the conſideration of the chymical elements. I have not attempted to give a complete hiſtory of each elementary ſubſtance, and of all the compounds that reſult from them, for it was not my intention to offer a ſyſtem of chymiſtry. I have only ſelected ſuch as were either curious or important, and ſuch as would naturally lead to ſubjects that were intereſting and uſeful. In my ſelection, I truſt, that I have not altogether failed either in amuſing or inſtructing; and ſhould any one, by the peruſal, have imbibed a reliſh for that ſcience, which I have here endeavoured to place in a pleaſing point of view, though not more ſo than it deſerves, my intention is completely anſwered.

I ſhall now add an eſſay or two on the mineral waters, which come properly to be treated of after the metals, and other mineral productions; and ſhall then conclude the work with the conſideration of ſome few of the arts that are intimately connected with chymiſtry; but for introducing which, no convenient opportunity occurred in the conſideration of the chymical elements.

ESSAY XX.

MINERAL WATERS.

The term of mineral water has, by common consent, been given to all natural waters, which have been found useful in the treatment of disease; and it has generally been restricted to such waters, although there are many others, that contain larger quantities of different mineral productions.

Some, as the Malvern waters in Wales, are chiefly useful in consequence of their containing less heterogeneous matter than even common spring water, and yet these are denominated mineral waters; whilst various others, containing the sulphate of copper, large quantities of common salt, or other mineral productions, are seldom enumerated among the mineral waters, because not applied to medicinal purposes.

It is very difficult to free any kind of water from all foreign admixture; even rain, or snow water contains a portion of calcareous earth, besides a quantity of common atmospheric air; nor is it wholly deprived of the former by repeated distillations. What we denominate hard waters contain selenite (a sulphate of lime) and generally chalk.

Many ſprings too, which afford good wholeſome water, that is uſed for all domeſtic purpoſes, are impregnated with ſmall quantities of different kinds of ſalts, with iron, or with fixed air.

It is only thoſe waters, that by their containing greater abundance of theſe impregnations, or from ſome other cauſe, have obtained conſiderable celebrity in the treatment of diſeaſes, that I ſhall now notice; and theſe I ſhall claſs, and deſcribe in order, according to their predominant qualities.

CLASS I. SIMPLE WATERS.

DIVISION 1ſt. *Cold.*

Several ſprings have acquired celebrity, which are remarkable for their purity, containing much leſs of earthy or ſaline impregnations than the ſpring waters in common uſe. They are chiefly employed as an external application in ſcrofulous or other old ulcers, in different chronic eruptions, and in ſore eyes. Internally they are recommended in calculous complaints, and other affections of the kidnies or bladder.

The moſt noted water of this claſs is that of the *Holy-well* at *Malvern*, in Worceſterſhire, which, except a ſmall quantity of fixed air, contains ſcarcely any foreign ingredients.

St. Winifrede's well at Holywell in Flintſhire is celebrated for fimilar virtues, and is likewife a remarkably pure water.

Division 2d. *Thermal, or warm.*

The moft celebrated of this divifion are Briftol, Matlock, and Buxton waters; which are tolerably pure waters, containing no metal or metallic falt, and no great quantity of other foreign matter. Their virtues chiefly depend upon their warmth; and the advantages received by invalides, vifiting thefe fafhionable reforts, are in a great meafure derived from other adventitious circumftances, as variety of fcenery and amufements; the genial warmth of Briftol, or the enchanting fcenery of Matlock, never failing to excite to exercife, and to exhilarate the fpirits of the hypochondriac or the exhaufted debauchee. Thefe waters being amongft the moft noted in the kingdom deferve more particular notice, and fhall be therefore treated of feparately.

Briftol hotwell. This is a pure warm flightly acidulated fpring. It contains lefs folid matter than moft common fprings, but is confiderably impregnated with fixed air. Its temperature upon an average may be reckoned at 74°.

The fite of Briftol hotwell is peculiarly favourable to invalides, being fheltered from the north, eaft, and weft winds, and only open to the fouth. It is chiefly on this account, that it has obtained fo much celebrity for confumptive patients.

The internal ufe of the waters is likewife fer-viceable in the hectic ftage of that complaint. It is particularly recommended to patients labour-ing under the effects of a long refidence in a warm climate, to dyfpeptics, and to perfons fubject to bilious diarrhœa and to dyfentery. Its ufe is likewife extended to calculous complaints, and to diabetes.

From its excellent property of keeping untainted for a long time in hot climates, it is frequently ex-ported, though its medical virtues are confiderably lefs, if not taken at the fpring. The water of the Sion fpring at Clifton only differs from the laft in being one or two degrees colder.

Matlock in Derbyfhire. There are feveral fprings here uniformly warm, being at 66°. The water is a pure fpring water without any impregnation of fixed air.

It may be drunk in all cafes, where a pure di-luent is advifeable; but its notoriety chiefly de-pends upon its ufe as a bath. Though warm, it is confiderably below the temperature of the body, which is commonly 97° or 98°. Immerfion in the Matlock bath is therefore attended with fome fhock, though confiderably lefs than common cold or fea bathing.

It is chiefly recommended in chronic rheuma-tifm, and all fuch cafes as require ultimately the cold bath; but where from the delicacy of the patient's habit, it is neceſſary to bring him gradually to its uſe. It forms a proper intermediate bath between Bath or Buxton and the ſea.

Buxton in the Peak of Derbyſhire. This water is, like the laſt, as pure as common ſpring water, except that it contains a ſmall quantity of azotic gas; and a larger quantity continually eſcapes in bubbles to the ſurface of the water in the ſprings. This gives to it no particular flavour or appearance, and, as far as is yet known, no particular medical virtues. Its temperature is at 82°, being conſiderably warmer than that of Matlock, though not ſo warm as the human body. Its chief uſe as a bath is in caſes of partial loſs of motion or of ſenſation, particularly after rheumatiſm. As an internal remedy it is ſerviceable in caſes of indigeſtion from free living, and in diſeaſes of the urinary organs. Its utility in gouty affections is more doubtful.

Class II. CHALYBEATE.

Division 1st. *Hot carbonated.*

Bath water, though ſlightly chalybeate, contains ſo ſmall a proportion of foreign ingredients, that it falls properly to be conſidered after the ſimple thermal waters.

The climate of Bath is mild and genial. Its waters have three principal ſources, which ſupply the King's bath, the Croſs bath, and the Hot bath, which differ fomewhat in their temperature, as well as contents.

The firft is at 116° when frefh drawn, and about 106° in the bath; whilft that of the Crofs bath, which is coldeft, is only 112° at the pump, and from 92° to 94° in the bath.

The former is likewife more chalybeate; although even that is fo flightly fo, as only to be evident to the tafte when warm, and not at all when cold. Befides this fmall quantity of iron, Bath water contains fome fixed air, though not fo much as to render it fparkling, or at all acid to the tafte. Its other ingredients are calcareous falts enough to render the water hard, a minute portion of neutral falts, and of filiceous earth, and a fmall quantity of azotic gas.

Ufed internally, Bath water fometimes produces headach, drynefs of the tongue, and a feverifh pulfe; when this is the cafe, its further ufe fhould not be advifed. When likely to prove beneficial, it produces an agreeable glow in the ftomach, and an increafe in the appetite, and fpirits; it alfo quickly determines to the kidnies.

Bath water, both internally and externally applied, is very beneficial in chlorofis, in irregular gout, and the fecondary ftage of rheumatifm. In paralytic affections, where there is no particular determination to the head; in jaundice, and other liver complaints, brought on by refidence in hot climates; and in moft hypochondriacal and dyfpeptic cafes, the ufe of the Bath waters is highly extolled.

In cafes of old fprains, or the partial effects of rheumatifm, the topical application of the water, by pumping it upon the part, is frequently ferviceable.

We have no other hot chalybeate waters in this country; but on the continent feveral have gained great celebrity, as *Vichy waters* in the Bourbonnois, a mountainous diftrict in the centre of France; which waters, befides being chalybeate, are alkaline, containing a very perceptible quantity of mild foda. Their temperature is about 120°.

Carlfbad, or *Caroline waters*, in Bohemia, are hot faline carbonated chalybeates. Their temperature is as high as 165°. They contain Glauber's falts, and other purging falts, much fixed air, and calcareous earth, and a fmall portion of iron. The two laft being held in folution by the redundant fixed air, are feparated (the former in confiderable quantity), when the water by expofure lofes its heat and its fixed air; in confequence of which ftalactites and calcareous petrefactions are very common in thefe fprings.

Thefe waters are purgative as well as tonic, and are ufeful in the fame cafes as the Bath waters.

Division 2d. *Cold carbonated.*

This divifion of mineral waters is the moft abundant, not only in this, but in other countries.

Befides fixed air and iron, many of them contain no foreign ingredients but fuch as are found in the moft common fprings. The quantity of thefe two ingredients, to which they owe all their virtues, varies confiderably in different waters.

Such as contains but a fmall quantity of the gas, not fufficient to give it a fparkling appearance, is termed fimple carbonated chalybeate water; and of this kind are all the natural fimple chalybeate fprings in this country, as *Tunbridge*, *Iflington*, &c.

Thofe chalybeate waters, that fparkle, and are fenfibly acid from the abundance of the gas, are called highly carbonated chalybeate waters. Of this clafs are the *Spa waters* in the principality of Liege, and the *Pyrmont water* in Weftphalia, which are frequently imported into this country, and are the mineral waters that we moft frequently imitate by artificial means.

Amongft the fimple chalybeate waters of this kingdom, *Tunbridge-wells* is moft reforted to; but thofe at *Iflington*, *Hampftead*, *Carlton* near Newark, *Leez*, *Markfhall*, and *Felftead* in Effex, *Aylefham* in Norfolk, and *Wellingborough* in Northamptonfhire, are of the fame clafs, and many of them as ftrongly impregnated.

There is a cold chalybeate at Buxton, and likewiſe at Harrowgate, that add to the celebrity of theſe places.

Waters are known to be chalybeate by their ſtriking a purple or black colour with an infuſion of galls, or other vegetable aſtringent; by their peculiar inky flavour; and by their depoſiting a yellowiſh ochre, when expoſed to the air.

Their medical virtues are chiefly as a tonic, producing a genial glow, improving the digeſtion, and giving ſtrength and tone to the whole ſyſtem. They are particularly ſerviceable in chloroſis, and other diſeaſes of females; in flatulency and indigeſtion, and in all caſes of debility from free living or debauchery.

The highly carbonated claſs, as Spa and Pyrmont, have a kind of intoxicating effect from the exceſs of fixed air, and frequently require to be diluted; and are never to be drunk, where there is much inflammatory action, or determination of blood to the head.

It is by means of the fixed air that theſe waters retain the iron in ſolution; if, therefore, they loſe this gas, which they gradually do, by mere expoſure, and more quickly by boiling, the iron is precipitated in the form of ochre, and the water loſes all its virtues and peculiar properties. If well corked, they may be kept good for ſome time.

The proper quantity to be taken is from a pint and a half to three pints daily; and the uſe of the waters ſhould not be continued more than from ſix to eight weeks, without a conſiderable intermiſſion.

Beſides the ſimple and highly carbonated chalybeate waters, there are others that are chalybeate with the addition of ſaline ſubſtances, as the *Cheltenham* and *Scarborough* waters. Theſe are purgative, particularly the former, and are chiefly beneficial in obſtructions of the liver, in all glandular ſwellings, and in caſes of ſcorbutic eruptions.

Theſe waters grow turbid and loſe their virtues by keeping, even in bottles well corked. At *Burlington* in Yorkſhire, at *Nevil Holt* in Leiceſterſhire, and at *Coventry*, are ſprings very much reſembling in all their properties thoſe of Scarborough: whilſt thoſe of *Gainſborough* in Lincolnſhire, and *Hartlepool* in Durham, more nearly reſemble the Cheltenham, having a ſlightly ſulphureous taint.

DIVISION 3d. *Vitriolated.*

This ſpecies of chalybeate water owes its property to the preſence of green vitriol, which is iron combined with ſulphuric or vitriolic acid. It alſo contains a portion of alum, and hardly any other foreign matter.

Theſe waters are not numerous; their ſtrength varies, and of courſe the doſe; it ought, however, ſeldom to exceed a pint in a day. In a large dofe they produce vomiting. They are ufeful in hemorrhages and other difcharges from debility, and in patients of a general lax habit.

At *Shadwell* near London, at *Hartfell* near Moffat, and at *Swanfey* in South Wales, are fprings thus impregnated.

CLASS III. SALINE.

DIVISION 1st. *Simple.*

Thefe are waters that differ from common water in holding in folution more or lefs of the different purging falts; but they contain no iron, and no fixed air, or fulphureous gas. The falts are chiefly either Epfom falt, or Glauber's falt, or both, with muriate of magnefia, and more or lefs of common falt.

Sedlitz and *Epfom* water abound in fulphate of magnefia or Epfom falt.

Sea water owes its faline tafte to common falt (muriate of foda), which it contains in abundance; and its bitter tafte to muriate of magnefia, of which it alfo contains a confiderable portion.

Both thefe falts are purgative; and the fea-water differs but little, if at all, in its medical virtues from the faline fprings, the purgative quality of which is generally derived from Epfom falt, or Glauber's falt.

The Epfom falt for fale is now obtained chiefly from ſea water, by adding green vitriol (ſulphate of iron) to the uncryſtallizable ſalt that remains after the common ſalt has been extracted from it. The ſulphuric acid of the vitriol leaves the iron to unite with the magneſia of the ſalt, which is a muriate of magneſia, and thus forms the Epſom ſalt (ſulphate of magneſia.)

The internal uſe of theſe ſalt or ſea waters is recommended in glandular, or ſcrofulous ſwellings; in dyſpepſia, attended with nauſea, and a foul tongue; in hypochondriaſis, attended with coſtiveneſs; and in moſt caſes of habitual coſtiveneſs, particularly where the more draſtic purges have been too freely adminiſtered.

Sea bathing, or ſalt water bathing, is uſeful wherever cold bathing of any kind is indicated; as in all caſes of debility, unaccompanied with inflammatory ſymptoms. How far it is to be conſidered preferable to the common cold bath is doubtful, except in caſes of cutaneous eruptions, and old ulcers, where the ſtimulating quality of the ſalt, as an external application, is generally attended with good effects.

In ſome delicate and irritable habits too, bathing in the ſea will be ſucceeded by that univerſal glow that is the certain teſt of the utility of the bath, when common cold bathing would be ſucceeded by chillineſs and coldneſs of the extremities. Warm falt bathing may be more advantageous in paralytic cafes than common warm bathing.

Division II. *Highly carbonated alkaline.*

The moft celebrated natural water of this clafs is that of *Seltzer.* It is a faline water, flightly alkaline from the foda that it contains, and highly acidulated with carbonic acid or fixed air, which is much more than fufficient to faturate the alkali.

This water is palatable to moft perfons, being brifk and fparkling, and but flightly alkaline; it raifes the fpirits, and promotes digeftion.

Seltzer is a village in the bifhoprick of Triers, in Germany; its water is tranfported in ftone bottles, well corked, to almoft every part of Europe. In Holland, as well as Germany, it is a common beverage at the tables of the fafhionable; and in this country, either the natural water, or an artificial imitation of it, under the name of *Soda water*, is now a very fafhionable drink.

This water is highly recommended in the hectic fevers of confumptive patients, attended with flufhings and night fweats; and for allaying feverifh irritation from other caufes.

In eruptions called fcorbutic, in cafes of indigeftion, and particularly in calculous complaints, its virtues are highly extolled.

The ufual dofe of the water is, from half a pint to a pint; but little or no inconvenience can arife from a much larger quantity.

CLASS IV. SULPHUREOUS WATERS.

The fulphureous waters of this country are all cold; as *Harrowgate*, in Yorkfhire; *Moffat*, in the fouth of Scotland; *Sutton-bog*, in Oxfordfhire; and *Shettlewood*, in Derbyfhire.

Thofe of *Aix-la-Chapelle*, in Flanders, and feveral others on the Continent, are very hot. The fulphur is retained in thofe waters by its union with inflammable air, which hepatic gas gives the peculiar fmell and tafte to them. It refembles that of rotten eggs, or the fcourings of a gun-barrel; which, with its property of tarnifhing filver, and rendering black, characters written on paper with fugar of lead diffolved in water, are fufficient tefts to afcertain its prefence in any water.

Some of thefe waters contain a fenfible portion of the purging falts; of which Harrowgate ftands the firft in renown.

The Moffat water contains only a little common falt.

Warm baths of thefe waters are recommended in almoft all cafes where their internal ufe is advifed; the principal of which are herpetic eruptions, and fuch as are termed fcorbutic. Dyfpeptic patients, and fuch as labour under worms, experience advantage from thefe waters. Two or three half-pint glaſſes of the water are taken in the courſe of the morning.

The hot ſulphureous waters on the Continent are reſorted to by gouty, rheumatic, and paralytic patients; and are uſed externally as tepid baths, as hot baths, or as vapour baths, with great advantage.

Having thus given a haſty ſketch of all the different kinds of mineral waters, I ſhall add a liſt or table of the particular ſprings of this kingdom, with ſome few of the more noted ones on the Continent. I ſhall ſo arrange them, that their peculiar properties may be immediately ſeen; and ſhall place the moſt noted of each kind at the head of its diviſion, as a point of compariſon for the reſt. I ſhall, laſtly, conclude the ſubject by an eſſay on the artificial mineral waters.

TABLE of the Mineral Waters of Great Britain, with a few of thofe on the Continent, fyftematically arranged*.

CLASS I. SIMPLE WATERS.

DIVISION I. *Cold.*	DIVISION II. *Hot.*
Malvern, Gloucefterfhire	*Briftol,* Somerfetfhire
St. Winifrede's Well, at Holywell, Flintfhire	Buxton, *Derbyfhire*
	Matlock, *Ditto*
	Mallow, *Cork*

CLASS II. CHALYBEATE.

DIVISION I. *Cold carbonated fimple.*

Tunbridge, Kent	Birmingham Well, near to the town
Aberbrothick, Scotland	Bromley, Kent
Aylefham, Norfolk	Cannock, near Stafford
Ballycaftle, Antrim	Carlton, Nottinghamfhire
Ballyspellan, near Kilkenny	Chippenham, Wilts

* Many of the following waters have not yet been accurately analyfed. We do not, therefore, prefume that all are properly arranged; but judging from their general qualities and characters, we truft that the errors are few, and of little importance. Neither do we offer it as a complete catalogue of Britifh mineral waters, there being, doubtlefs, many that are not yet generally known.

Cobham, Surrey
Colurian, Cornwall
Coolauran, Fermanagh
Derby, near to the town
Dortſhill, Staffordſhire
Dunnard, near Dublin
Dunſe, Scotland
Felſtead, Eſſex
Galway, Ireland
Glanmile, near Naul
Glendy, Scotland
Hampſtead, near London
Iſlington, Ditto
Kanturk, Cork
Kincardine, Scotland
Kirby, Weſtmoreland
Lancaſter, or Sale's Spa
Latham, Lancaſhire
Leez, Eſſex
Llandrindon, South Wales
Markſhall, Eſſex
Millar's Spa, Lancaſhire
Moſs Houſe, Ditto
Newton Stewart, Ireland
Oulton, Norfolk
Peterhead, Aberdeenſhire
Sene, Wiltſhire
Tibſhelf, Derbyſhire
Weatherſtack, Weſtmoreland
Wellingborough, Northamptonſhire
Weſt Aſhton, Wiltſhire
Wexford, Ireland
Whiteacre, Lancaſhire
Wigan, Ditto

DIVISION II. *Hot carbonated ſimple.*

Bath, Somerſetſhire.

DIVISION III. *Cold highly carbonated.*

Pyrmont, Germany
Spa, Ditto
Abcourt, France
Paſſy, Ditto
*Ilmington, Warwickſhire
Lincomb, near Bath
Lis-done-verna, Ireland
Maccroomp, Ditto
Thetford, Norfolk

* The waters of this diviſion that are found in this kingdom, have much leſs fixed air than the Spa waters, which they otherwiſe reſemble.

DIVISION IV. *Cold ſaline carbonated.*

(a) *ſlightly ſulphureous.*	(b) *not ſulphureous.*
Cheltenham	*Scarborough*
Ballynahinch, Down	Aſtrope, Oxfordſhire
Caſtlemain, Kerry	Aſwarby, Lincolnſhire
Deddington	Bingley, Warwickſhire
Drigwell, Cumberland	Burlington, Yorkſhire
Gainſborough, Lincolnſh.	Coventry, Warwickſhire
Hartlepool, Durham	Hanbridge, Lancaſhire
Orſton, Nottinghamſhire	Jeſſop's Well, Surrey
Stenfield, Lincolnſhire	Kingſcliff, Northamptonſh.
Tarleton, Lancaſhire	Malton, Yorkſhire
Thoroton, Nottinghamſh.	Nevil Holt, Leiceſterſhire
Workſworth, Derbyſhire	Newnham, Warwickſhire
	Thurſk, Yorkſhire

DIVISION V. *Hot ſaline highly carbonated.*

Bourbon,
Mount d'Or, } France.
Vichy,

Carlſbad, or Caroline Baths, Bohemia.

DIVISION VI. *Vitriolated.*

Hartfell, Scotland	Haigh, Lancaſhire
Caſhmore, Waterford	Kilbrew, Meath
Croſs Town, Ditto	Nobber, Meath

Shadwell, near London
Somerſham, Huntingdonſhire
Stanger, Cumberland
Swansey, North Wales

CLASS III. SALINE WATERS.

DIVISION I. *Simple.*

(a) *common ſalt abounding.*
Sea Water
Alford, Somerſetſhire
Barrowdale, Cumberland
Cargyrle, Wales
Dortſhill, Staffordſhire
Dublin ſalt Springs
Kilroot, Antrim
Leamington, Warwickſhire
St. Eraſmus's Well, Staffordſhire
Brentwood, Eſſex
Colcheſter, Ditto
Dog and Duck, near London
Kenſington, Ditto
Kilburn, Ditto
Llandrindod, South Wales
Pancras, near London
Richmond, Surrey
Sedlitz, Germany
Sydenham, near London
Tewkſbury, Glouceſterſh.

(b) *Epſom ſalt abounding.*
Epſom, Surrey
Acton, near London
Alkerton, near Glouceſter
Bagnigge, near London
Barnet, Hertfordſhire

(c) *Alkaline ſalt abounding.*
Tilbury, Eſſex
Clifton, Oxfordſhire
Glaſtonbury, Somerſetſhire
St. Bartholomew, near Cork
Streatham, Surrey

DIVISION II. *Highly carbonated alkaline.*

Seltzer, Germany.
Tonſtein, Ditto.

Class IV. SULPHUREOUS WATERS.

Division I. *Cold.*

(a) *with purging Salts.*

Harrowgate, Yorkſhire
Aghaloo, Ireland
Aſhwood, Ditto
Aſkeron, Yorkſhire
Bilton, Ditto
Broughton, Ditto
Buglawton, Cheſhire
Cawley, Derbyſhire
Chadlington, Oxfordſhire
Codſalwood, Staffordſhire
Crickle Spaw, Lancaſhire
Croft, Yorkſhire
Cunley-houſe, Lancaſhire
Derrindaff, Ireland
Derryhence, Ditto
Derryleſter, Ditto
Drumaſnave, Ditto
Drumgoon, Ditto
Durham, near to
Keddleſtone, Derbyſhire
Killaſher, Ireland
Liſbeak, Ditto
Maudeſley, Lancaſhire
Mechan, Ireland
Normanby, Yorkſhire
Owen Breun, Ireland
Laonſbury, Yorkſhire
Pettigoe, Ireland
Queen Camel, Somerſetſh.
Shapmore, Weſtmoreland
Shettlewood, Derbyſhire
Shipton, Yorkſhire
Sutton-bog, Oxfordſhire
Swadlingbar, Ireland
Upminſter, Eſſex
Wardrew, Northumberland
Wigglefworth, Yorkſhire

(b) *without purging Salts.*

Moffat, Scotland
Carſtarphin, Ditto
Llandrindod, South Wales
Nottington, Dorſetſhire

Division II. *Hot.*

Aix la Chapelle, Germany	Borfet, Germany
Baden, Ditto	Mont d'Or, France
Bareges, France	

ESSAY XXI.

ARTIFICIAL MINERAL WATERS.

THE natural mineral waters have been ſo repeatedly and ably ſubmitted to chymical inveſtigation, that we poſſeſs now a very accurate analyſis of all that are important.

This knowledge of their compoſition has enabled us to imitate moſt of them, and thus to diffuſe more generally the benefits that ſuch waters afford.

Thoſe waters that contain only ſolid ingredients are very eaſily imitated. Such as contain gaſeous ſubſtances, require more contrivance, and ſome of them are only to be exactly imitated by very complex and intricate proceſſes.

This point, however, has been attained; and the artificial waters of Paul, Scheppe, and of Mr. William Henry of Mancheſter, may be depended upon as very accurate imitations, and as poſſeſſing all the medical virtues of the natural waters.

Thoſe of the laſt gentleman I can more particularly recommend from my knowledge of his very intimate acquaintance with all chymical ſubjects, and his wonted accuracy in experiment; and likewiſe from my knowing him to have laboured of late with peculiar aſſiduity in this particular branch of the ſcience.

Our acquaintance with the compoſition and medical qualities of the natural waters gives us an opportunity of forming artificial ones, that differ from them in both particulars; and, by leaving out the more inert materials, to form waters more ſimple than the natural ones, and yet poſſeſſing the ſame properties as medicines.

It is only ſuch as can be eaſily made, that I ſhall here enumerate and deſcribe; and, for theſe, the only apparatus, that is required, is that invented by Dr. Nooth, and known by the name of Nooth's apparatus for making the artificial mineral waters.

Class I. *Simple Waters.*

Should the cold ſimple waters, as the *Malvern*, be required to be imitated, common rain water ſhould be deprived of its chalk by boiling, and rendered ſtill purer by diſtillation. This water ſhould then be expoſed to the air, that it may abſorb a portion of common air, which boiling has deprived it of, and which the Malvern water always holds in ſolution. It will now only differ in holding perhaps more ſelenite than Malvern water does; but this will be very trifling, if rain or ſnow water has been uſed.

The ſame water heated to 66° will reſemble *Matlock*, and heated to 82° *Buxton* water.

To form *Briſtol* water, impregnate diſtilled water with fixed air, by means of Nooth's apparatus*, and add to a wine gallon ſeven grains of muriated magneſia, four of common ſalt, and eleven of Glauber's ſalt. This imitation will be tolerably accurate, and when heated to 74° will poſſeſs the ſame properties as the natural water when freſh drawn.

To heat this and ſimilar waters for drink, immerſe a bottle of it, well corked, into hot water, till it has acquired the proper heat, which may eaſily be learnt after a few trials.

Class II. *Chalybeate waters.*

This is by far the moſt extenſive claſs, and contains the greateſt variety. To imitate the ſimple cold carbonated chalybeates, ſuch as that of *Tunbridge*, and a long liſt of others that follow it in the preceding table, impregnate diſtilled or even common pump water with fixed air, but not ſo much as for the Briſtol water, and ſuſpend a drachm of iron wire, or iron filings, in the middle veſſel of the apparatus. The more fixed air is abſorbed by the water, and the longer it remains before it is drawn off, the more iron it will diſ

* Vide Page 131.

ſolve, and the more ſtrongly chalybeate it will prove.

The highly carbonated, as *Spa*, and *Pyrmont*, contain much more air and iron. To imitate the firſt, uſe rain water, and for the latter a very hard water. To the firſt, add nine grains of magneſia and three of ſoda to each quart; to the latter, one ſcruple of magneſia, eleven grains of Epſom ſalt, and three of common ſalt, and allow them to abſorb more of the fixed air than the common chalybeates, particularly for the Pyrmont water.

To imitate the *Bath water* preciſely would be difficult, and perhaps in the preſent ſtate of chymiſtry impoſſible, as it contains the ſiliceous earth in ſolution, which is generally conſidered as inſoluble.

Common water very ſlightly impregnated with iron and fixed air (not ſo much ſo as to ſparkle) when heated to 116° will not differ much in its medical qualities from Bath water.

The *ſaline carbonated chalybeate* waters may be pretty nearly imitated, as the *Cheltenham* and *Scarborough*, by adding more ſalts to the common chalybeates. To each quart, for the former, add a drachm of Glauber's ſalt, and a drachm of Epſom ſalt; and, to be more accurate, impregnate it very ſlightly with ſulphureous gas, as will be directed presently for the sulphureous waters.

To imitate the *Scarborough* add only one third as much salts, use a harder water, and omit the sulphureous impregnation. The hot saline highly carbonated chalybeates, as *Vichy* and *Carlsbad*, are imitated by impregnating water strongly with fixed air, slightly with iron, and then adding to each pint, of Glauber's salt two scruples, common salt five grains, and mild soda 11 or 12 grains. The water is then to be heated to a sufficient temperature for use; the natural waters being too hot either for bathing or drinking when fresh drawn.

The *vitriolated chalybeates* are imitated by adding more or less of green vitriol, and a small portion of alum, to common water.

For an accurate imitation of the *Hartfell* water, first impregnate a very pure water slightly with iron and fixed air in the common way, and to a quart of this water add a scruple of green vitriol, and three grains of alum.

CLASS III. *Saline waters.*

The simple saline waters are imitated by adding some of the purging salts to a tolerably pure water.

For *artificial sea water*, add half an ounce of common salt, and a drachm of muriate of magnesia;

to a pint of water. For *Epſom water*, diſſolve a drachm of Epſom ſalt, and a few grains of muriate of magneſia, in each pint; and for *Sedlitz water*, add of Epſom ſalt five drachms, magneſia five grains, and of muriate of magneſia nine grains.

Other ſaline waters contain small quantities of common ſalt with the Epſom or Glauber's ſalt, or both; but, as in virtues they are nearly if not altogether ſimilar, it is needleſs to deſcribe them.

The *highly carbonated alkaline* waters are more difficult of imitation; and whoever requires good Seltzer or ſoda water, had better apply to the noted venders of them, than attempt an imitation.

To a pint of clear water, add five grains of magneſia, four grains of ſoda, and 17 grains of common ſalt; then impregnate with as much fixed air as poſſible, and the more air you make it imbibe, the nearer will it be in quality to the Seltzer water.

CLASS IV. *Sulphureous waters.*

The ſulphureous quality of theſe waters depends upon the preſence of inflammable air holding ſulphur in ſolution; and to impregnate water with this ſulphurated, or hepatic gas, the ſame apparatus and ſame proceſs are required as for impregnating it with fixed air; with this difference, that liver of ſulphur muſt be ſubſtituted for chalk or marble.

Liver of ſulphur is made by mixing equal parts of ſulphur and of potaſh or quicklime, placing the mixture in an unglazed diſh over a gentle fire, and ſtirring it till it forms a uniform blood-red maſs.

Some of the chalybeate waters are ſlightly ſulphureous, as we before mentioned; to imitate which ſome liver of ſulphur muſt be added to the chalk in the bottom veſſel.

To imitate the true *Sulphureous waters*, only liver of ſulphur and the vitriolic acid are to be put into the bottom veſſel; and the neceſſary ſalts, without iron, into the middle one. Moſt of the ſulphureous waters contain ſo much ſaline matter as to prove purgative, of which *Harrowgate* water is the moſt noted. To imitate this you muſt add to each quart $2\frac{1}{2}$ drachms of common ſalt, 22 grains of muriate of magneſia, and $2\frac{1}{2}$ grains of Epſom ſalt.

Of thoſe ſulphureous waters, that are not purgative, the *Moffat* water ſtands firſt; which is very nearly imitated by adding 8 grains of common ſalt to a quart of the ſulphurated water.

The artificial ſulphureous and chalybeate waters, made according to the above directions, cannot be expected to be accurate imitations, becauſe it is difficult to appreciate the quantity of ſulphurated gas in the latter, or fixed air and iron in the former, that the water may have abſorbed. They will however be found to poſſeſs the diſtinguiſhing properties, and perhaps all the medical virtues, of the natural waters.

ESSAY XXII.

ON THE RED WELL AT WELLINGBOROUGH.

WELLINGBOROUGH is ſuppoſed by ſome to be the ſame with Wendlynburc, mentioned by Ingulphus as one of the many towns deſtroyed by the Danes; but by others it is ſuppoſed to be a town of more modern date, deriving its name from the well, which we are about to treat of, the waters of which had formerly obtained very great celebrity for their medicinal virtues in the cure of a variety of complaints. Nearly two centuries ago it was in conſiderable repute, being noticed and recommended by Sir Theodore Mayern, a writer of that time, and phyſician to King Charles the fiirſt. It is likewiſe mentioned by Mr. John Goodyer, and by Dr. Merret; and there is a tradition, conſidered as tolerably authentic, that King Charles the Firſt and his Queen reſided here in tents erected on the hill, during a whole ſeaſon, for the benefit of the water.

Amongſt the inhabitants it has ſtill retained conſiderable repute, and many of them have occaſionally reſorted to its water, and derived conſiderable advantages from the uſe of it.

From theſe circumſtances, from an accurate analyſis of the water, and a compariſon of it with that of Tunbridge, and other chalybeates, I believe it to be a water of confiderable virtues; and I am induced to publifh this account of it in hopes that it will one day recover its wonted and deferved celebrity.

Wellingborough is a well built flourifhing market town in Northamptonfhire, ftanding in a dry fituation on the fouth fide of a hill; at the bottom of which, about a quarter of a mile from the town, runs the river Nyne, a low hill or rifing ground intervening.

Shoemaking and lacemaking are the chief employments of its inhabitants, the number of whom by the late calculation appeared to be about three thoufand.

The well or fpring, called Red well, is fituated in a hollow on the top of the hill, on the fouth fide of which the town is built. It is north weft of the town, at the diftance of nearly half a mile.

Its name is derived from the ochre or ruft of iron depofited in its courfe, which gives a red appearance to the ftones, weeds, and other fubftances, over which the water runs.

The quantity of water that the fpring affords is very confiderable at all feafons, fufficiently fo for all the purpofes it would be required for, were it as much reforted to as any of our moft celebrated chalybeates.

The water has been obferved to flow during very intenfe frofts; nor am I certain that it has ever been known to be frozen.

When frefh drawn the water is beautifully clear and tranfparent, but not fparkling like the Seltzer water. When drunk it has the peculiar inky flavour of all chalybeates, but not fo intenfely as to be difagreeable to the tafte.

Its effects are to quicken the pulfe, produce a general glow immediately after being drunk, and to prove gently aperient, more fo than moft chalybeates; befide which, it almoft univerfally increafes the quantity of urine.

The continued ufe of the water increafes the appetite, exhilarates the fpirits, improves the ftrength, and braces the whole fyftem.

Like all other chalybeates it blackens the fæces of perfons who drink it, which is a thing of no importance, but neceffary to be mentioned, and made known to the patient, left he take any groundlefs alarm.

Examined with the proper chymical reagents this water appears to differ from Tunbridge water in no refpects, except that of containing rather a larger proportion of earthy ingredients, chiefly chalk (carbonat of lime), which being held in folution by the fixed air is depofited on boiling, and alfo by mere expofure. The depofition of this matter forms a calcareous cruft intermixed with the ochre on the fides and bottom of the bafin, into which the water flows.

The other contents of the water are iron, fixed air, and a fmall quantity of purging falts.

The chalybeate waters fometimes produce naufea and vomiting, or headach and dizzinefs, on beginning a courfe of them; but thefe fymptoms ufually go off in a few days, particularly if the water proves aperient, and increafes the flow of urine.

The water very frequently purges pretty brifkly at firft, but often after a long ufe produces a coftive habit of body. When this is the cafe aperient medicines fhould occafionally be taken.

The difeafes, in which the ufe of the Red well water promifes to be of moft fervice, are indigeftion, with its various fymptoms, and a variety of complaints peculiar to the female fex.

Of the latter, that debility and pallid countenance, liftleffnefs and averfion to every kind of exercife, fo frequent amongft the young, and particularly thofe of a delicate habit, are more fpeedily and certainly removed by a courfe of thefe waters than by any other means.

Thefe waters may likewife be taken with great profpect of advantage in all cafes of debility, and relaxation, from exceffive difcharges of any kind; provided they be not attended with fever, or with local irritation, or pain.

Of ſtomach complaints, flatulency, an uncertain and capricious appetite, heartburn, and all the ſymptoms attendant upon irregular and incomplete digeſtion, are ſuch as point out the uſe of this claſs of waters; and whether they proceed from irregularity in diet; habitual ſmoking or chewing of tobacco, which are not unfrequent cauſes; from long confinement, with want of air and exerciſe; or from intenſe application, and continued inclination of the body, as in writing, reading, and many of the employments of mechanics; the continued uſe of this water with regular exerciſe and mental relaxation in different amuſements, may be had recourſe to with ſanguine expectations of advantage.

Patients that are low and hypochondriacal, languid and inactive, with general relaxation and debility, and all convaleſcents from fevers, or other complaints, in whom the appetite is long in returning, may likewiſe expect benefit from the uſe of chalybeate waters.

The beſt mode of taking the water is to begin early in the morning with a doſe of half a pint, then to walk or take other exerciſe for an hour, and after that to take another half pint, and to repeat the doſe a third time an hour or two before dinner. This plan ſhould be continued daily for ſix weeks or two months; and, if the complaints are not by that time removed, after two or three months interval a ſecond courſe ſhould be gone through in the ſame way.

There is no occaſion for any preparation previous to the uſe of the water, unleſs the ſtomach is judged to be foul, and then a ſingle emetic may precede its uſe. If the body ſhould be coſtive during the courſe, the water ſhould occaſionally be omitted for a day, and a gentle laxative medicine be given; or a ſmall quantity of ſome purging ſalt may be daily added to the water.

ESSAY XXIII.

ON DYEING.

The art of dyeing confifts chiefly of chymical proceffes, and comprifes a vaft collection of chymical experiments. To give a detailed account of all the complicated operations of the dye-houfe would be tedious, and uninterefting to any but the practical dyer. Our intention is only to give the rationale of the art, and convey fuch general information, as fhall fatisfy the curiofity of the general reader, but without qualifying him for the practical department of it.

It is neceffary to preface the confideration of dyeing with fome obfervations on the fubftances, that are to be fubmitted to the operation. Wool, hair, filk, cotton, hemp, and flax, are what are principally fubjected to the dyer's art.

Of thefe the animal productions, namely, wool, hair, and filk, are more eafily dyed than the vegetable fubftances, cotton, hemp, and flax, becaufe they have a ftronger attiaction for the colouring particles of the various dyes employed.

The animal fubftances are more eafily injured by acids and alkalies, which makes it neceffary to be more careful in the ufe of thefe, when dyeing or preparing for the dye ſuch ſubſtances, viz. wool, hair, and ſilk.

Wool has a natural covering of greaſe, which it is neceſſary to deprive it of, before ſubmitting it to the dye. This is done by ſcouring it with warm water, to which is added one fourth of ſtale chamber lie, and by afterwards waſhing it in a ſtream of clear water. The wool loſes a great deal in weight by this operation, often as much as one fifth of the whole. Beſide this cleanſing it is generally neceſſary to boil the wool in a ſolution of alum and tartar, before it is dyed. This however is not requiſite for all kinds of dyes; and then it only needs, after the above cleanſing, to be waſhed in warm water, wrung out, and left to drain, which indeed is neceſſary with every other ſubſtance that we intend to dye.

Silk is naturally covered with a glairy varniſh, which is perfectly ſoluble in water; and the European ſilk has a yellow colour, which water alone will not deprive it of; ſilk, therefore, is always ſcoured with ſoap and water, previous to dyeing; and to make it take and retain the colour, it is always alumed, which is done by waſhing it in a cold ſolution of alum in water.

Cotton, which is a vegetable production, found enveloping the ſeeds of certain plants, has uſually in its natural ſtate a lighter or deeper tinge of yellow, of which it muſt be deprived by bleaching. It muſt then be ſcoured in an alkaline lie, or in ſour water, which is prepared by mixing bran with water, and ſuffering it to remain until it ferments, and becomes ſour. Afterwards, beſides aluming, as with ſilk, it requires to be waſhed in a decoction of galls, or other aſtringent, as hot as the operator can well bear it.

Linen, which is made either of flax or hemp, has always a brown colour, of which it muſt be deprived, like cotton, by bleaching, and then undergoing the ſame proceſs as we have juſt deſcribed.

In the art of dyeing there is a ſtep, which is in almoſt all caſes neceſſary to be taken previous to immerſion of the ſtuff into the dyeing liquor. This is the application of what is termed a *mordant*, the nature and intention of which I ſhall now endeavour to explain.

In moſt caſes it is found neceſſary to employ ſomething for the purpoſe of making the ſtuff, to be dyed, take the colour more readily, and retain it more firmly; for by merely immerſing the ſtuffs into the dyeing liquor, they will ſeldom take a deep dye; and the ſtuffs will in almoſt every caſe loſe their colour again, by expoſure to the air, or by waſhing in water. The ſubſtances thus employed, to give luſtre and durability to the colours, are called *mordants*.

Different mordants are uſed for preparing different goods, and for preparing the ſame for different colouring drugs. Alum is by far the moſt extenſively uſeful, being always employed in the printing of linens, and cottons, which is a ſpecies of dyeing now very much practiſed. For the dyeing of ſilk and wool, metallic ſolutions are more frequently employed as mordants.

The art of printing on cotton and linen depends chiefly on the application of the mordant. What is uſed for this purpoſe is called the aluminous mordant, being prepared by diſſolving three pounds of alum in a gallon of hot water, then adding a pound of ſugar of lead, ſtirring the mixture well at times for two or three days, and afterwards adding to it two ounces of potaſh, and the ſame quantity of chalk.

The alum and ſugar of lead in this preparation are both decompoſed, the ſulphuric acid of the alum uniting with the lead forms an inſoluble powder, which therefore ſubſides to the bottom, whilſt the vinegar (which is the other conſtituent of ſugar of lead) combines with the clay or alumine of the alum, and remains diſſolved in the fluid. This liquor then is not a ſolution of alum and ſugar of lead in water, but a ſolution of acetite of alumine, that is, a ſalt compoſed of vinegar and clay.

This mordant, being thickened with ſtarch or gum, is applied to the cloth by blocks, or by the pencil on thofe parts where the dye is afterwards intended to take, and give the pattern.

It is then dried, and afterward wafhed, to get out the gum or ftarch, and is now to be immerfed into the dyeing liquor. The pattern or part, to which the mordant was applied, has a much deeper tinge than the reft, when the ftuff is taken out of the liquor; and after the cloth has been repeatedly boiled in bran and water, and bleached in the air, this is the only part that retains the colour.

The ufe of the mordant is explained, by fuppofing that the particles of clay have a ftrong attraction for the particles of the colouring drug, and that having itfelf penetrated the cloth, it attracts and retains there thefe colouring particles. To illuftrate this attraction or affinity, diffolve cochineal in a folution of alum, and then add an alkali, which will feparate the clay of the alum from its fulphuric acid, and caufe it to be precipitated. The clay, as it falls, attracts and carries with it to the bottom the colouring particles of the cochineal, the liquor above remaining clear and colourlefs.

Solutions of different metallic falts are frequently employed as mordants, having a great affinity for the colouring matter of fome fubftances. They have a ftronger attraction for animal than for vegetable ftuffs, and are therefore principally ufed in dyeing filk and wool.

We now proceed to the confideration of the colouring drugs, and the mode of employing them as dyes for different fubftances. Dr. Bancroft in treating this fubject has divided the colouring drugs into fubftantive and adjective, the former including fuch as may be permanently fixed in or upon the dyed fubftance without the interpofition either of an earthy or metallic mordant, the latter including thofe which require the aid of a mordant.

Others have divided this part of the fubject according to the kingdom of nature, which affords the dyes, treating feparately of the animal, vegetable, and mineral colouring drugs.

The divifion we fhall adopt, which is according to the colours they afford, though perhaps lefs fcientific, will be more congenial to our plan, as we mean to treat of the proceffes of dyeing, at the fame time that we particularize the fubftances that afford the colours.

The three fimple colours are red, yellow, and blue; all other colours are compounded of thefe. Different fhades or tints of the fame colour are produced by ufing different drugs, or by varying the quantity of colouring particles; or, in the cafe of the compound colours, by varying the proportion of the different fimple ones, of which they are compofed.

Reds. We fhall treat of the fimple colours firft, and begin with RED. Cochineal, kermes, and gum lac, amongft the animal productions; and madder, archil, carthamus, and Brazil wood, amongſt the vegetables, are the chief ſubſtances employed as red dyes; and as they differ in the tint and other properties, as well as in the manner in which they are applied, we ſhall ſay a few words reſpecting each.

Cochineal is a ſmall inſect brought from Mexico, where it is found only on one plant, the cactus, or Indian fig. This is planted for the purpoſe, and the growth of the inſect artificially encouraged. It is the principal ſubſtance now employed in dyeing the compound colour of ſcarlet; in conſidering which, the beſt mode of uſing cochineal will be mentioned.

Kermes, a production very much of the ſame nature with cochineal, gives a fine red dye to woollen goods, leſs vivid but more laſting than that from cochineal. It is not much uſed in the preſent day, but is ſeen frequently in old tapeſtry, where it retains nearly its original luſtre. Wool muſt be prepared for this dye by boiling in water with one-fifth of its weight of alum, and half as much tartar, for two hours, and by being afterwards left in the ſame liquor four or five days; then being rinſed it is to be dyed in a warm bath, containing about twelve ounces of kermes to each pound of wool.

Lacca, or gumlac, a production of certain inſects, ſomething in its nature like bees-wax, is brought from the Eaſt Indies, in form either of ſticklac, feed lac, or lump lac. It is ufed almoft folely for dyeing what is called red Morocco leather.

Madder is chiefly ufed in dyeing linen and cotton ftuffs red, and by admixture with other fubftances in dyeing them of other colours. A very beautiful and lively red is produced by adding ox's gall to the madder bath. If the ufual proportion of tartar in the preparation of the bath, which is from one feventh to one fourth, is much increafed, a deep and durable cinnamon is produced.

Archil is fold in the form of a pafte. It is made by powdering and fteeping in chamber-lie and lime, either the *lichen roccella*, or the *lichen parellus*. The former called herb, or Canary archil, the latter ground or Auvergne archil. It gives a beautiful though fading lilac colour to filks, and is ufed, mixed with other dyes, to deepen their fhades and give a bloom.

Carthamus, a dye made of the bloffoms of a plant called *carthamus tinctorius*, cultivated in Spain, Egypt, and on the coaft of the Levant, is ufed for giving a poppy red to filk, and in dyeing orange red, cherry red, rofe, and flefh colour. When diffolved by an alkali, and precipitated by lemon juice, a powder is obtained, which, when mixed with finely pulverized talc, forms that beautiful pigment *rouge*.

Brazil wood imparts all its colouring matter to water by boiling; and wool, previoufly alumed, is dyed a good red by gently boiling in this decoction.

YELLOWS. All the fubftances employed for dyeing yellow colours are vegetable productions. The chief are weld, fuftic, arnotta, quercitron bark, and fumach.

Weld is prepared from the *refeda luteola* of botanifts. It was very much ufed formerly in dyeing a yellow, but is now daily giving way more and more to the ufe of quercitron bark. If arnotta be added to the weld bath, a golden or jonquil colour is produced.

Fuftic is the wood of a tree called *morus tinctoria*. According to the quantity employed it gives a yellow of different fhades, from a lemon to a reddifh yellow colour.

Arnotta is a pafte procured from the feeds of an American plant called *bixa orellana*. It gives a reddifh yellow, and is chiefly employed as a ground colour for other dyes.

Quercitron bark is got from a fpecies of oak called *quercus nigra*. Dr. Bancroft, who firft introduced it, has the fole right of importing and felling it. It contains ten times as much colouring matter as the fame quantity of weld, and will probably foon entirely fuperfede the ufe of it.

Sumach, which is the powdered root of a plant of that name, gives a durable yellow to cottons previoufly prepared with the aluminous mordant.

There are many other vegetables which may occasionally be had recourse to for dyeing a yellow. The saw-wort, dyer's broom, leaves of the sweet willow, and the bark of the Lombardy poplar, may all be used for this purpose. The green outer rind of the walnut gives to wool a good fawn colour, and requires no mordant to fix it, though if a mordant be used it improves its lustre.

Blues. The principal blue dyes are from indigo, woad, logwood, and Prussian blue.

Indigo is prepared by a long and tedious process from a plant called *indigofera*, cultivated both in America and the East Indies. One part of indigo dissolved in six or eight parts of strong sulphuric acid, and afterwards diluted with water, forms the dye called Saxon blue.

To dye silks with what is called English blue, the silk must be first dyed a light blue, then dipped in hot water, and washed in a stream, and lastly immersed in the bath composed of indigo dissolved in sulphuric acid with a small quantity of the solution of tin. And there it must be left till it has acquired the proper shade.

Woad is a kind of paste prepared in this country by grinding and fermenting the leaves of the *isatis tinctoria*, or, as it is called in English, the woad plant. The blue colour which it affords is much inferior in lustre, but is more permanent than that from indigo. These two dyes are mixed in forming the blue vat or bath in which all woollen goods are dyed blue.

Logwood, called alfo Campechy or Jamaica wood, is boiled in water with a little alum, and a little verdigrife, when employed for dyeing blue; but it is much more frequently ufed in dyeing blacks and grays, as will prefently appear.

Pruffian blue is a chymical compound of iron and a peculiar acid, called Pruffic acid. Both the mode of obtaining and the mode of ufing this dye are intricate and complicated; too much fo to prove interefting in their detail. The dye which it affords is very beautiful and very durable.

COMPOUND COLOURS. In dyeing, the compound colours are produced fometimes by mixing the fimple colours in the bath or dyeing liquor, and fometimes by dyeing the ftuff firft in a bath of one fimple colour, then in that of another. Scarlet, green, purple, violet, and black are the compound colours that I fhall now proceed to notice.

Scarlet is a compound of red and yellow. The moft common mode of dyeing a bright fcarlet is by means of the cochineal vat, which is thus prepared.

In the firft place, diffolve one part of fal ammoniac in eight parts of nitric acid, at a temperature of 30° Fahrenheit's. Then add, by very fmall portions, one part of tin, and afterwards dilute with a fourth of its weight of water. This is now a nitro-muriate of tin, or ſolution of tin in aquafortis and ſpirit of ſalt.

To make the dyeing liquor, put eighteen ounces of this ſolution into a tin boiler, nearly filled with clear water; then add ten ounces of tartar, and ſix of cochineal, and boil the mixture.

The cloth to be dyed is now to be immerſed, and the boiling continued till it has received a good colour. By adding a little turmeric, which is a yellow dyeing drug, the ſcarlet is rendered more lively.

Doctor Bancroft propoſes to ſubſtitute quercitron bark for the tartar, and ſays, that a farther improvement in the ſcarlet dye is effected by uſing ſulphuric acid inſtead of the nitric acid, or aqua-fortis, in making the ſolution of tin.

A good *crimſon* is produced by boiling the cloth, dyed as above, in a ſolution of alum, or by boiling in alum and tartar firſt, and then dyeing with cochineal. Silk, that is to be dyed crimſon, ſhould not be thoroughly ſcoured, its natural yellow hue being favourable to this dye.

Articles firſt dyed red with madder, then in a yellow dye of weld, or quercitron bark, have a cinnamon colour.

When walnut peel is uſed for the yellow, the reſult is a cheſnut, muſk, or ſnuff colour; all of which, like ſcarlet, are compounds of red and yellow. Thread and cotton take a cinnamon colour when firſt dyed with verdigriſe and weld, then dipped into a ſolution of green vitriol, afterwards into a decoction of galls, and laſtly dyed in the madder bath.

Green is a compound of blue and yellow. To dye woollens and cottons of this colour, it is moſt adviſeable to give the blue colour firſt, and then the yellow. Woad is commonly uſed for the former, and weld or quercitron bark for the latter. But for the Saxon green dye, indigo is the blue, and fuſtic the yellow, that is preferred. For very deep greens it is neceſſary to uſe logwood and green vitriol, as in dyeing blacks, only in ſmaller quantities.

In giving a green dye to ſilk, the yellow bath is firſt applied; and to deepen the colour, or vary its hue, decoction of logwood, fuſtic, or arnotta, is added to the yellow bath, after the weld has been taken out.

Violets, *purples*, and *lilacs*, are compounds of red and blue. In dyeing of theſe colours the blue ground is given firſt; which, even for a dark purple, ſhould not be deeper than a ſky-blue.

Logwood with galls gives ſeveral ſhades of purple to wool that has been previouſly dyed blue. Any of the red and blue dyes may be uſed for theſe colours; the ſelection of which, and the determining their proportions for different tints and ſhades requires a great degree of experience, and a great deal of nicety in the operator.

Black cannot be confidered a colour, thofe bodies only appearing black which abforb all and reflect none of the prifmatic rays. With refpect to the dyer's art, however, it ftands upon the fame footing with any of the colours which we have mentioned.

To dye a black is as proper an expreffion as to dye a blue. By the firft is meant to impregnate fubftances with fuch particles as fhall make them capable of abforbing all the prifmatic rays, and by the laft is meant to impregnate with fuch particles as fhall enable the fubftance dyed to abforb all but the blue rays, which being confequently reflected, produce on the organ of vifion the fenfation which we call a blue colour.

To give cloth a good black, it fhould be previoufly dyed a deep blue, and cleanfed by fulling. It fhould then be dipped into a decoction of galls, and a bath of logwood and green vitriol alternately, feveral times fucceffively, being expofed for a little time to the air between each immerfion.

To dye filk black it muft be firft cleaned by boiling with foap, beetling, and wafhing it well; it is then to be foaked for feveral hours in a warm decoction of galls; and laftly immerfed three or four times in the bath of logwood and green vitriol.

Grays are only ſhades of black, and are pro duced by the ſame ſubſtances uſed in ſmaller quantities.

ESSAY XXIV.

OF TANNING.

THE hides or ſkins of almoſt all animals are converted to ſome uſeful purpoſe. The hair, wool, or fur of ſome is the part employed, in others it is the ſkin itſelf.

The preparation of the ſkins is different according to their kinds, and according to their intended uſes.

The ſtrong hides of oxen are wholly prepared by the tanner, when intended for the ſoles of ſhoes and boots; but ſuch as are intended for harneſs leather, and for coach leather, are afterwards ſubmitted to the currier's art.

The ſkins of horſes, and of calves, are always curried, being uſed for the upper leathers of ſhoes and boots; and the ſkins of ſheep, deer, dogs, and ſome other animals, are prepared for a variety of purpoſes by the fellmonger and leather-dreſſer.

The converſion of hides and ſkins into leather is always effected by the proceſs of tanning, which is the art that I now intend to take into conſideration.

In tanning, the object is, to convert the ſoft and porous hide into a hard compact ſubſtance, not eaſily putreſcible, and in a great degree impenetrable to water; in which ſtate it is called leather.

This object has always been chiefly effected by impregnating the ſubſtance of the hide with oak bark or tan, which is done by ſuffering the hides to remain immerſed for a long time in an infuſion of the bark in water, called by the tanners, ooze.

Different plans have been propoſed and adopted in different tan-yards, for extracting the virtues of the bark, and for impregnating the hides with the ſame.

The grand object to be attempted is to ſave both bark, and time; the latter of which has been chiefly attended to by the new tanners. Before noticing, however, the late improvements, it will be right to give a conciſe deſcription of what is termed the old mode of tanning, which has been adopted for many generations with ſcarcely any alterations, and is ſtill moſt generally followed in this country.

To prepare the ſkins for the tan pit, they are firſt waſhed, and cleanſed, if poſſible in running water; the looſe cellular membrane is then cut away, which part of the proceſs is called fleſhing. After this, the hair is to be taken off, which is called depilation, and is effected by different means by different tanners.

Some do it by laying the ſkins in heaps, and leaving them together, till a putrefaction commences, which looſens the hair, and makes it very eaſy to be ſcraped off. This plan, however, requiring great care, leſt the putrefaction ſhould advance too far, and injure the ſkin, is pretty generally laid aſide as inconvenient.

A ſecond mode of effecting the depilation, is by immerſing the ſkins for two or three days in lime water, and then ſcraping off the hair, which the lime has looſened. This plan is almoſt always adopted for calf ſkins, but for the ſtronger hides it is leſs generally approved of, becauſe, it being neceſſary by waſhing and preſſing to extract all the lime before the application of the tan, in theſe thick ſkins it becomes a laborious and tedious proceſs.

A third mode of depilation is by immerſion in an acid liquor, namely, the ſulphuric acid, or oil of vitriol, very much diluted, as one pint of acid to a hundred and twenty gallons of water. After two or three days immerſion the hair is looſened, and very eaſily ſcraped off.

The laſt improvement in this part of the buſineſs is to uſe the infuſion or ooze, after it is become exhauſted of its tanning principle, inſtead of water, to dilute the acid with.

After depilation there is a proceſs called *raiſing*, which is often but not conſtantly had recourſe to, with a view of opening the pores, and rendering the hide more pervious to the tanning principle. This is done by ſteeping the hides in an alkaline lie, and then ſuffering them to remain ten or twelve hours in a vat of acid liquor, having twice as much acid in it, as that recommended for looſening the hair.

The hides and ſkins prepared in one or other of the above ways are now to be ſubjected to the *tanning*, properly ſo called.

The uſual mode of doing this is to immerſe them in pits or vats containing the oak bark, coarſely powdered, and a proper quantity of water. It is neceſſary to immerſe them firſt in a weaker, then in a ſtronger ooze, till at laſt the ſkins are laid in alternate layers with the bark, and the pits then filled with water. The hides require twelve, eighteen, and ſometimes twenty-four months immerſion, to be fully ſaturated with the tanning principle.

During this proceſs the hides require what is termed *handling*, to be repeated very frequently at firſt, but not ſo often as they are advanced to the ſtronger oozes. This conſiſts in removing them from the liquor, expoſing them for a ſhort time to the air, and immerſing them again in the pits.

The tan by this means gets more uniformly applied to the ſurface of the hide, and any folds or wrinkles that are made at one time are ſmoothed out at another.

But, befides this, I believe handling to have other effects, in confequence of fome chymical action of the air and light; for it is a fact, known to experienced tanners, that handling is more ufeful in a funny day than in cloudy weather, in an expofed fituation than a fheltered one, and much more fo in warm than in cold weather.

From certain facts refpecting the depofition of tan from an infufion of bark when expofed to the air, and certain appearances when treated with a folution of glue in clofe and open veffels, I am inclined to believe, that the procefs of handling is of much more importance than it is generally confidered to be, and that hides would much fooner take the tan, if fome eafy means were contrived for expofing them much more frequently to the air and light; in the fame way that many dyes are taken much more fpeedily and effectually by occafionally removing the ftuff, and expofing it to the air, than if it be allowed to remain conftantly in the dyeing liquor. A good black cannot be given to cloth without fuch repeated expofures.

Such is the ufual mode of tanning. Many improvements have been propofed, fome of which we fhall now notice. Oak bark I have ftated as the fubftance moft generally employed, but a variety of other barks contain the tanning principle; as that of the afh, the willow, the poplar, the chefnut, &c. The barks of thefe trees may, and have been, very advantageoufly employed in certain fituations. The ufe of oak leaves has been propofed as a fubftitute for bark; and, as they would require a great deal of ftore-room, it has been propofed to form an extract from them, to be ufed as required; but I know not whether the plan has ever been adopted.

Dr. Macbride, of Dublin, recommends the ufe of lime water inftead of plain water for making the ooze, it being well known that lime water will form a ftronger infufion than plain water from the fame quantity of bark. Whether it has been found to anfwer in tanning, I know not, but believe it to be very feldom if ever practifed.

Mr. Samuel Afhton, of Sheffield, obtained a patent for a new mode of tanning, in which he profeffes to employ nothing but mineral fubftances.

An Italian has propofed the following deviations from the eftablifhed mode of tanning. 1ft. To foak the green hides feparately in running water for a length of time, fufficient to extract all the lymph, which is known by putting a piece of the hide into water, and gradually heating it; if no fcum rifes to the furface, it is a proof that no more lymph remains. 2dly. To immerfe them for one hour in water, heated to 167° Fahrenheit; to fcrape off the hair as ufual, and then expofe to a ftream of water at 167° till the water contains no more animal jelly, which is known by evaporating a portion of it.

3dly. To take off the loofe membraneous parts, wafh in cold water, and then tan them in an ooze kept at 167° which has been filtered from the tan or bark.

The warm ooze has been ufed by feveral tanners in this country, but is now lefs approved of than at firft.

The moft important improvements in the art of tanning have been made by a Frenchman of the name of Seguin, and his plan is known to tanners of this country under the name of Defmond's plan.

As thefe improvements are grounded on the chymical qualities of the tan or bark, and on the chymical combination of the tanning principle and the hide, in the formation of leather, I fhall precede an account of his plan with a few obfervations upon thefe points.

When a folution of green vitriol in water is added to an infufion or decoction of oak bark, of galls, of afh bark, or any other of the tanning barks, it immediately ftrikes a black colour; and fuch fubftances have been confidered more or lefs aftringent, as the vitriol has caufed a deeper or a fainter black. All fubftances poffeffing this quality have been called aftringent; all fuch fubftances have been confidered as poffeffing the tanning quality; and the property of tanning, it has been concluded, depends upon this aftringent principle; and hence it has been haftily inferred, that, in proportion as the vitriol ſtrikes a blacker colour does the aſtringent ſubſtance poſſeſs a ſtronger tanning property.

Later chymiſts, detecting an acid in theſe aſtringent vegetables, which they have called the gallic acid, or acid of galls, have attributed to this acid the property of ſtriking black with vitriol, and have alſo conſidered it as the true tanning principle.

Theſe opinions are now found to be erroneous. There are in the barks above ſpecified, and in other vegetables, two diſtinct principles; the one ſtriking a black with green vitriol, called gallic acid; the other tanning or forming leather when combined with the ſubſtance of the hide, called properly *tannin.*

Theſe two principles exiſt in different proportions in different ſubſtances; and their preſence is eaſily detected ſeparately, by certain chymical teſts. The mode of judging of the tanning quality of any particular bark by the colour produced on adding green vitriol, is therefore very inaccurate.

To detect the tannin or tanning principle in any ſubſtance, add a few drops of the ſolution of animal glue (made by diſſolving a little common glue in water over a moderate fire) to a wine glaſs full of an infuſion of the ſubſtance to be examined. If tannin is preſent, the liquor becomes turbid, and a whitiſh ſubſtance falls to the bottom, which is a true powder of leather, being a compound of tannin and glue, which glue is of the ſame nature with the ſkin or hide, that by union with tannin forms leather.

The teſt of gallic acid is green vitriol or copperas; which, as I have before ſtated, ſtrikes a black, when added to any ſubſtance containing the gallic acid.

Theſe two principles, it is true, very frequently, perhaps always, exiſt together; but they exiſt in very different proportions in different vegetable productions, and are ſeparable from each other.

The tannin is more ſoluble, and more eaſily extracted from the bark, than the gallic acid.

Pour water upon powdered bark; after an hour draw it off, and pour on freſh water; repeating this until the water is drawn off quite clear. This infuſion contains tannin as long as it is coloured, and will cauſe a yellowiſh or whitiſh precipitate on addition of the ſolution of glue; but the clear liquor no longer contains tannin, though it ſtill contains the gallic acid, as appears by its turning black when green copperas is added.

After theſe obſervations, the directions of Mr. Deſmond, for adopting Seguin's mode of tanning, will be more eaſily comprehended. They are briefly as follows.

Provide five digeſters, having apertures at bottom; place them near to each other, and elevate them upon ſtillages. Fill them with ground tan, and pour water into the firſt. After ſtanding a little time, draw it off, and pour it on the tan in the ſecond; and ſo on, till it has paſſed them all. When this liquor, which is called the *tanning lixivium*, is drawn off from the firſt digeſter, freſh water muſt be poured on, and paſs through all the digeſters in the ſame way. After this is repeated ſeveral times, the liquor no longer depoſits a ſediment on addition of the ſolution of glue, and therefore contains no more tannin.

What paſſes after this is to be kept ſeparately, and more water paſſed through, until it no longer gives a black colour with green copperas. This liquor is called the *gallic lixivium*, and is uſed inſtead of water in the proceſs of depilation.

The tan is now completely ſpent or exhauſted, and muſt be removed, that its place may be ſupplied by freſh. The tan in the other digeſters will likewiſe preſently be exhauſted, and require to be replaced by freſh in the ſame manner.

The tanning lixivium ſhould always be ſo ſtrong, as to mark from ſix to eight degrees on the hydrometer for ſalts; and when, therefore, what paſſes from the laſt digeſter is of leſs ſtrength, it muſt be poured upon the freſh tan in the firſt digeſter.

The hides and ſkins being waſhed and fleſhed in the uſual way, are immerſed in a liquor formed of one part of ſulphuric acid to a thouſand of gallic lixivium; and the hair is then to be ſcraped off.

Raiſing is very ſeldom neceſſary; and the hides, being waſhed and dreſſed with the round knife, are fully prepared for tanning.

Firſt ſteep the ſkins or hides for ſome hours in a weak lixivium of only one or two degrees, as that which runs from the ſecond digeſter, or ſome that has been already uſed for tanning. Then put them into a ſtronger lixivium; and after a few days renew the lixivium, which will now be found to be much weaker than at firſt. Let it be renewed as often as it is found neceſſary, until the hides are quite tanned, which may be known by cutting off a ſmall piece of the edge. Now remove the leather, and dry it in a ſhady place.

The peculiarity in this mode of tanning is the uſing a ſtrong infuſion of the tan ſeparated from much of the gallic acid, inſtead of immerſing the hides together with the bark in the tan pits.

The advantage of it is the ſaving of time, hides being tanned in this way in fewer weeks than in months according to the old plan.

Some tanners ſay that it requires more bark, and that the leather is of an inferior quality. Others deny this, and aſſert the contrary.

I believe the chief reaſon, why this plan is ſo little adopted in this country, is the uncertainty of the market. A tanner muſt be daily receiving freſh hides, and ſhould therefore be regularly diſpoſing of his leather; otherwiſe it lies long upon his hands, and he loſes in profit. Now in adopting this mode of tanning, which is ſo ſpeedy, there muſt be ſeaſons, when the tanner's ſtock muſt be immenſe; and of courſe the capital employed in ſuch a trade muſt be at one time very great, whilſt at another he can employ but little.

This inconvenience, added to the prejudices of old manufacturers againſt all innovations, has retarded the introduction of Deſmond's plan very conſiderably.

ESSAY XXV.

OF CURRYING.

THE art of the currier confifts in rendering the tanned fkins fupple and of uniform denfity; in giving a proper grain, and in blacking fuch as are required to be of that colour.

The leather, generally fubmitted to the currier's art, is of the thinner fofter kind, as calf, feal, and dogfkins, horfe-hides, and the lighter cow-hides.

The ftronger hides are almoft folely employed for making the foles of boots and fhoes, and fuch require no preparation after tanning but what is effected by the fhoemakers, after they are cut up into pieces fit for ufe.

Such, however, as are intended for coach and harnefs leather, are prepared by the currier; and hog-hides, of which the feats of faddles are ufually made, likewife undergo part of the procefs of currying.

After the face and ends of the fhanks have been cut off, if not previoufly done by the tanner, the currier commences his bufinefs by foaking the fkins in water, till they are completely wetted through. They are then taken out, and after draining are placed upon ſhort flatſided poſts, called beams, to undergo what is termed the *ſhaving*.

The workman ſtanding behind the beam, ſhaves or cuts off the looſe cellular membrane from the fleſh ſide of the ſkin with a round-edged knife, having a double handle, and worked with both hands. The knife is firſt carried lengthways, and then acroſs the ſkin, from the back to the belly; and by this proceſs the different parts are brought to a more equal ſubſtance.

The ſkins, thus ſhaved, are again immerſed in water, till they are well ſoaked, and are then brought out to be *ſcoured*.

The *ſcouring* is generally, and ought always to e, performed at twice; the firſt part of the proceſs being called *water ſcouring*, and the latter *ſleeking*.

For this purpoſe the ſkin is ſtretched out upon a marble or ſtone ſlab, and the water ſcouring conſiſts in preſſing along it with a thin blunt-edged ſtone, fixed into a wooden handle, or with a lump of pumice ſtone; and in occaſionally ſcouring it with a hard bruſh dipped in water.

The ſkin being again ſoaked in clean water, is taken out and ſleeked; which ſleeking is done preciſely in the ſame manner as the water ſcouring, except that a blunt-edged iron inſtrument, fixed into a wooden handle, and which is called a ſleeker, is ſubſtituted for that of ſtone.

The object of the ſcouring is to extract all the lime, and other filth, that the leather had acquired in tanning; and the uſe of the ſleeker, that is employed laſt, is to force out all the water, extend the ſkin, and obliterate the natural grain. The more the ſkin is extended, the finer grain will it afterwards aſſume.

The next part of the proceſs is to impregnate the leather with oil, which renders it ſupple, and in a great meaſure impervious to water.

The ſkins for this purpoſe ſhould only be half dried; and therefore in general, when ſcoured, they are laid in heaps till wanted. But ſometimes, for the ſake of diſpatch, they are hung up ſeparately in the ſheds to undergo this partial drying; and this is called by the workmen *ſamming*.

To impregnate them with oil, or as the workmen term it, *ſtuff them*, they are laid out upon tables, and firſt the grain ſide of the leather is rubbed over with a mixture of cod oil, and an oil obtained from the leather dreſſers, called ſod oil. Then the fleſh ſide is rubbed over with a larger quantity of a mixture of ſod oil and tallow, with only ſo much cod oil as will render it of a proper conſiſtence to be eaſily ſpread upon the leather.

When the ſkins are thus ſtuffed, they are again hung up ſeparately in airy ſheds to dry; but before they become quite dry, they are taken down and *ſet;* i. e. they are ſtretched out upon a table, and the neck and other coarfe parts are preffed with a ftone, fimilar to that ufed in fcouring, with a view of extending them, taking out all wrinkles, and obliterating what may remain of the natural grain. They are then hung up again to be thoroughly dried, either in the fheds, or in ftoves, according to the weather. If fhed-dried they require to be expofed laft of all to the funfhine.

The procefs of currying, as far as we have now defcribed it, is termed by the workmen *the putting out.*

It now remains to render the leather more fupple and pliable, to give it a grain, and to blacken it, if required. This part of the bufinefs is called *the making up.*

The dried fkin is laid upon a large board with the grain fide upwards, and being doubled is rolled with confiderable preffure upon the flefh fide firft, and afterwards upon the grain, with a fluted board, faftened to the operator's hand by a ftrop. This rolling is done in the direction from the hinder fhank to the cheek each way.

To take off the greafe, that remains on the furface of the leather, the flefh fide is gone over with a fharp fleeker, and the grain rubbed with tow and the finer fhavings called whitenings. To complete this object, the flefh fide is flightly fhaved with a fine-edged knife, which is called the *whitening*, and the grain is very highly fleeked.

To give a grain to the leather, it is now rolled upon the flesh side with a much finer fluted board than before, and with greater exactness.

The blacking, which is the only part of the business that remains to be described, is performed very differently on the different sides. Leather, that is to be blackened on the flesh side, which is the case with most of the finer leather for shoes and boots, is blackened with lamp-black; and what is blackened on the grain side, receives that colour from the application of copperas or green vitriol.

For the first kind a mixture of lamp-black, cod oil and allow, with a small quantity of the water in which the leather was soaked previously to the shaving, is rubbed into the flesh side with a round brush, and it is then brushed over with strong size and tallow.

When this has dried, it is sleeked with a round smooth-edged glass sleeker, and is lastly washed over with a weak size, to fix the colour.

The leather that is to be blackened on the grain side, after being shaved and scoured as usual, is brushed over with chamberlie, and then with a solution of green copperas. To prevent its striking too deep, it is then washed with water, and sleeked out.

It is now to be stuffed as the other leather, but with a less proportion of tallow, and more sod oil.

This ſhould be done as ſoon as it conveniently can, leſt the copperas ſhould injure the leather.

When it has imbibed the oil, it is not expoſed to the ſun, but taken down, ſtoned quite ſmooth, and again waſhed with the ſolution of copperas, till quite black.

If any artificial grain is wanted, it is now imprinted with a piece of the dried ſkin of the dog-fiſh. If the natural grain is wiſhed for, the ſkin is rolled with a very fine fluted board upon the fleſh ſide in two or three directions, and laſtly upon the grain with one ſtill finer.

The leather is now hung up to dry, either in the ſun, or by the ſtoves, and when dried is whitened, but not with the ſame care that the other kind requires.

After whitening, it is again rolled with the fine fluted board, and the proceſs is finiſhed by rubbing it over with a ſmall quantity of cod oil and tallow.

In blacking the leather in this way, the copperas acts the ſame, as when it is added to an infuſion of bark or tan, which is immediately turned black by it.

THE END.

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